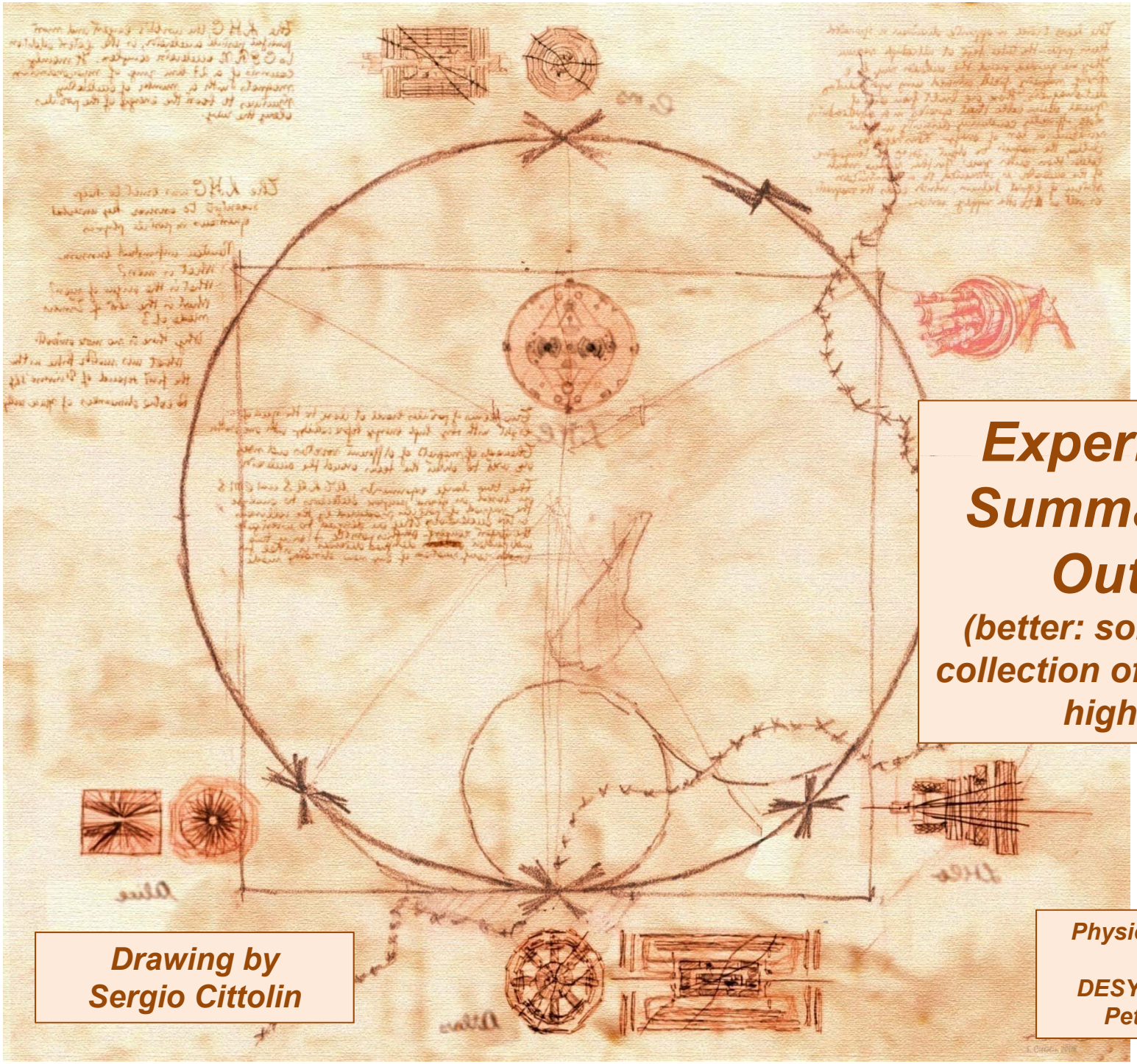


Experimental Summary and Outlook

(better: some personal collection of experimental highlights)

Drawing by Sergio Cittolin

Physics at the LHC 2010

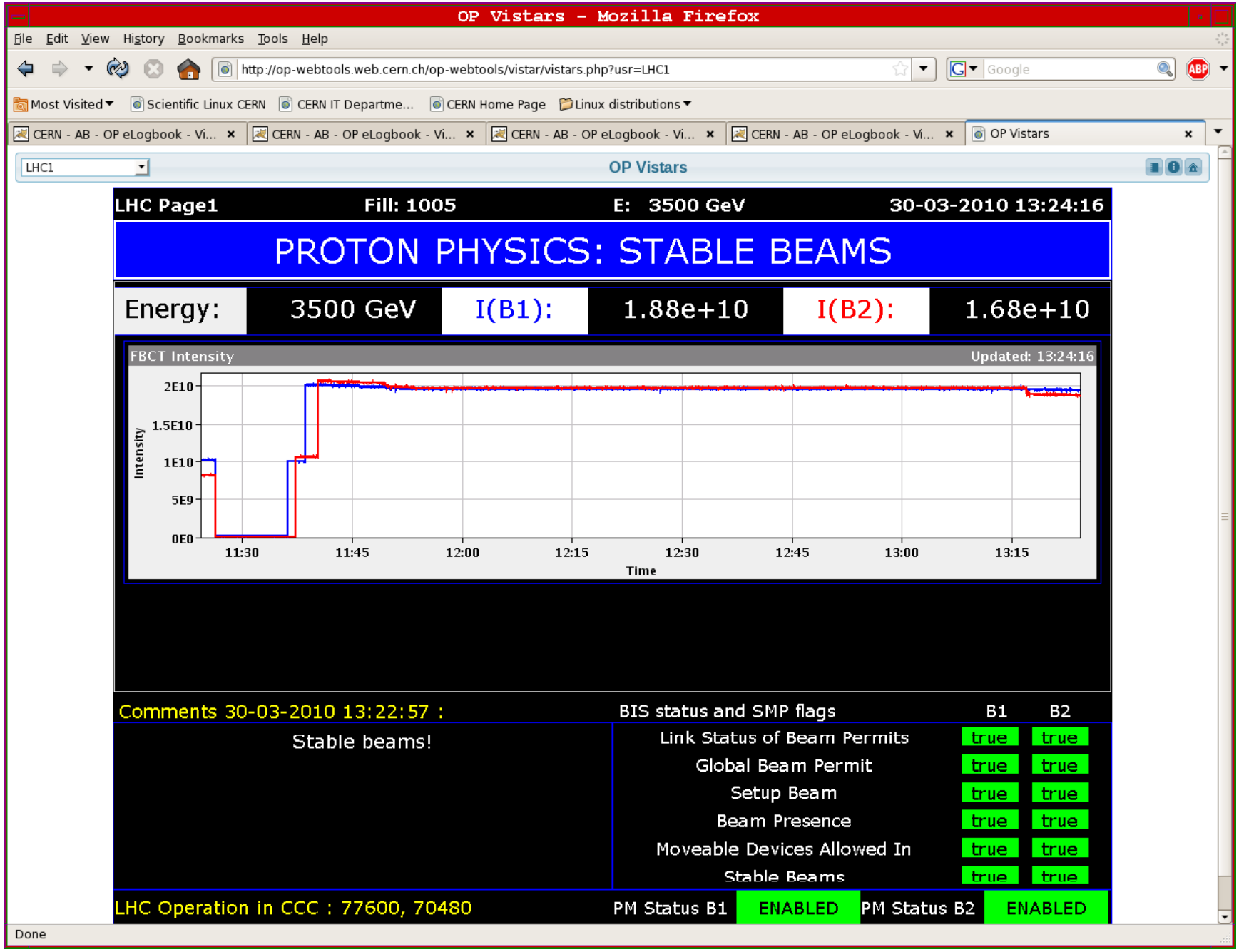
DESY, 7 – 12 June 2010

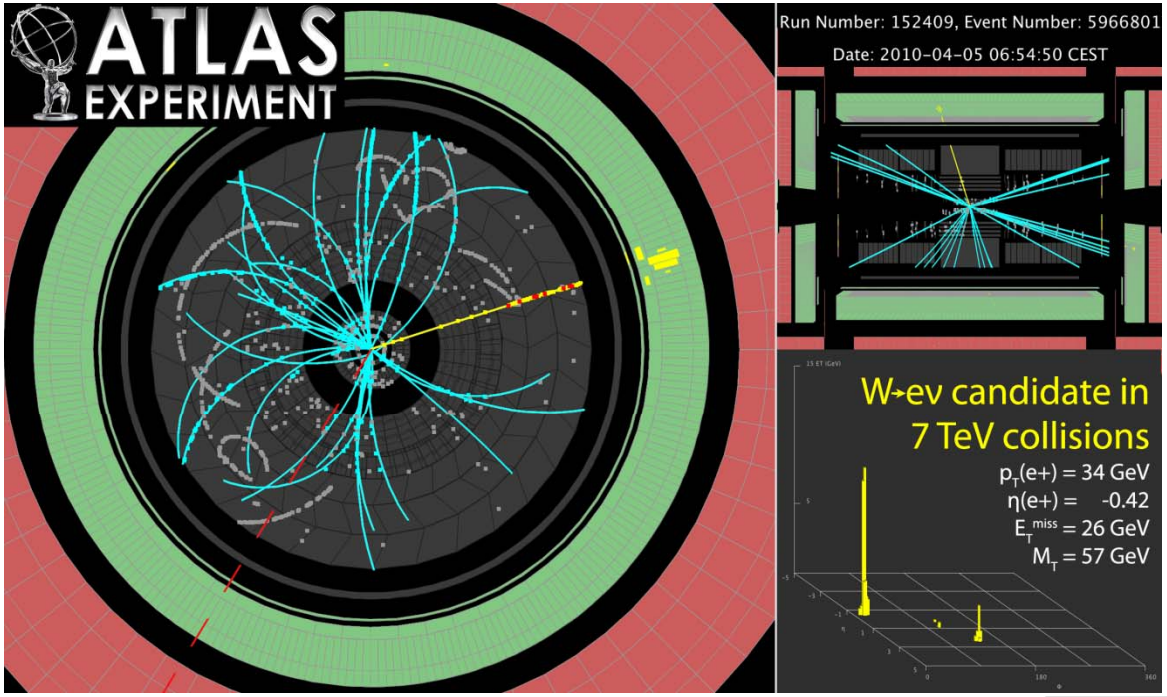
Peter Jenni, CERN

The most important message to take home:

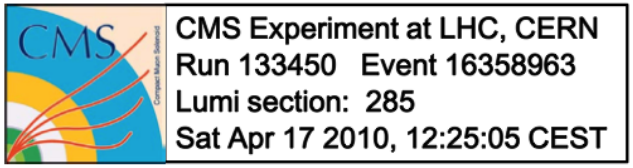
This is the first 'Physics at the LHC' conference with the LHC running, and the LHC experiments presenting real data from collisions!

And the data presented demonstrate that the experiments are extremely well prepared for producing fast high quality physics results

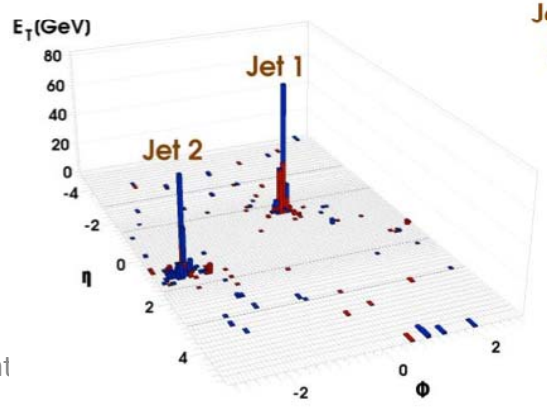

OP Vistars - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://op-webtools.web.cern.ch/op-webtools/vistar/vistars.php?usr=LHC1
Most Visited
Scientific Linux CERN
CERN IT Departme...
CERN Home Page
Linux distributions
CERN - AB - OP eLogbook - Vi...
CERN - AB - OP eLogbook - Vi...
CERN - AB - OP eLogbook - Vi...
CERN - AB - OP eLogbook - Vi...
OP Vistars
LHC1
OP Vistars
LHC Page1
Fill: 1005
E: 3500 GeV
30-03-2010 13:24:16
PROTON PHYSICS: STABLE BEAMS
Energy:
3500 GeV
I(B1):
1.88e+10
I(B2):
1.68e+10
FBCT Intensity
Updated: 13:24:16
Intensity
2E10
1.5E10
1E10
5E9
0E0
11:30
11:45
12:00
12:15
12:30
12:45
13:00
13:15
Time
Comments 30-03-2010 13:22:57 :
Stable beams!
BIS status and SMP flags
B1
B2
Link Status of Beam Permits
true
true
Global Beam Permit
true
true
Setup Beam
true
true
Beam Presence
true
true
Moveable Devices Allowed In
true
true
Stable Beams
true
true
LHC Operation in CCC : 77600, 70480
PM Status B1
ENABLED
PM Status B2
ENABLED
Done

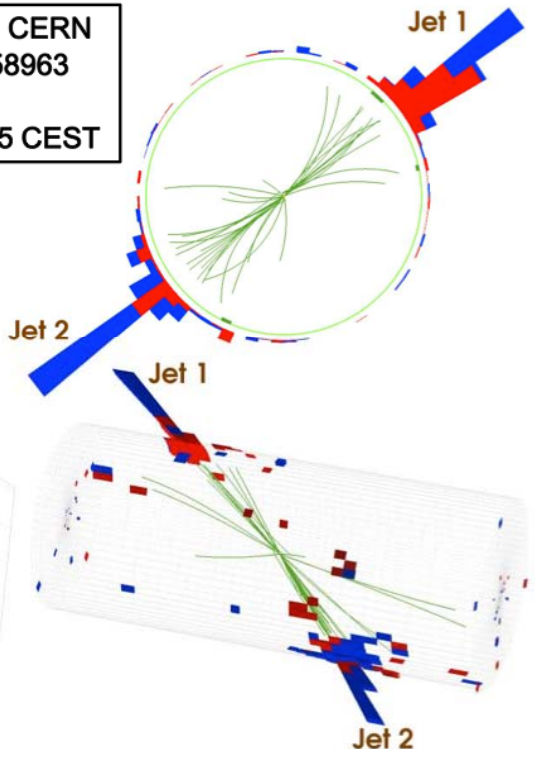


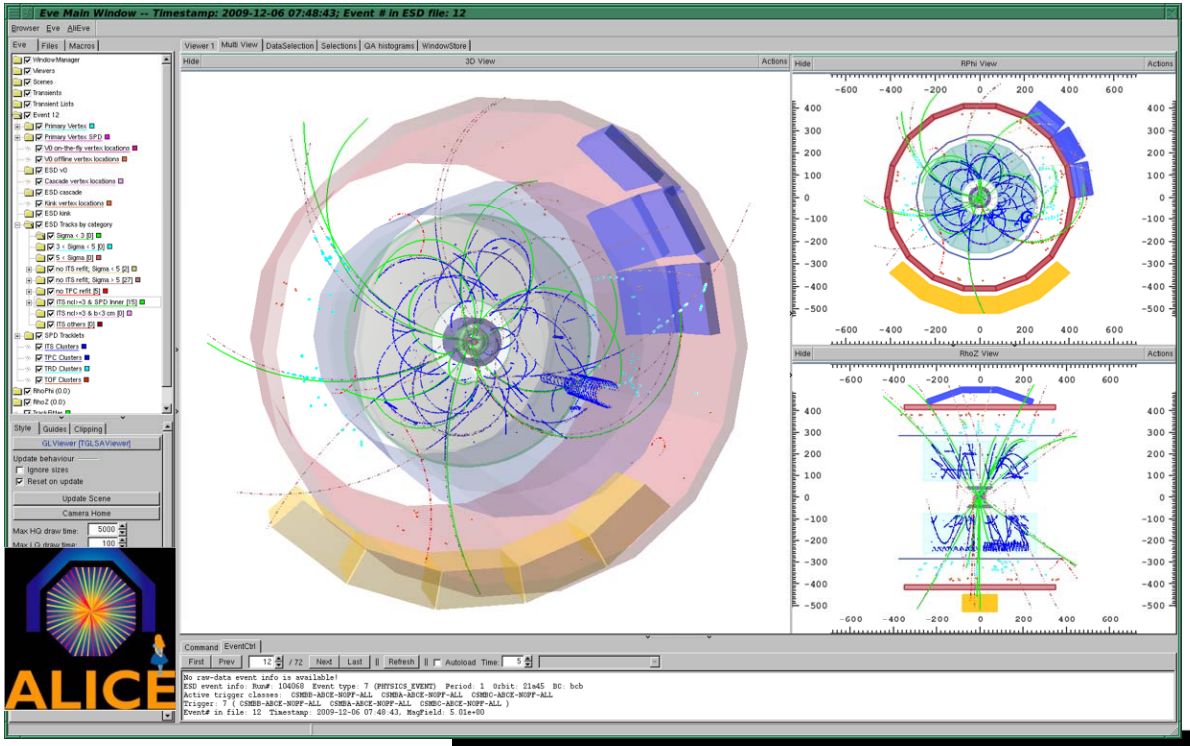
Some 'typical' real events

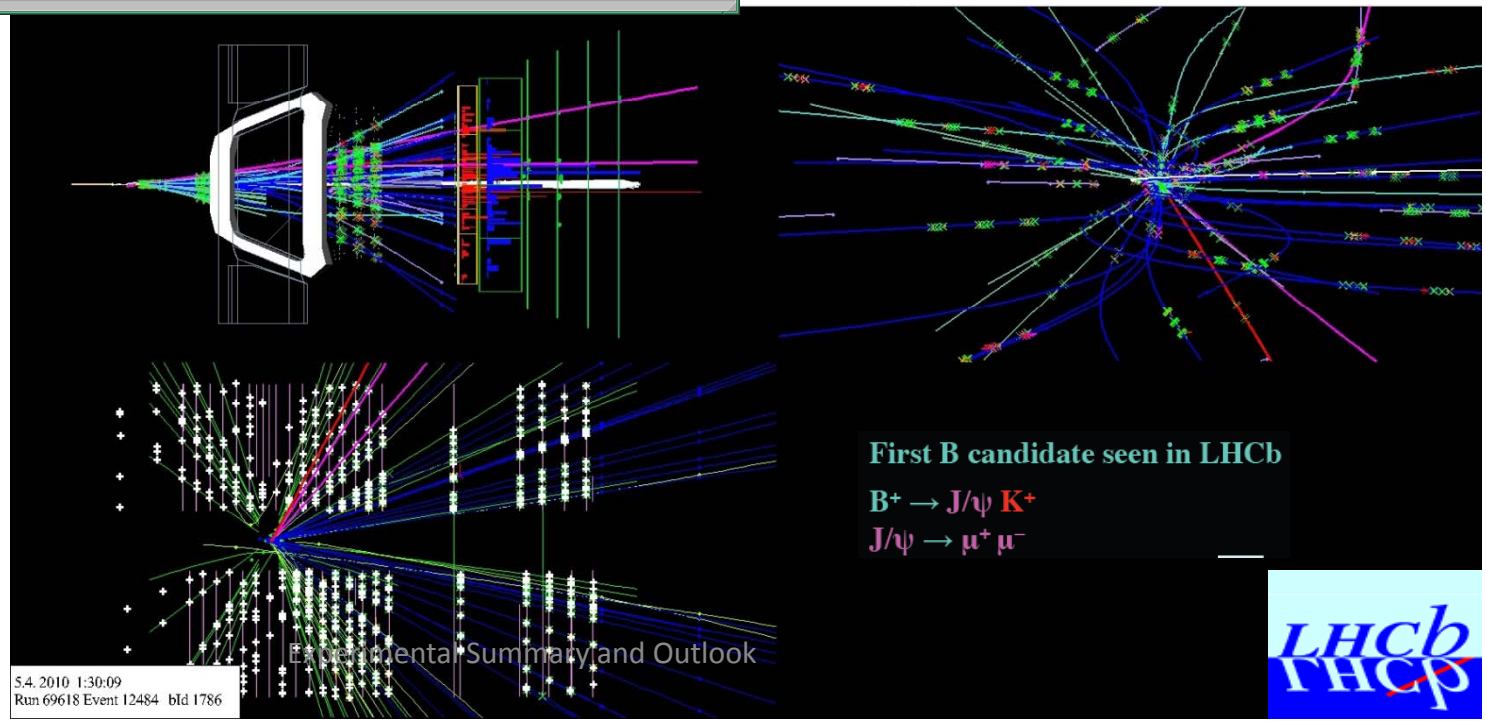


Jet1 p_T : 253 GeV
Jet2 p_T : 244 GeV
Dijet Mass : 764 GeV





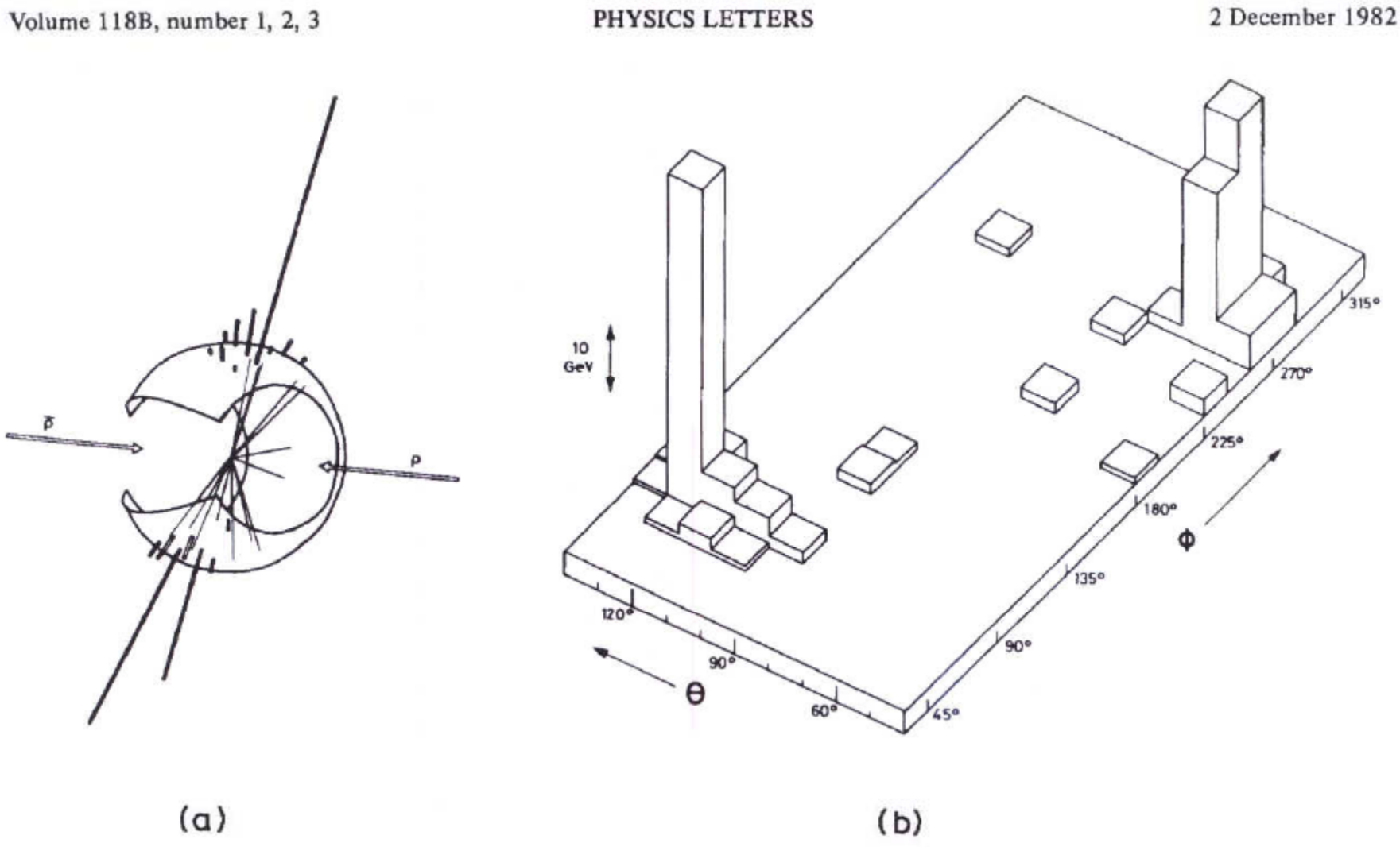




PLHC2010, 7-12 June 2010
Peter Jenni (CERN)

Experimental Summary and Outlook

Note also that the event displays have become more sophisticated since the first spectacular events, hand-drawn, at a hadron collider …



Plan for this presentation

Understanding the instruments
- Commissioning of the LHC experiments and computing

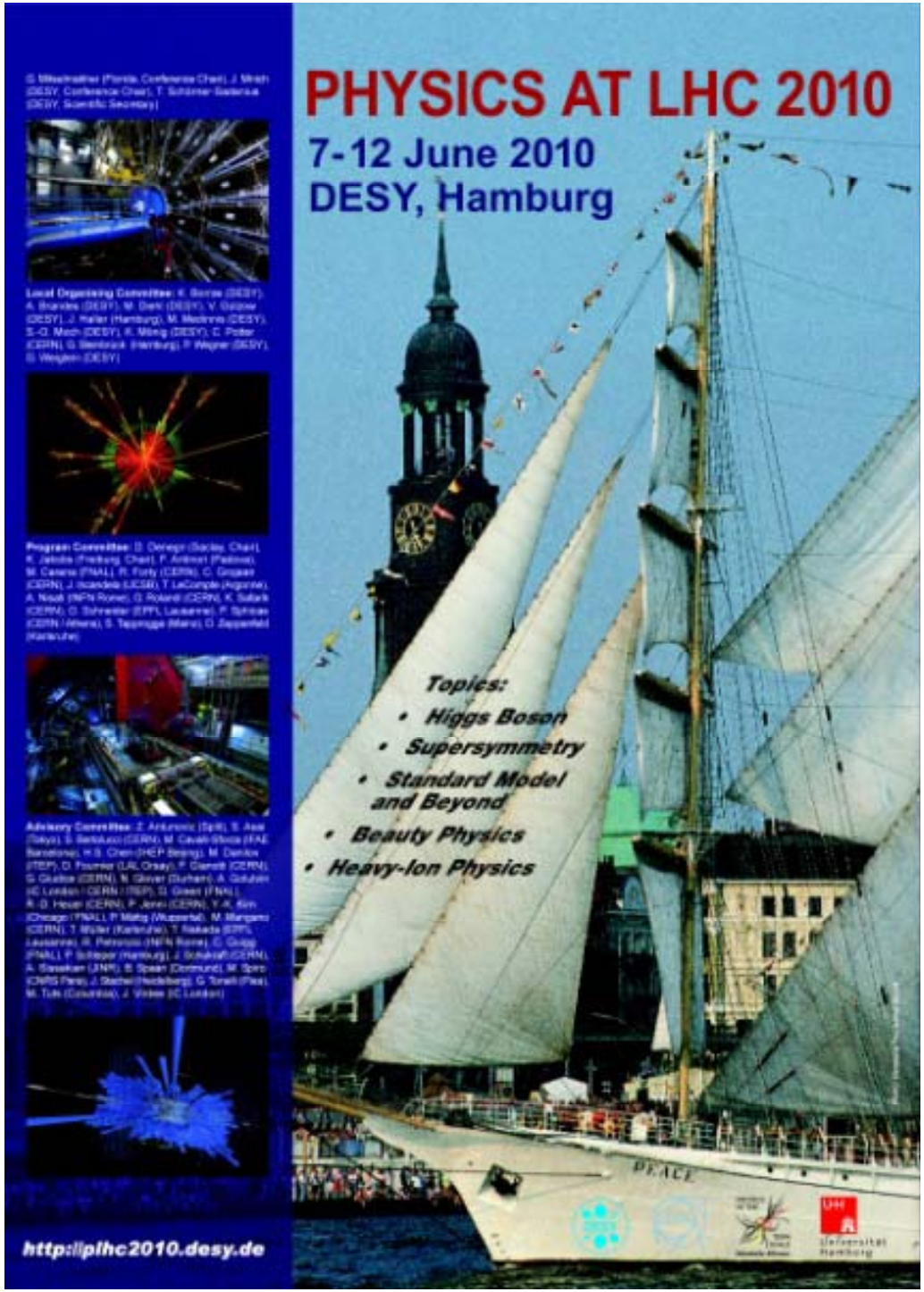
Understanding the environment
- Minimum bias events at LHC

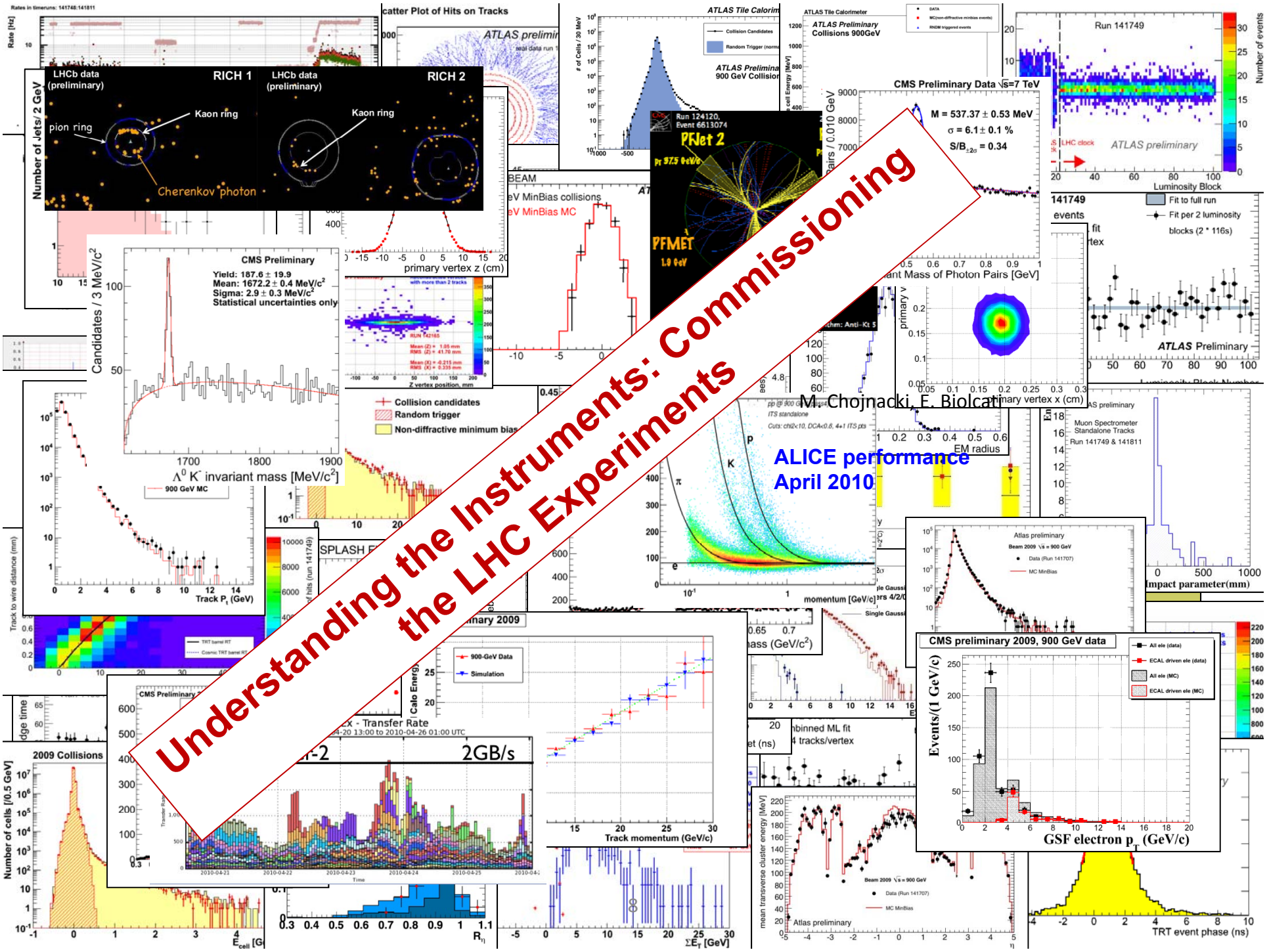
Machines
- Tevatron and LHC projections

Physics and outlook
- A few examples of Tevatron results
- Some LHC expectations

Note: This cannot be a direct summary, I would in no way be capable of giving justice and fair credit to the fantastic amount of work presented during this enjoyable week

Therefore I will also not quote any names of experiments speakers, remember, this is a collaborative effort!

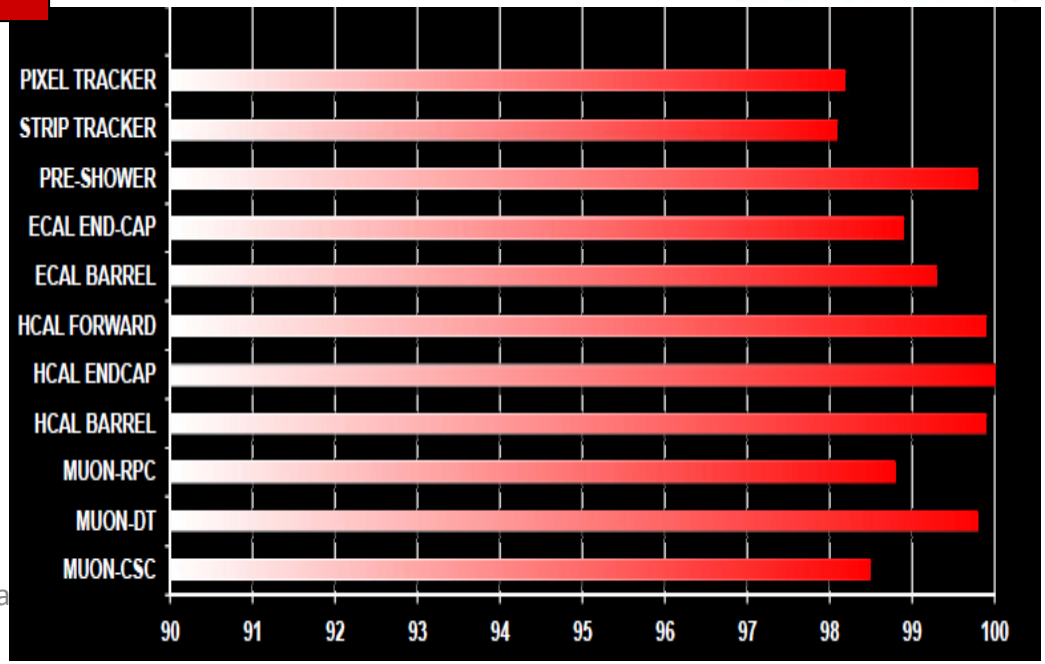


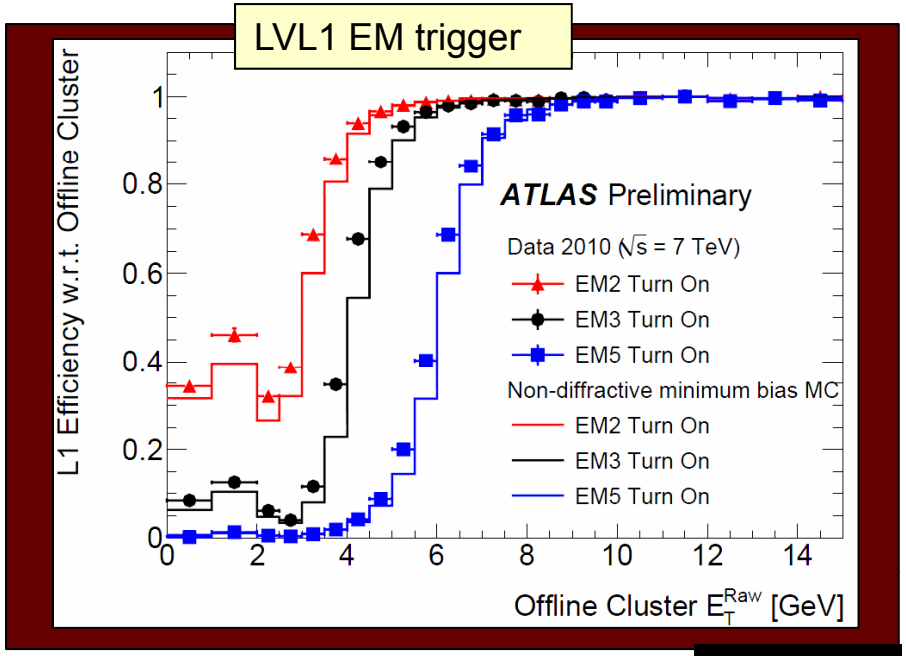

LHCb data (preliminary)
RICH 1
RICH 2
Kaon ring
pion ring
Cherenkov photon
CMS Preliminary
Yield: 187.6 ± 19.9
Mean: 1672.2 ± 0.4 MeV/c²
Sigma: 2.9 ± 0.3 MeV/c²
Statistical uncertainties only
Candidates / 3 MeV/c²
Λ⁰ K⁻ invariant mass [MeV/c²]
Collision candidates
Random trigger
Non-diffractive minimum bias
ATLAS preliminary
Run 141749
Luminosity Block
CMS Preliminary Data √s=7 TeV
M = 537.37 ± 0.53 MeV
σ = 6.1 ± 0.1 %
S/B±2σ = 0.34
ATLAS Preliminary
Collisions 900GeV
Run 124120, Event 6613074
PFJet 2
PFMET
ALICE performance
April 2010
M. Chojnacki, E. Biolcati
Understanding the Instruments: Commissioning the LHC Experiments
CMS preliminary 2009, 900 GeV data
GSF electron p_T (GeV/c)
Events/(1 GeV/c)
2009 Collisions
Track momentum (GeV/c)
TRT event phase (ns)
Muon Spectrometer Standalone Tracks
Run 141749 & 141811
Impact parameter(mm)
Track P_t (GeV)
primary vertex z (cm)
primary vertex x (cm)
momentum [GeV/c]
EM radius

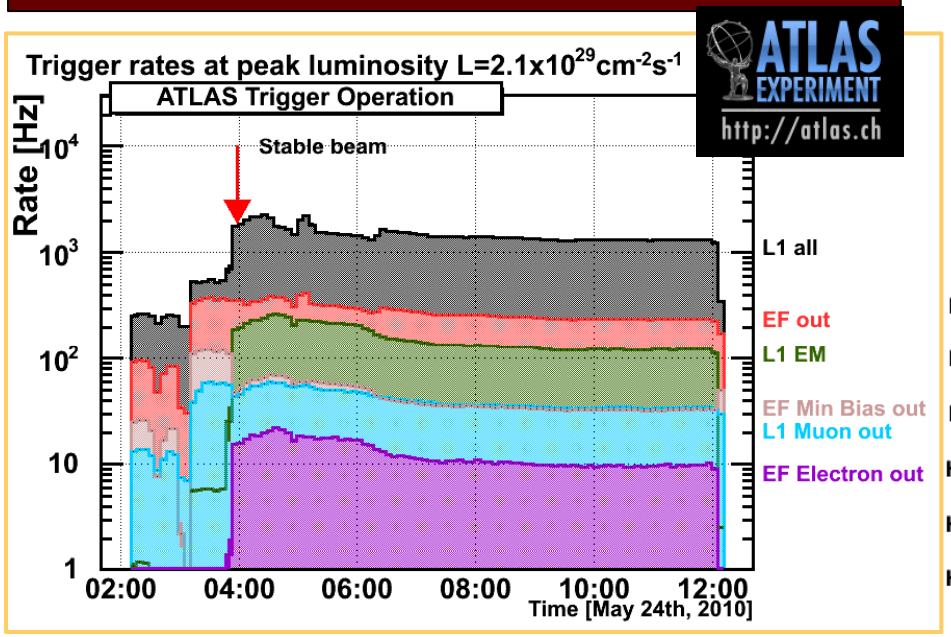
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.8%
LVL1 Muon RPC trigger	370 k	99.7%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.3%
TGC Endcap Muon Chambers	320 k	98.8%

The complex detectors take data with an impressive fraction of operational channels, and high efficiencies

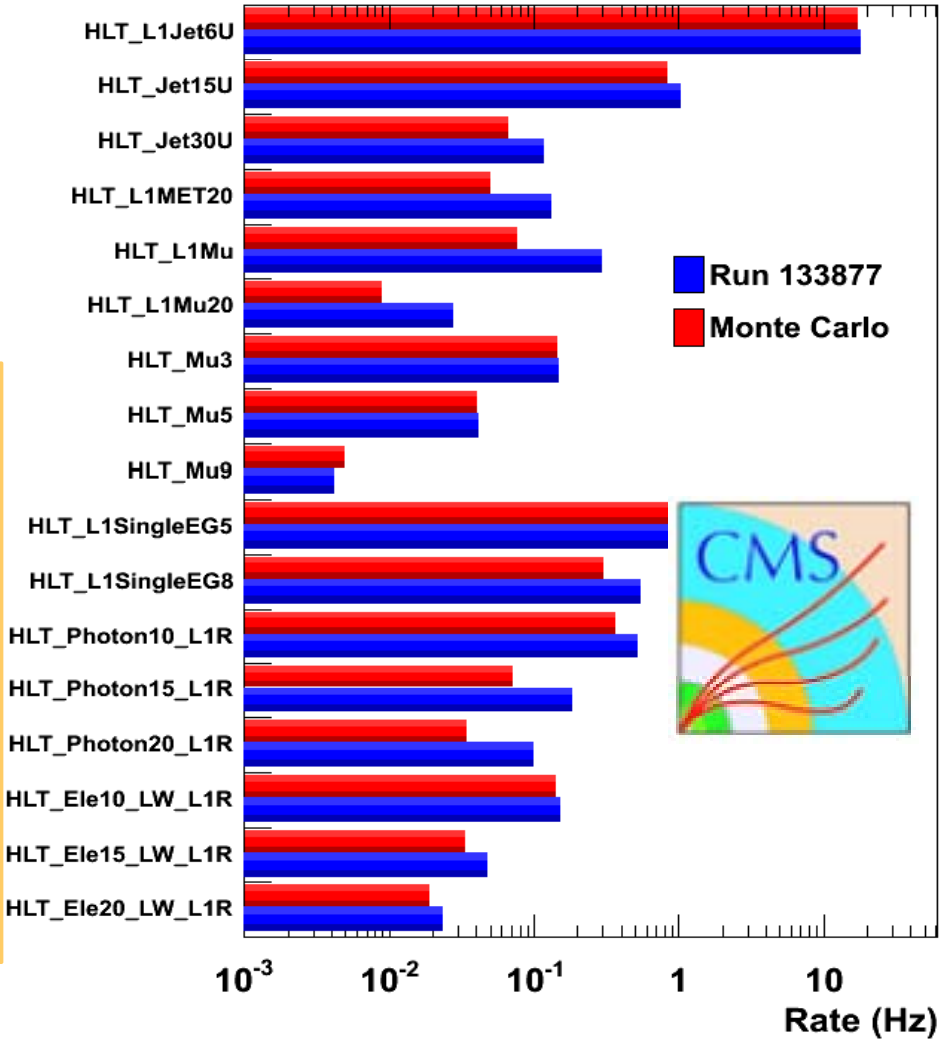
ATLAS EXPERIMENT
http://atlas.ch



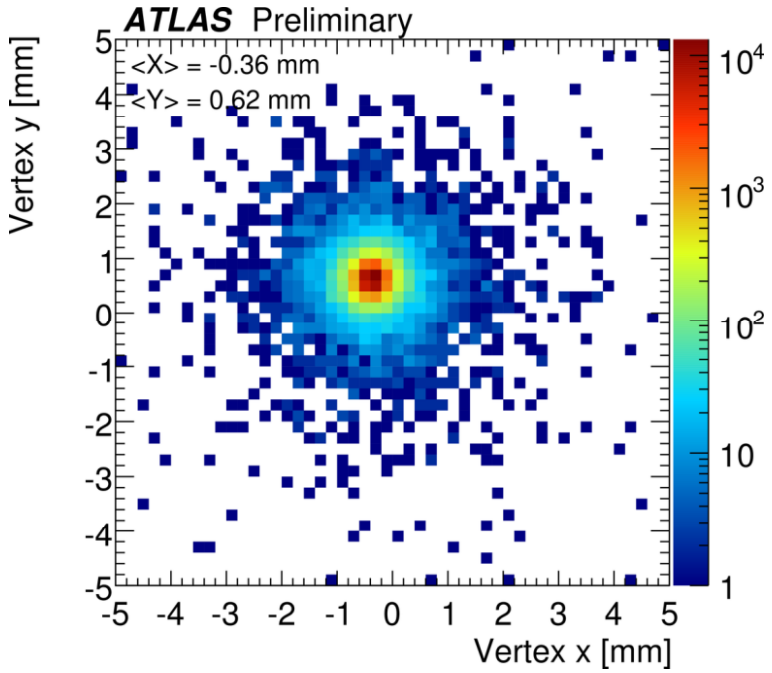


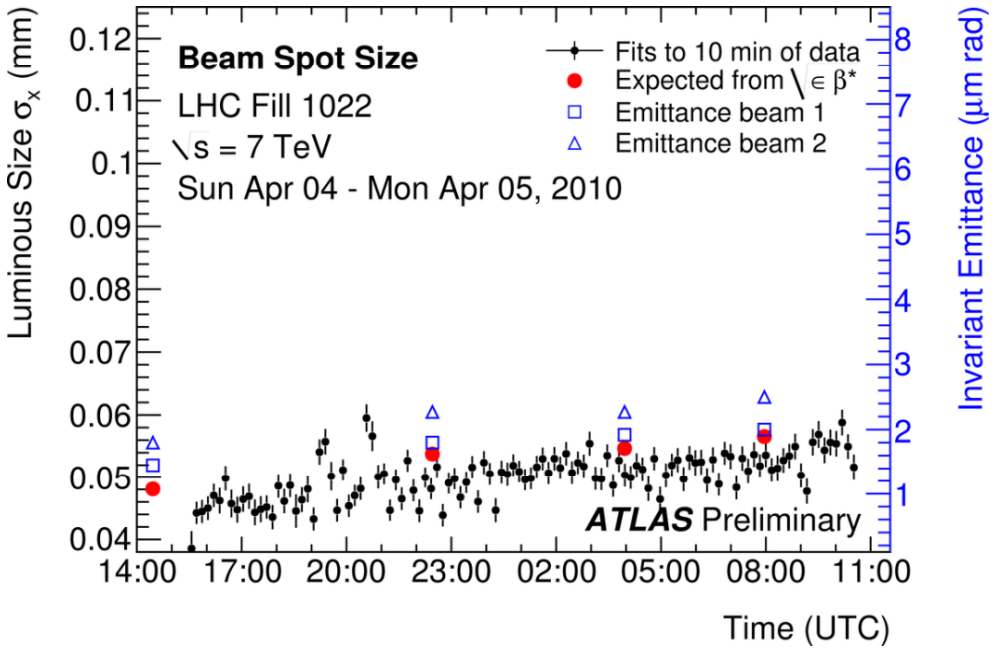


Triggers work and are well understood, but did not yet have a 'hard' job to do…



Examples of good feedback of beam parameters to the LHC



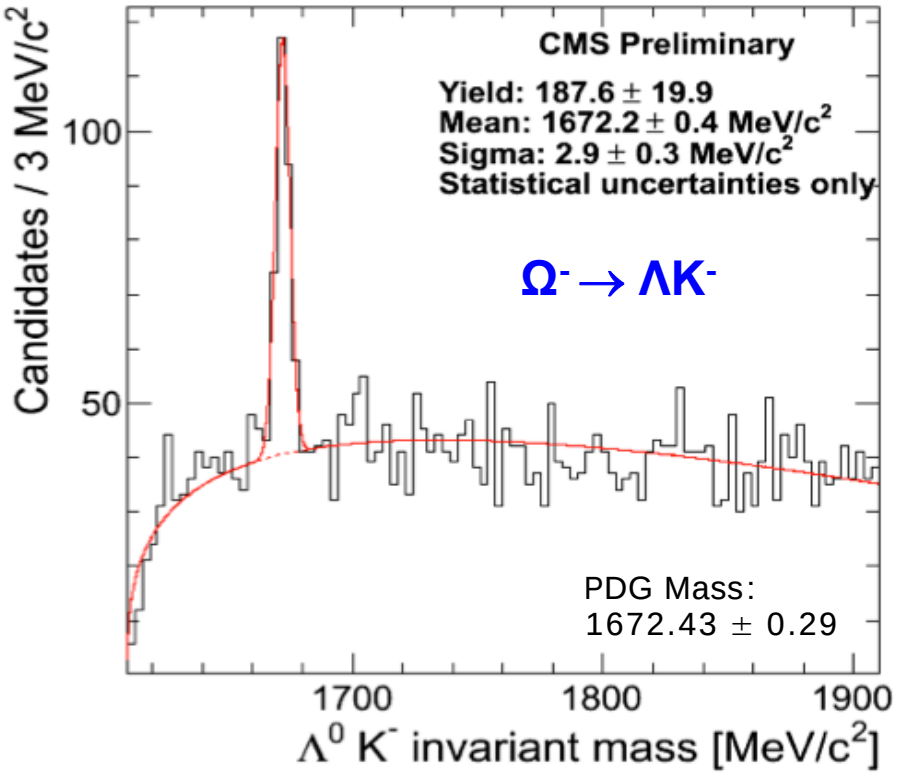


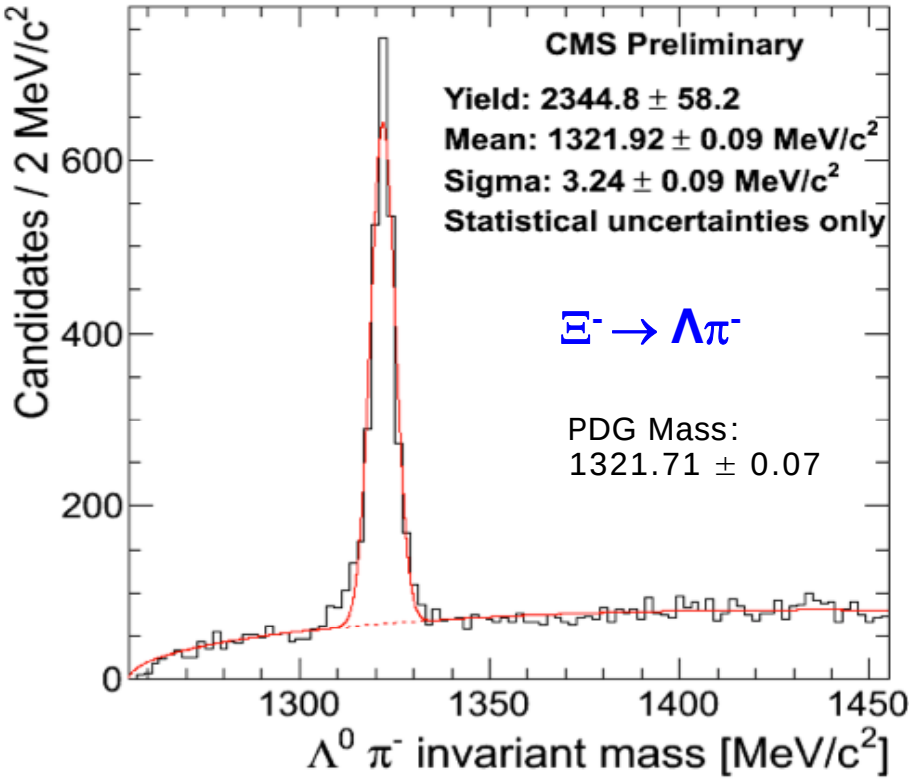
Primary vertex determined online by HLT during 1st fill at 7 TeV (30-3-2010)

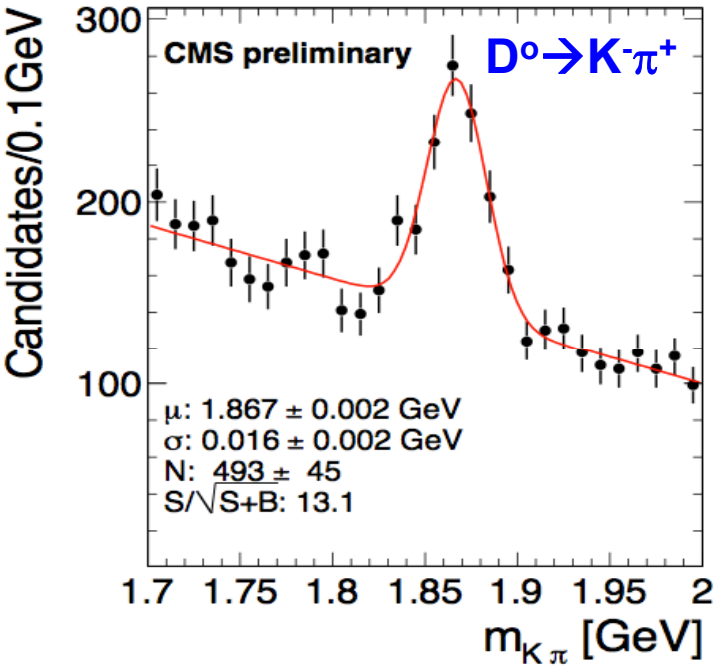
Beam spot size in the transverse plane at IP1: ATLAS measurement (from offline reconstruction of event vertex) compared to machine prediction

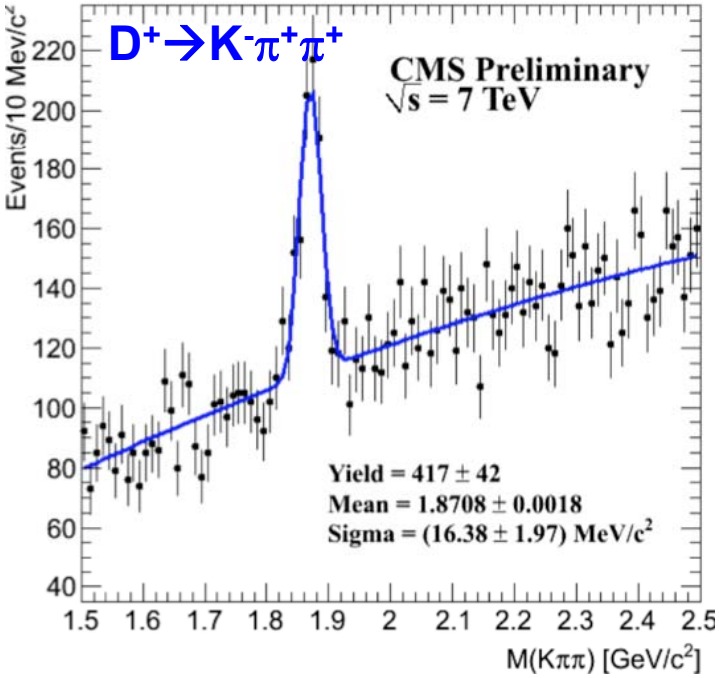
Enormous amount of tracking work, exploiting to the best also 100s of millions of cosmics, has led already to excellent performance for all experiments

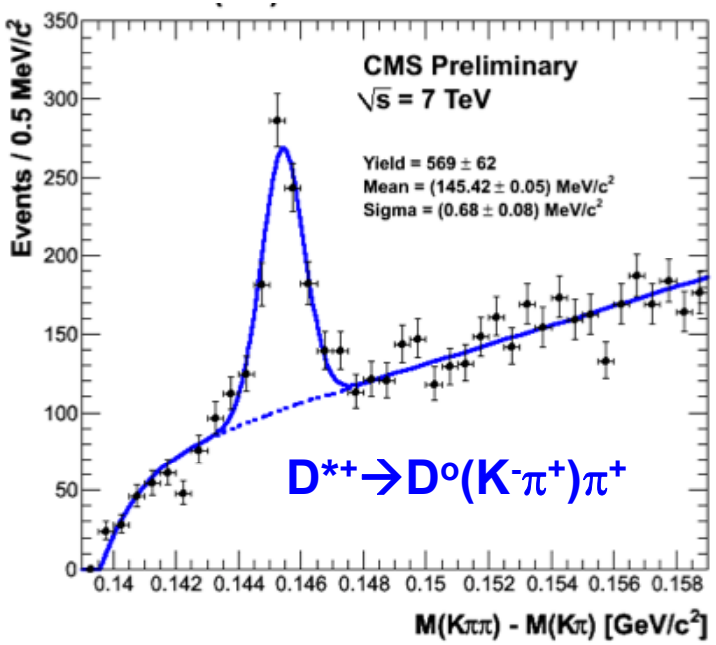
Here just a few examples from CMS, but ATLAS, LHCb and ALICE have a nice collection as well…

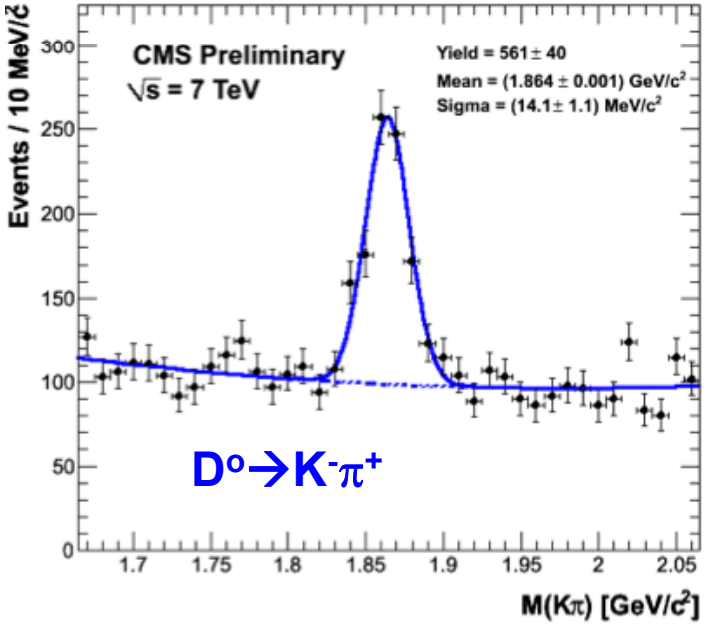





CMS preliminary
$D^o \to K^-\pi^+$
Candidates/0.1GeV
μ: 1.867 ± 0.002 GeV
σ: 0.016 ± 0.002 GeV
N: 493 ± 45
S/√S+B: 13.1
$m_{K\pi}$ [GeV]

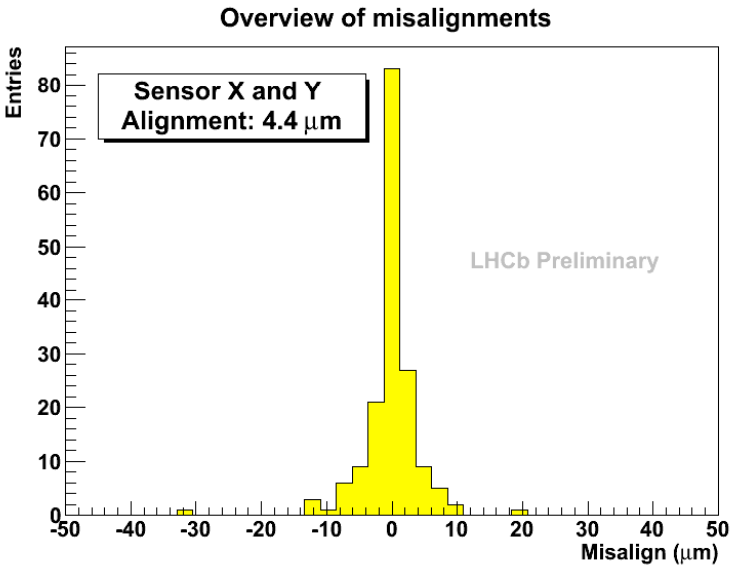

$D^+ \to K^-\pi^+\pi^+$
CMS Preliminary
√s = 7 TeV
Yield = 417 ± 42
Mean = 1.8708 ± 0.0018
Sigma = (16.38 ± 1.97) MeV/c²
M(Kππ) [GeV/c²]

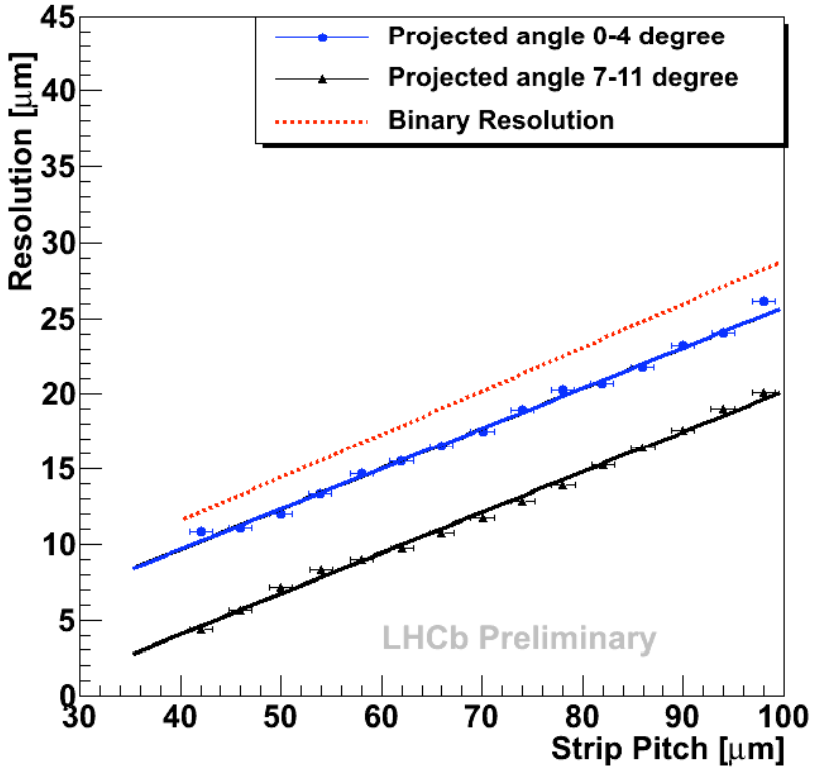

CMS Preliminary
√s = 7 TeV
Yield = 569 ± 62
Mean = (145.42 ± 0.05) MeV/c²
Sigma = (0.68 ± 0.08) MeV/c²
$D^{*+} \to D^o(K^-\pi^+)\pi^+$
Events / 0.5 MeV/c²
M(Kππ) - M(Kπ) [GeV/c²]


CMS Preliminary
√s = 7 TeV
Yield = 561 ± 40
Mean = (1.864 ± 0.001) GeV/c²
Sigma = (14.1 ± 1.1) MeV/c²
$D^o \to K^-\pi^+$
Events / 10 MeV/c²
M(Kπ) [GeV/c²]

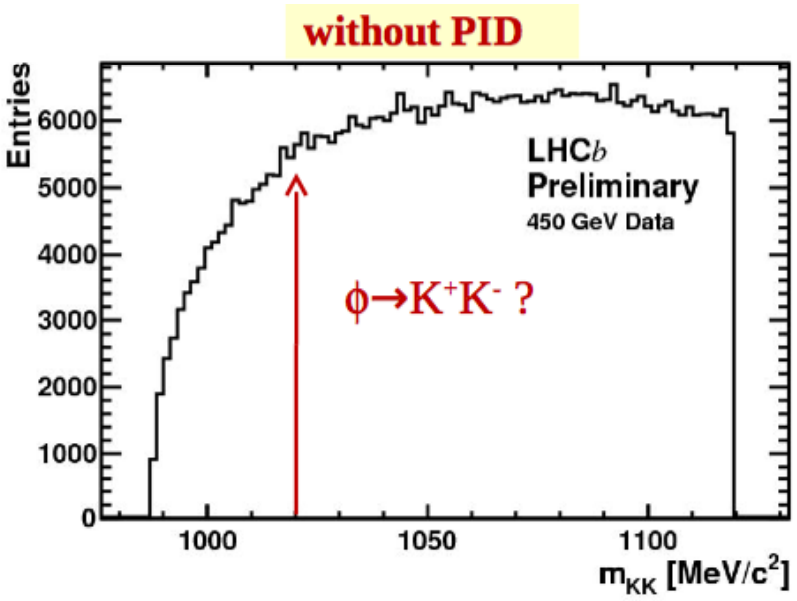

CMS

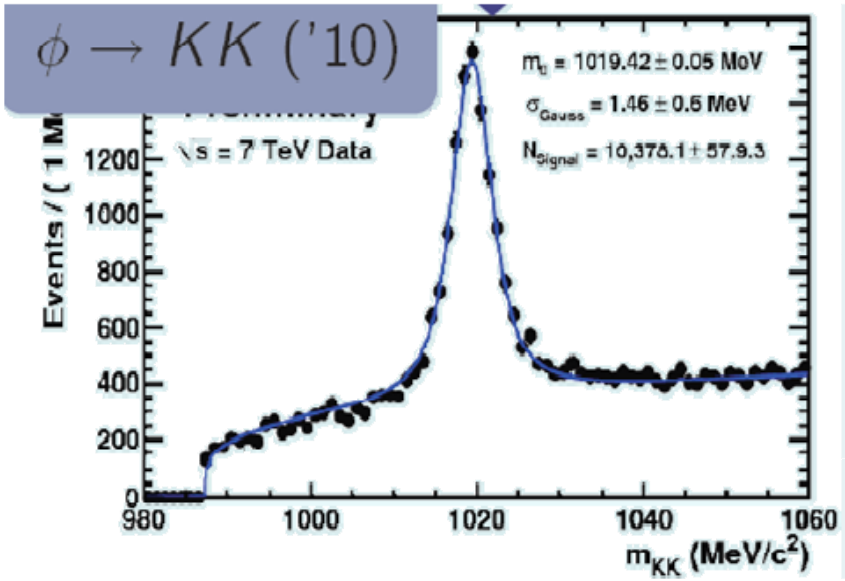
Impressive resolutions have been achieved, this must be the record…



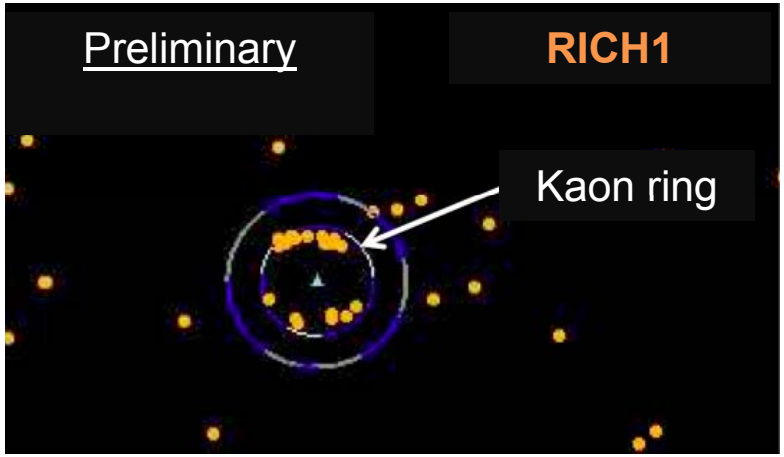


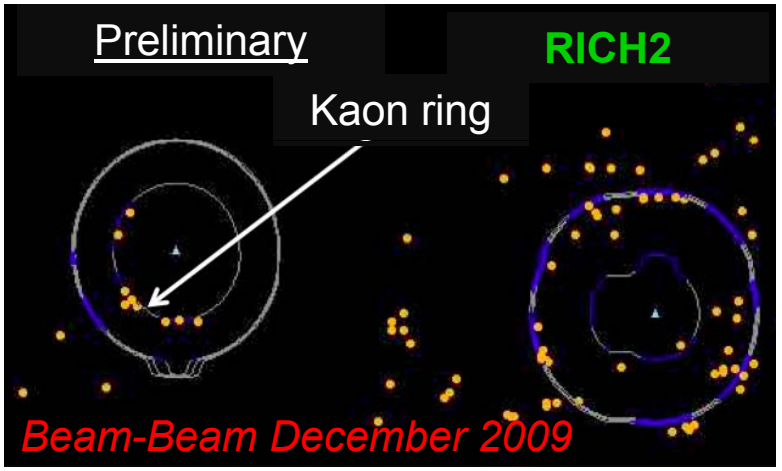
LHCb RICH detectors





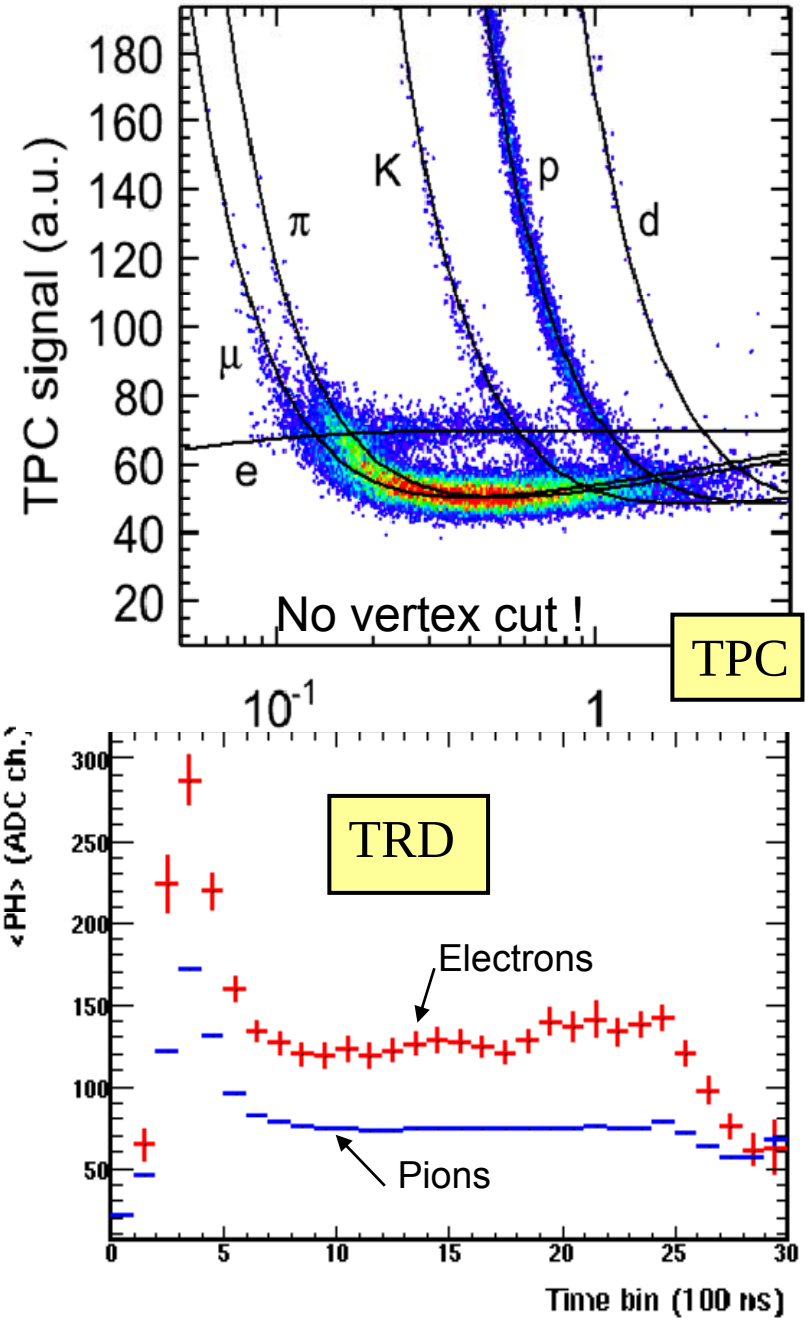
With RICHes PID!

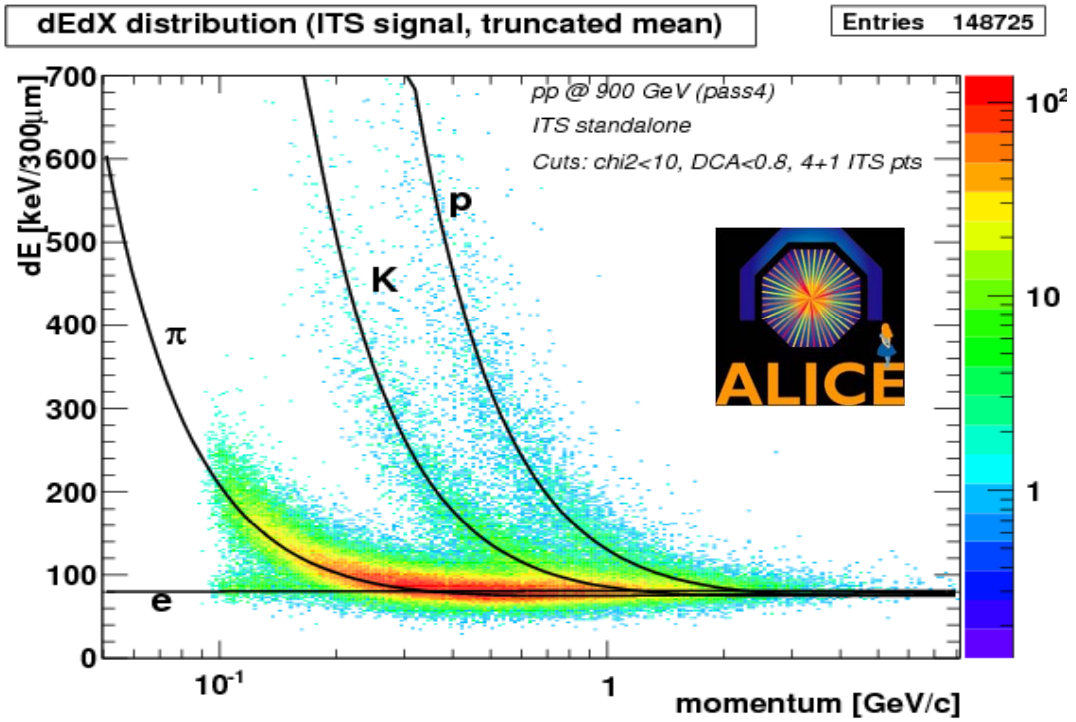


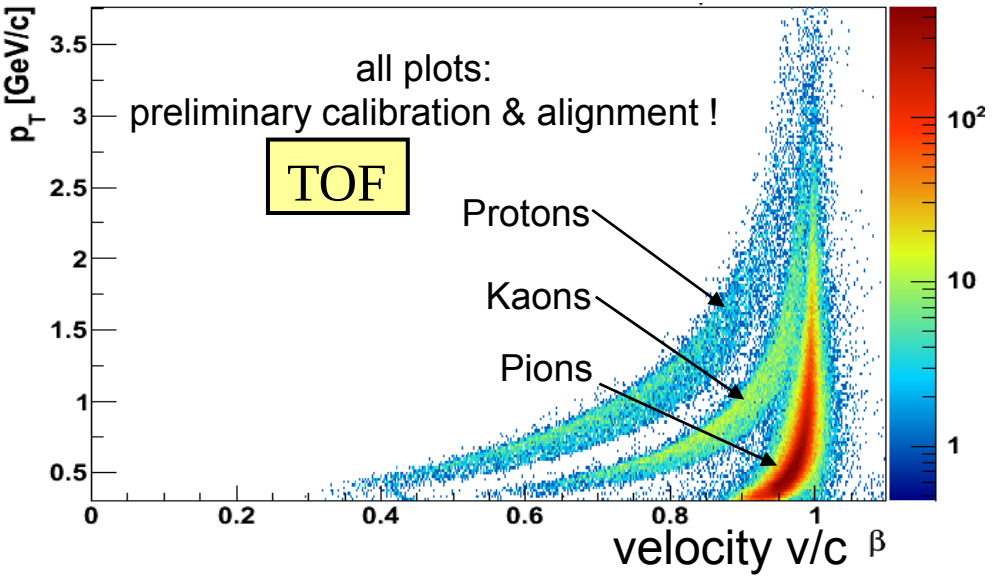


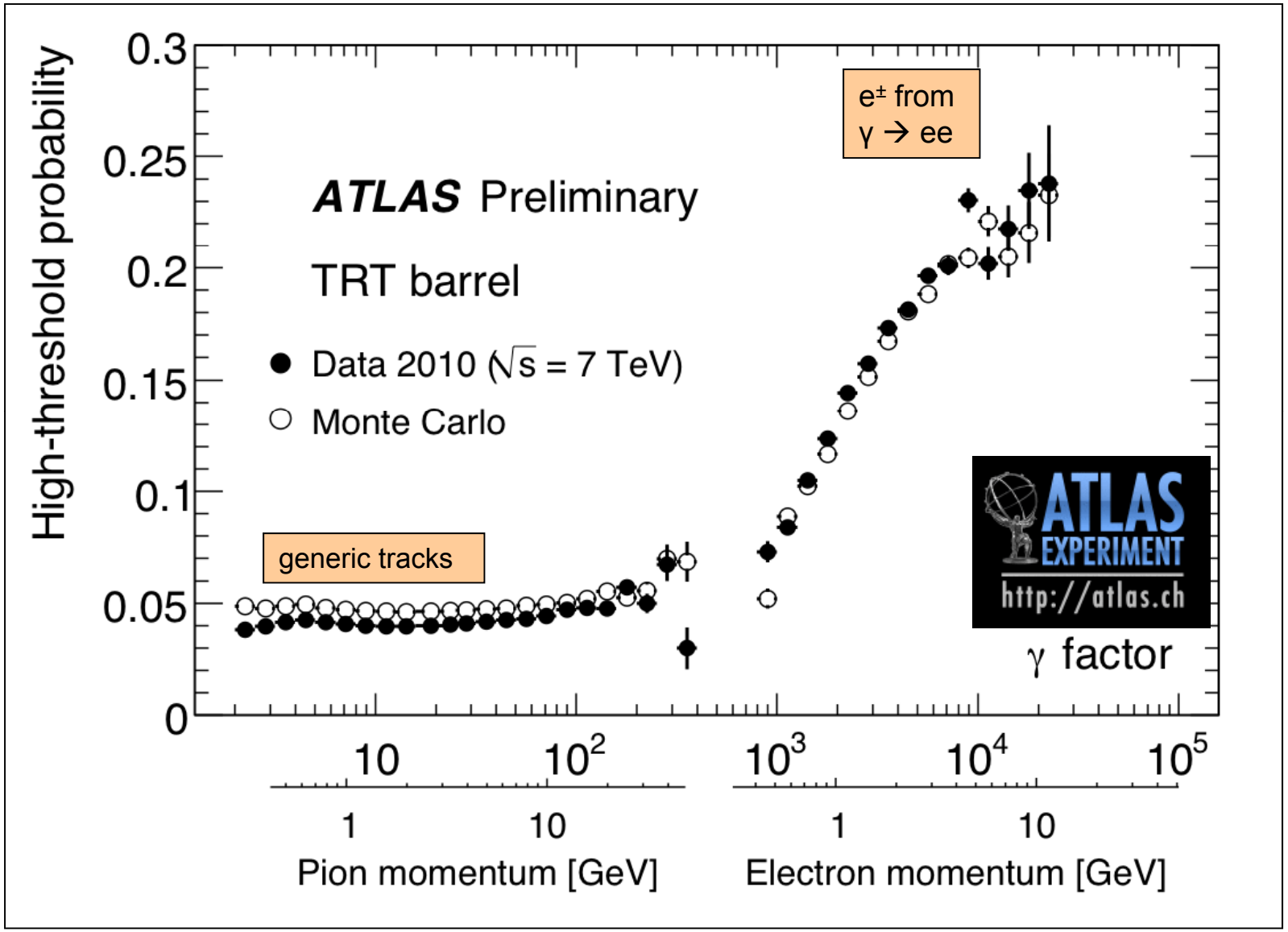
- RICH (Ring Imaging CHerenkov)
  - allow K-π identification from ~ 2 to 100 GeV
- Particle IDentification with RICHes
  - orange points: photon hits
  - Continuous lines: expected distribution for each particle hypothesis

ALICE particle identification





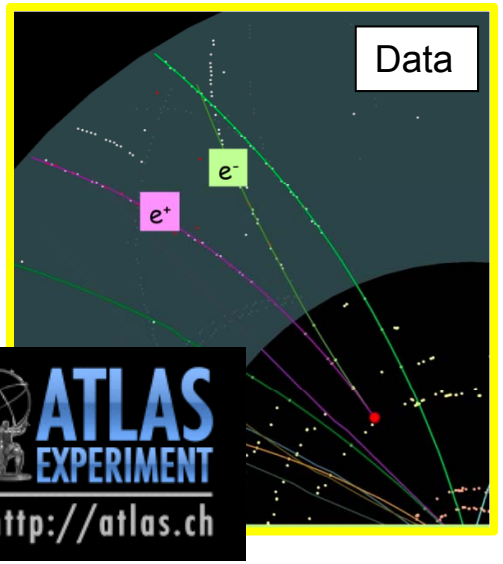




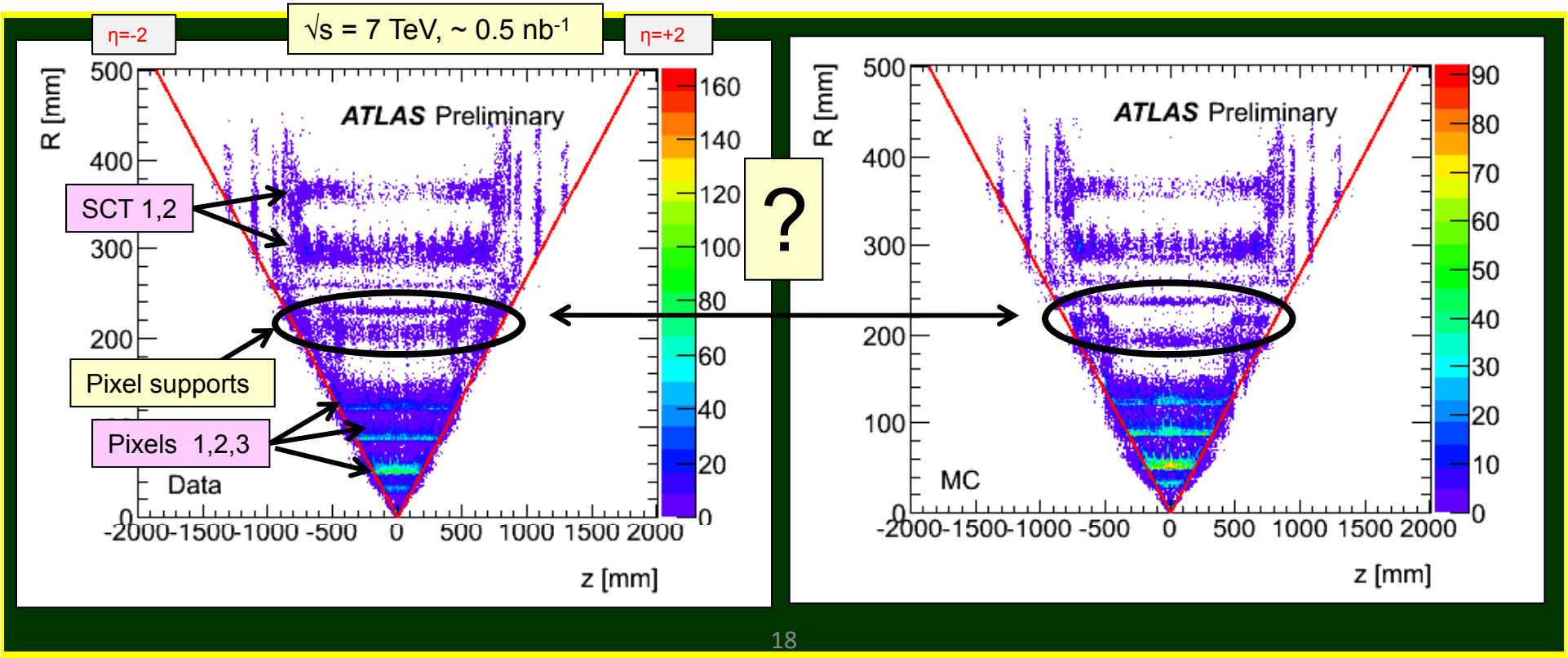
Transition radiation intensity proportional to particle relativistic factor $\gamma = E/mc^2$.
Onset for $\gamma \sim 1000$ (MC tuned with test-beam data only)

Mapping the Inner Detector material with γ → e^+e^- conversions

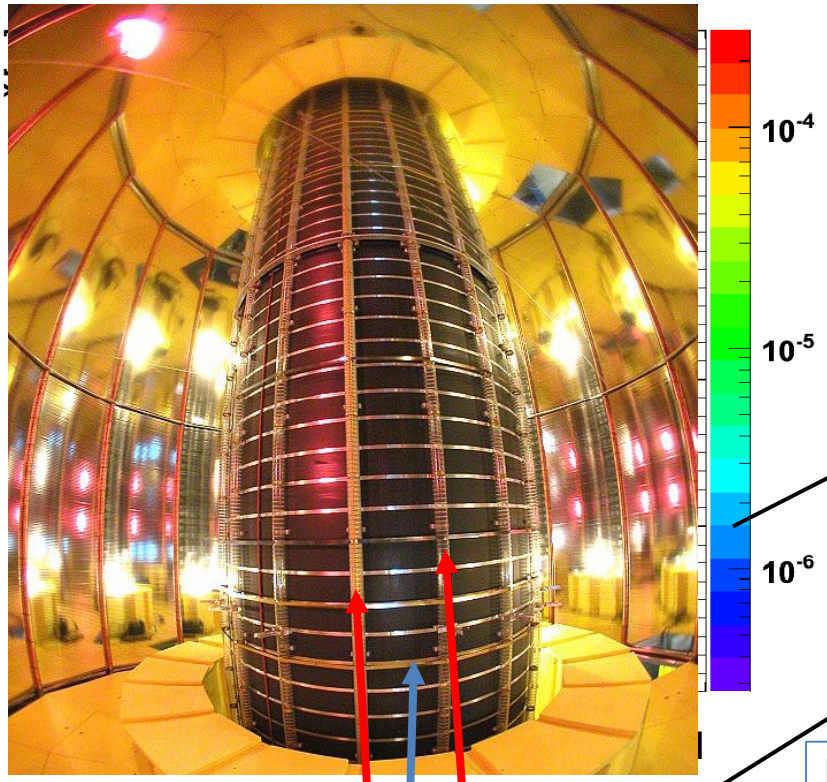
… and using data to find geometry imperfections in the simulation

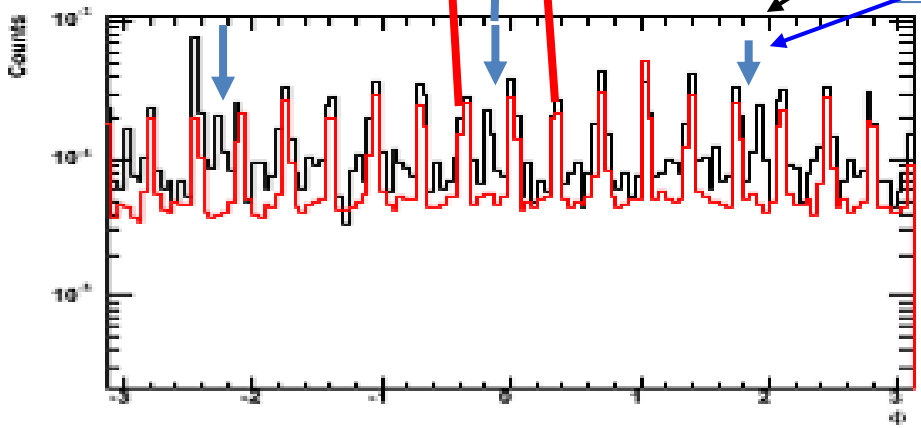


Reconstructed γ → e^+e^- conversion points in the Rz plane in minimum bias events

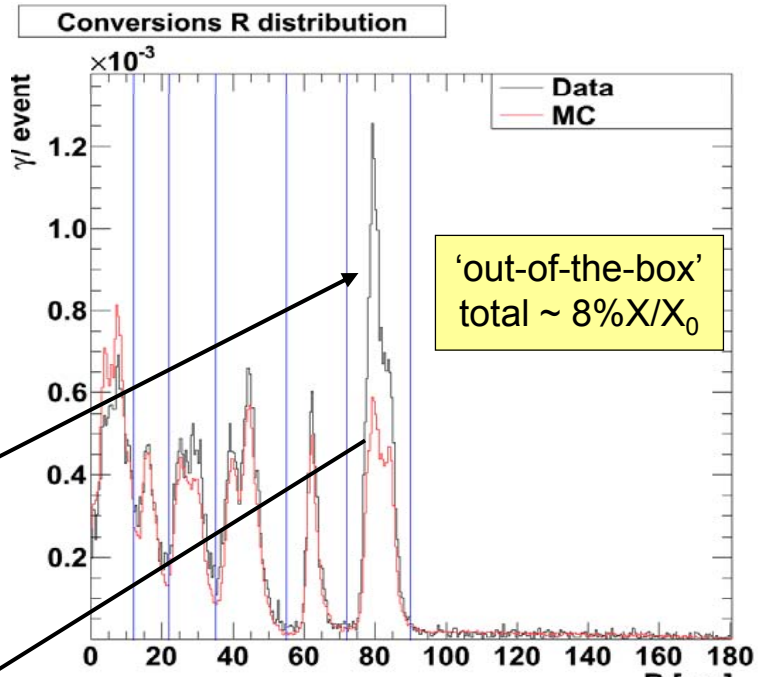


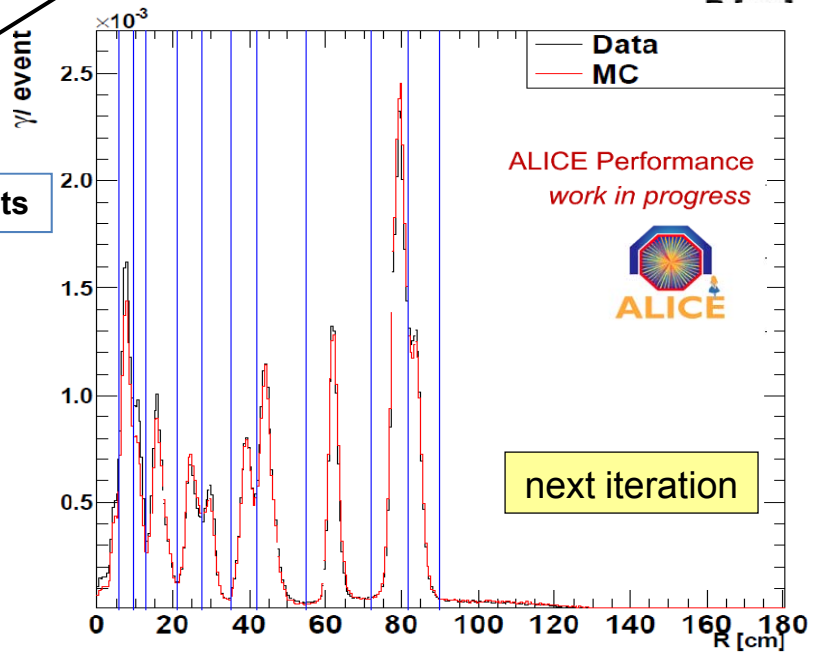
Material studies in ALICE



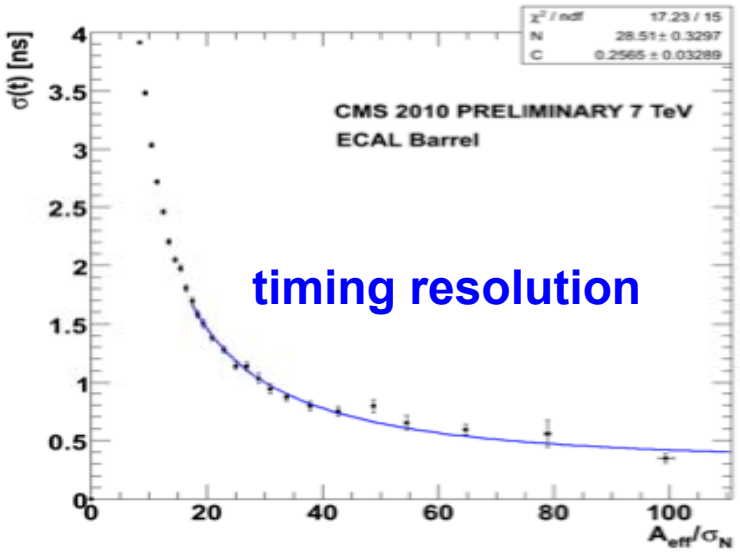


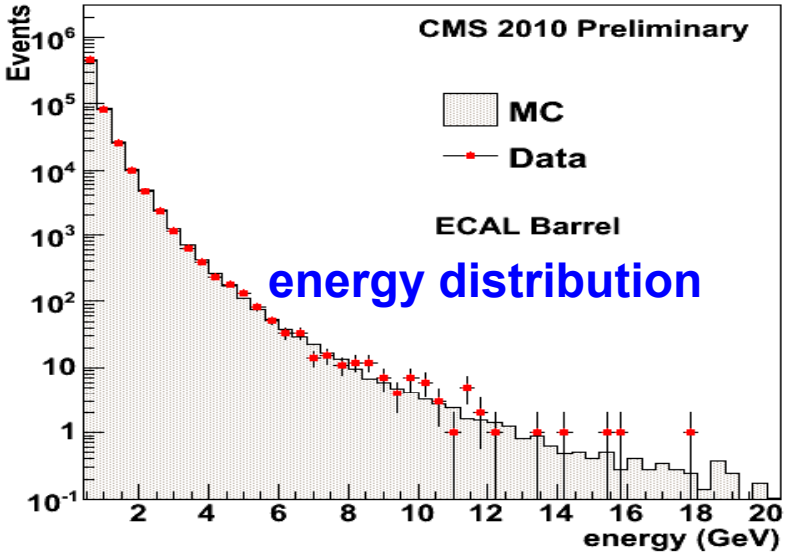
IFC glue joints

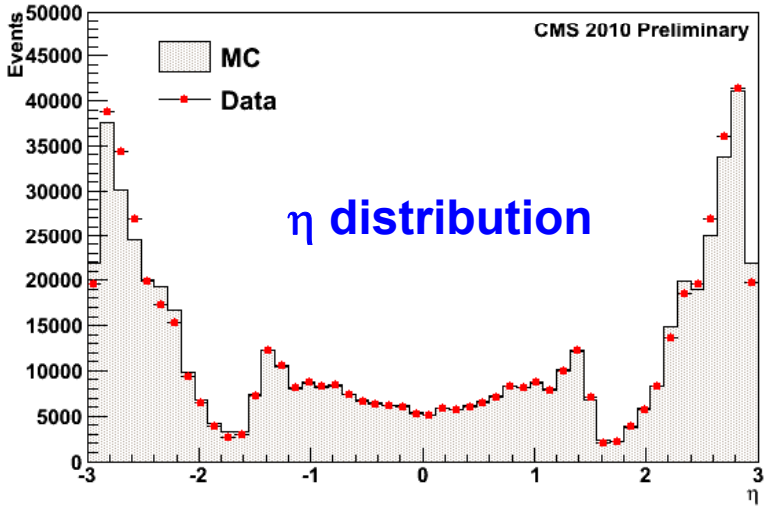


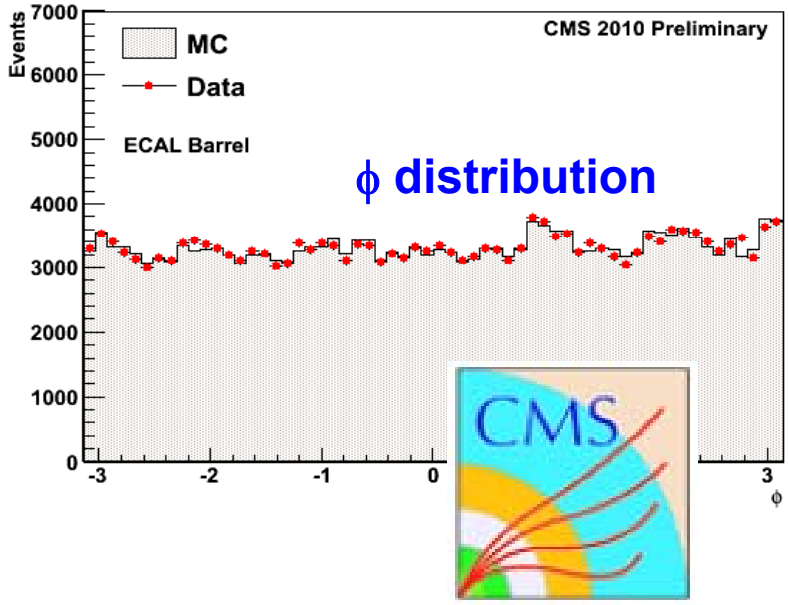


ECAL clusters (electrons and photons)









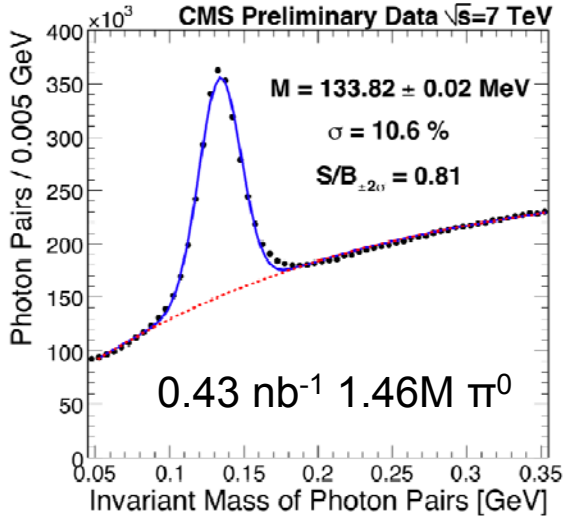
Low mass di-photons: π^0 and η

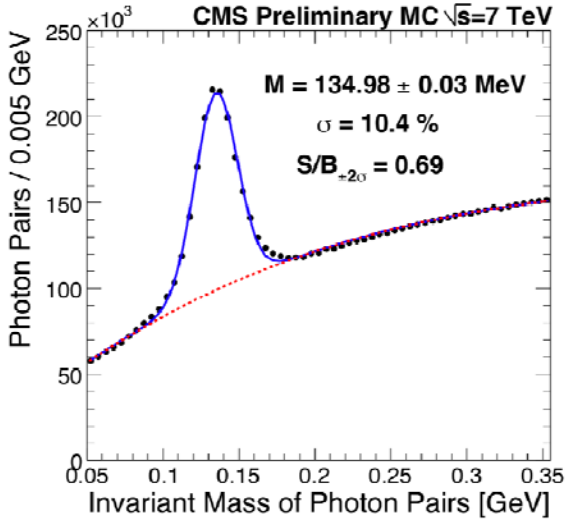
MC based correction applied according to cluster η and energy

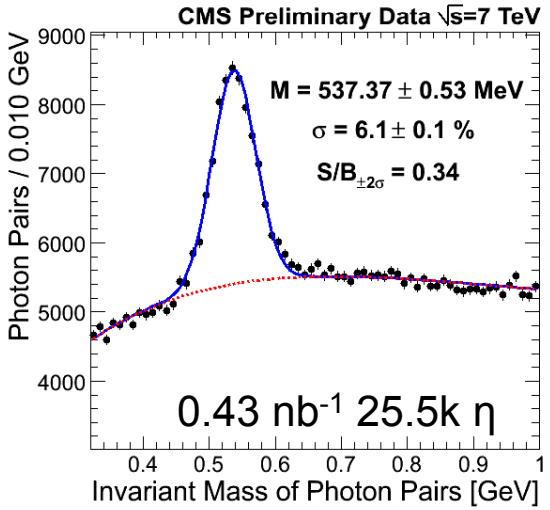
1.46M of $\pi^0 \rightarrow \gamma\gamma$
$P_T(\gamma) > 0.4$ GeV,
$P_T(pair) > 1$ GeV

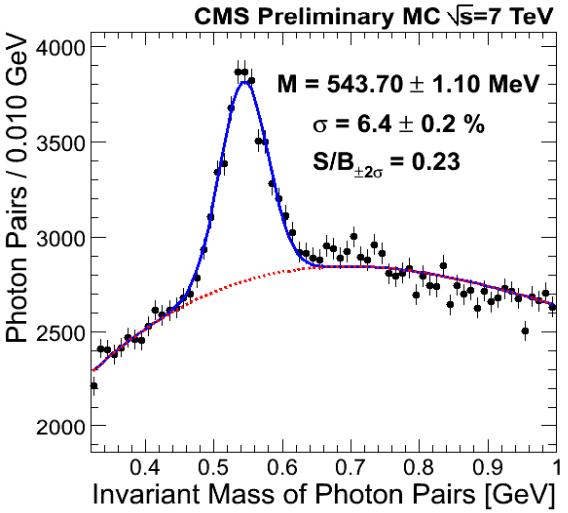
25.5K $\eta \rightarrow \gamma\gamma$
$P_T(\gamma) > 0.5$ GeV,
$P_T(pair) > 2.5$ GeV

Numbers refer to ~10% of the currently available statistics.
Very useful tool to intercalibrate the crystals.

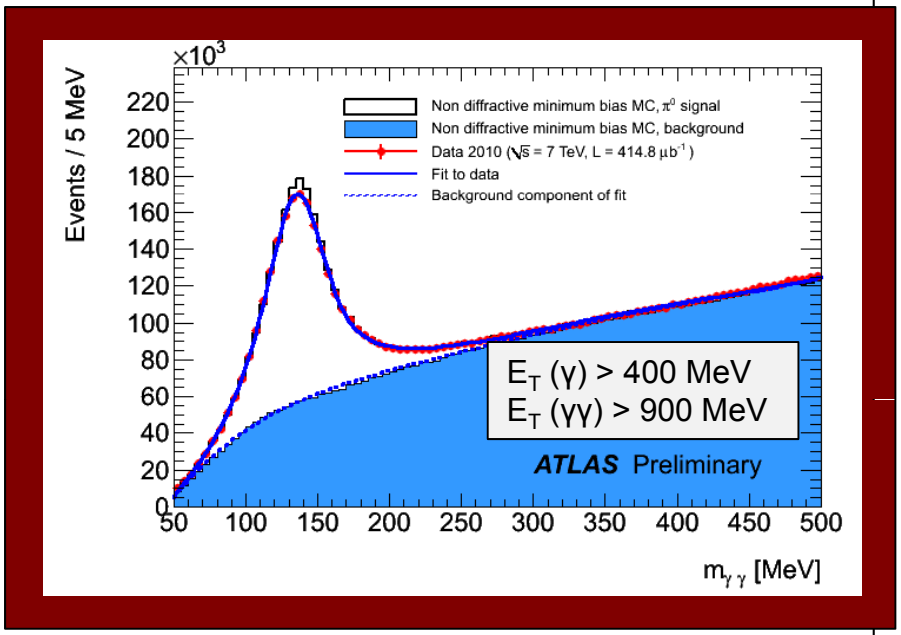






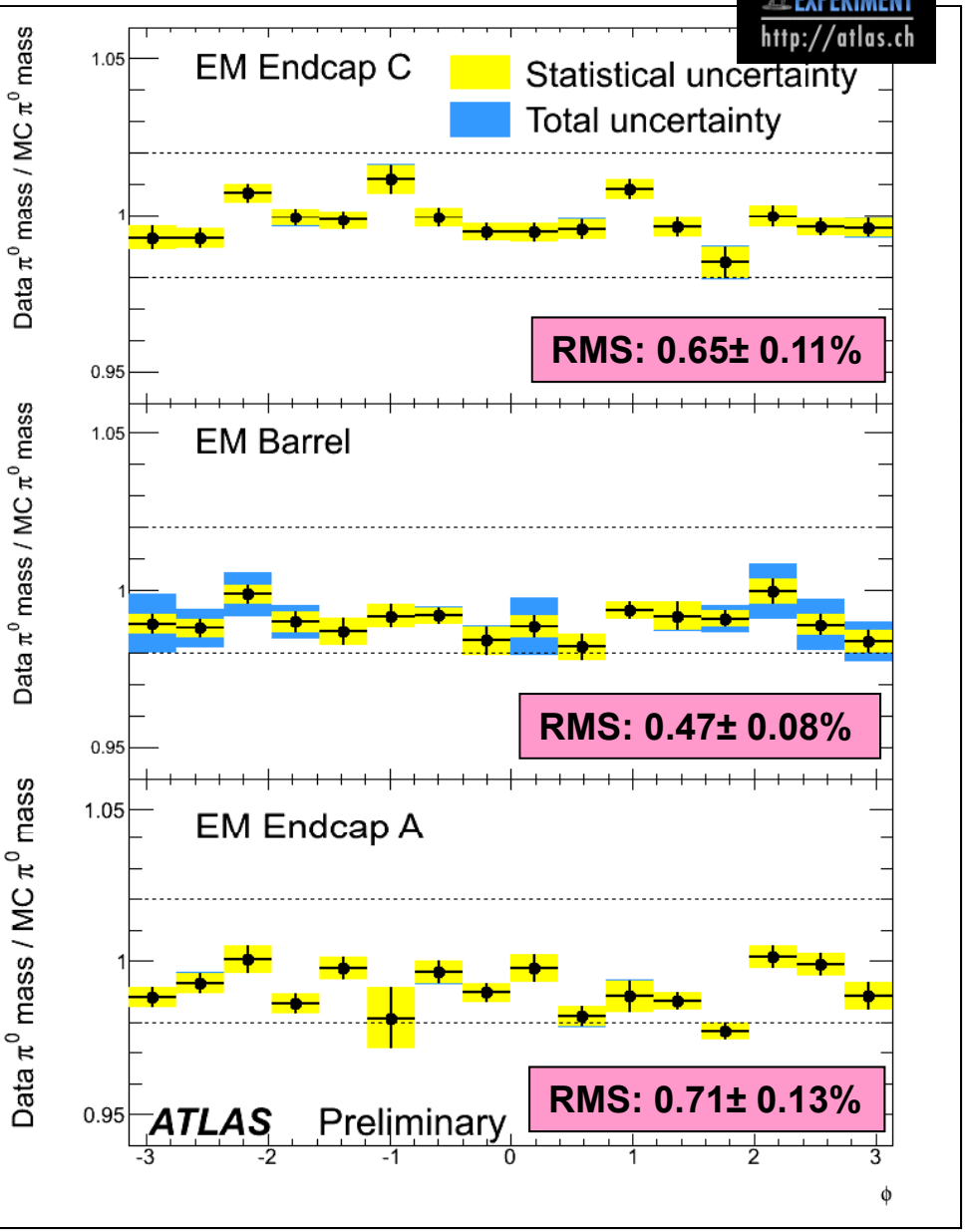


Understanding the EM calorimeter response uniformity and E-scale with $\pi^0 \rightarrow \gamma\gamma$

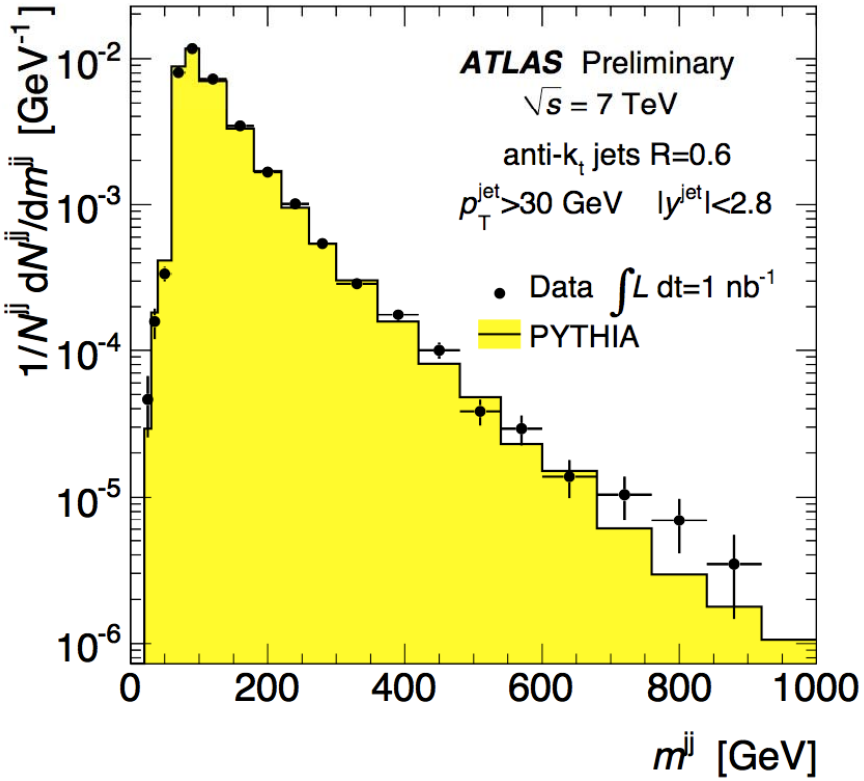


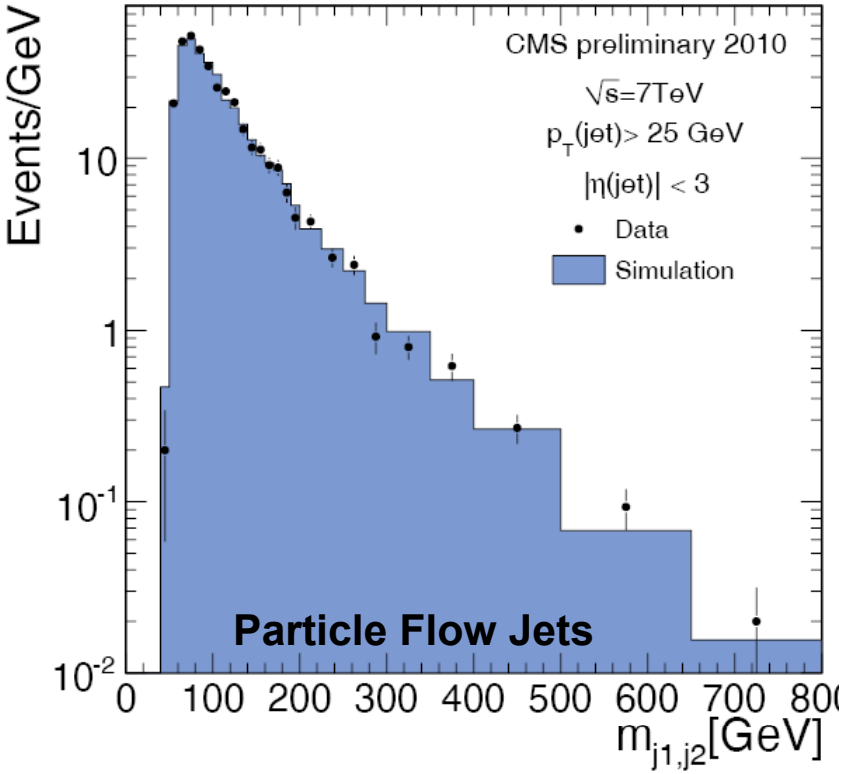
Fit results:
M= 135.05 ± 0.04 MeV (PDG: 134.98)
σ ~ 20 MeV
Systematics: m: 1%; σ~ 10%

E-scale in this range known to ~ 2 %
Response uniformity in φ in each calorimeter: ~ 0.7%



Hadronic energy measurements and jets … underway for physics measurements soon!





MET resolution vs Sum ET

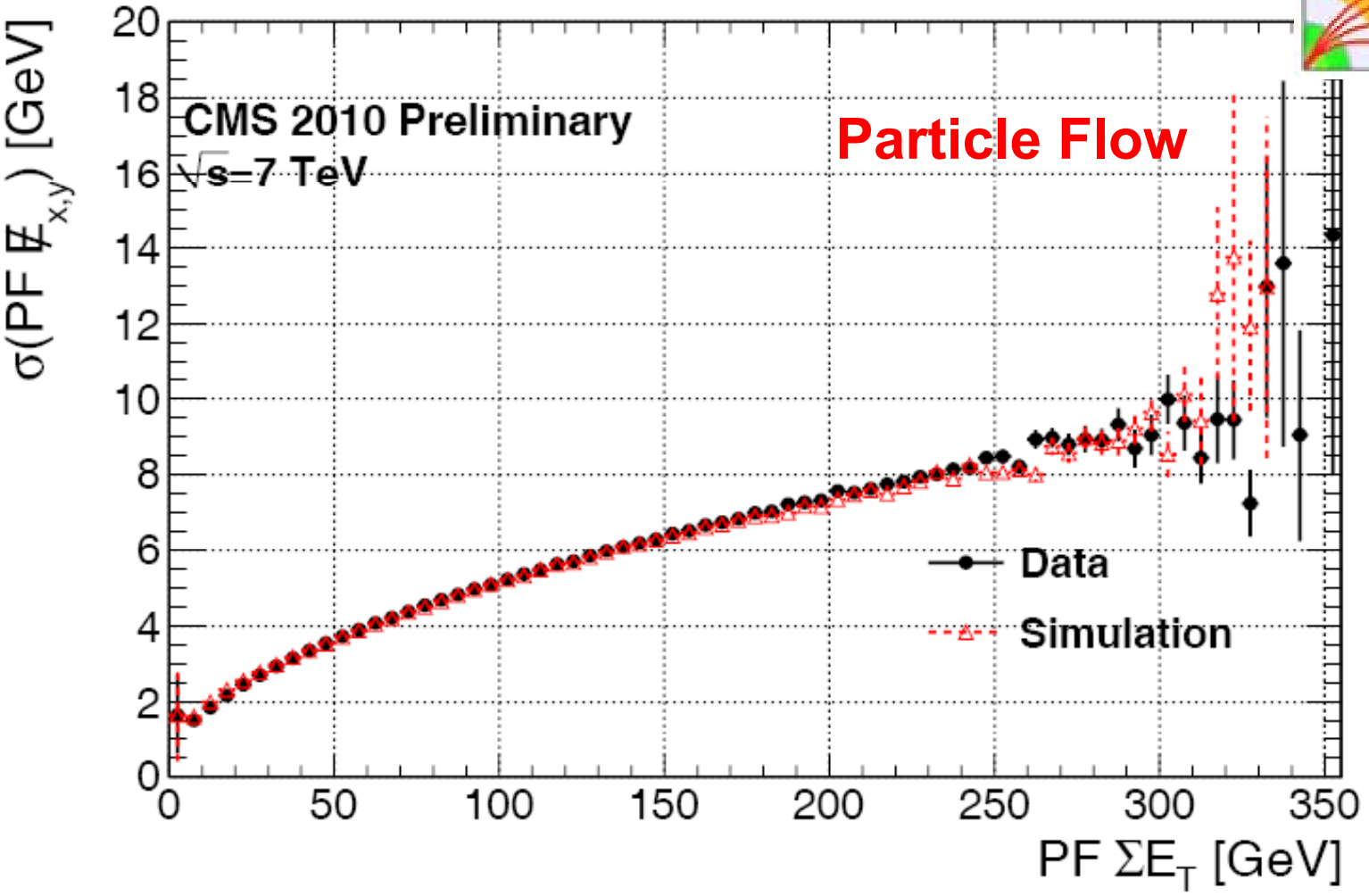
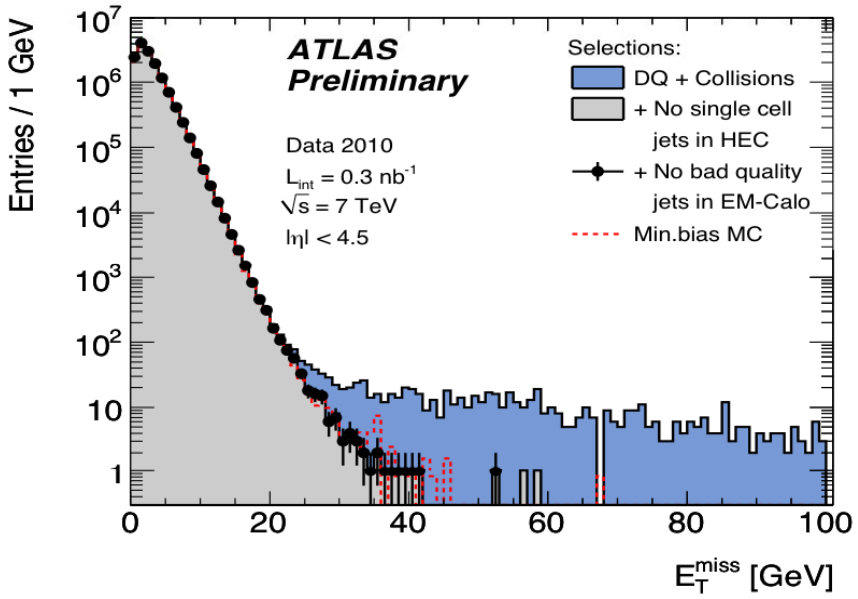
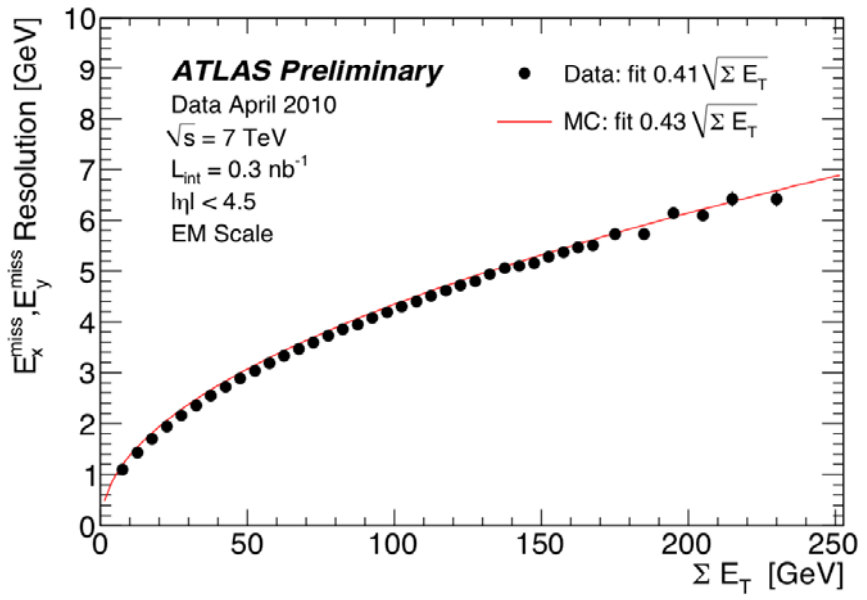


Figure: Data vs MC: PF $\not\!\!E_{xy}$ resolution as function of PF ΣE_{T}

Missing transverse energy

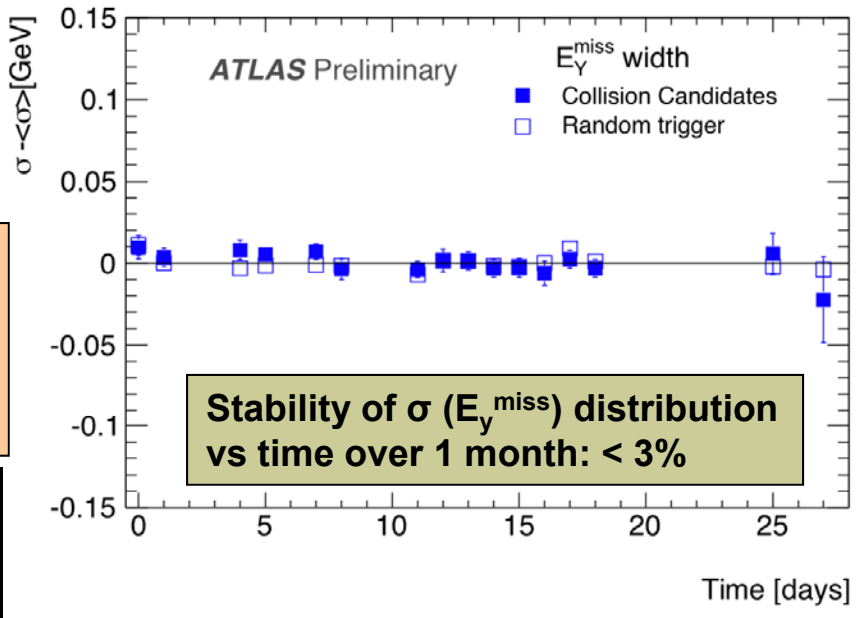


Measured over ~ full calorimeter coverage (360^0 in φ, |η| < 4.5, ~ 200k cells)



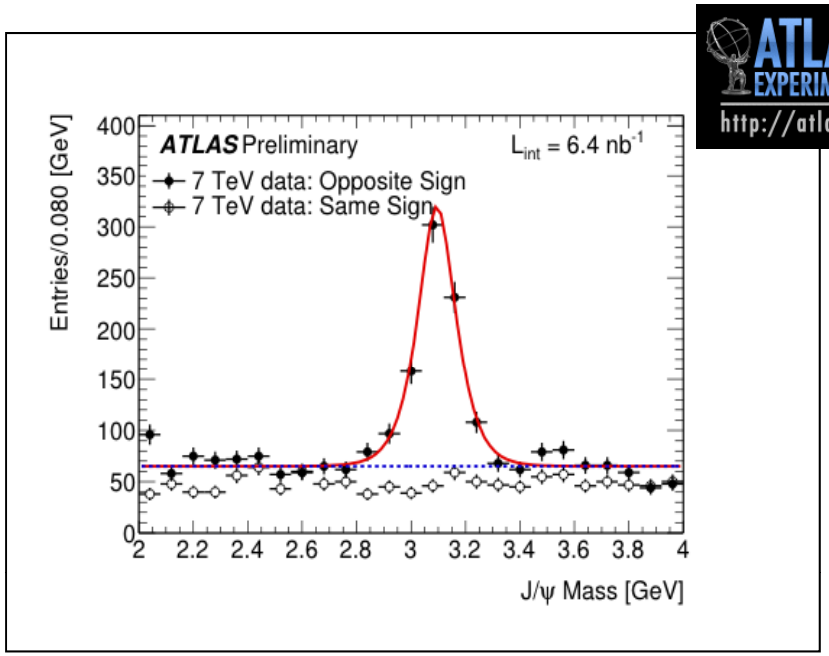
Event fraction removed by additional cleaning cuts: ~ 10^{-4}

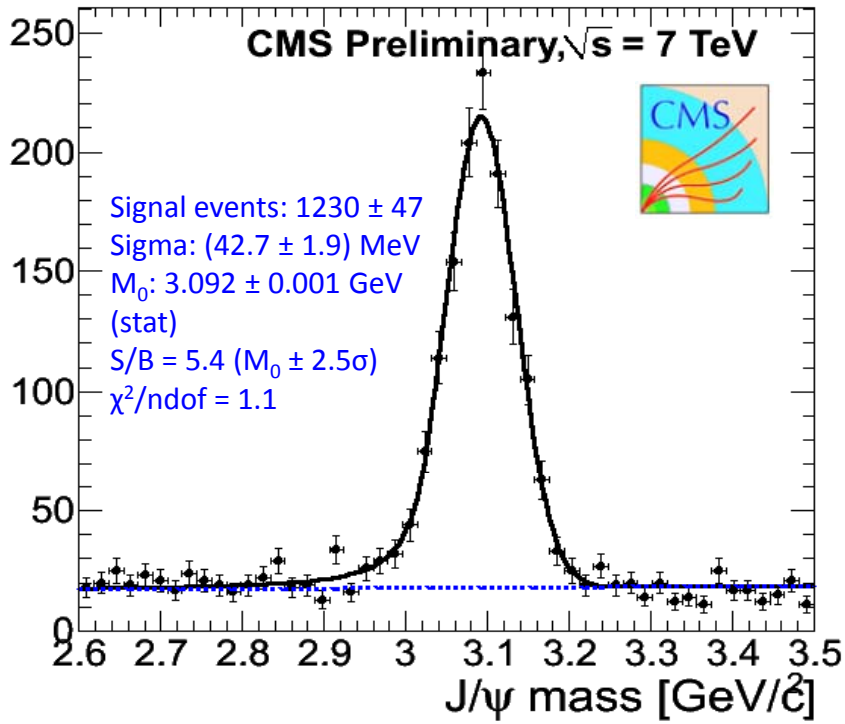
E_T^{miss} is sensitive to calorimeter performance (noise, coherent noise, dead cells, mis-calibrations, cracks, etc.), and cosmics and beam-related backgrounds

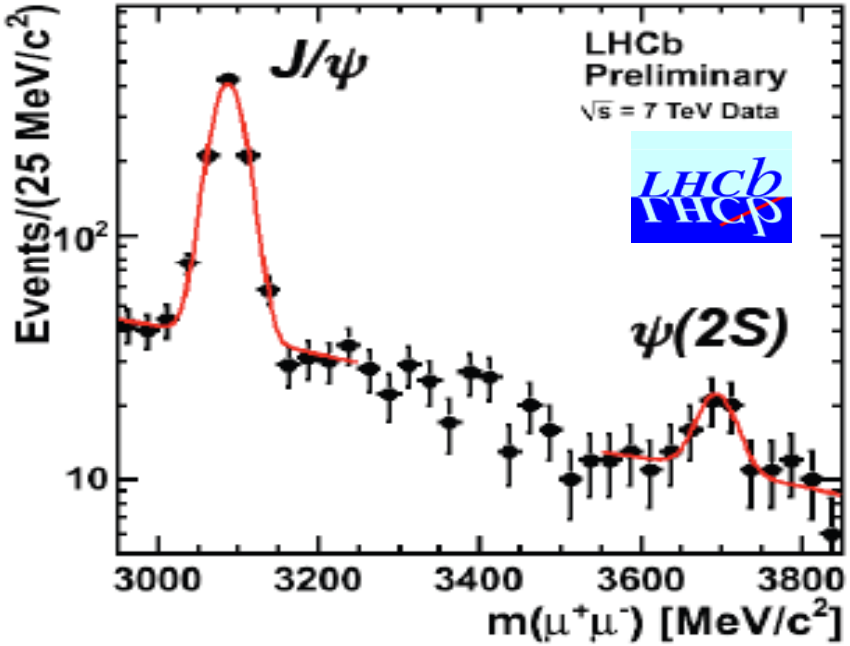


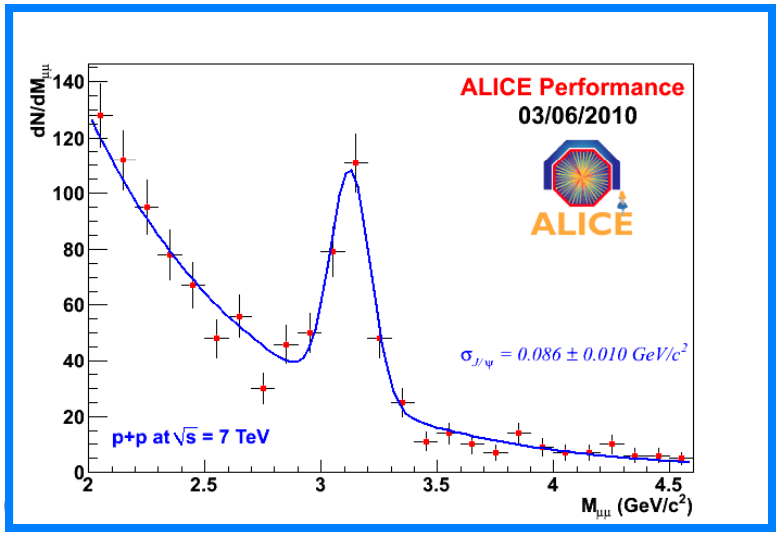
ATLAS EXPERIMENT
http://atlas.ch

J/ψ Production







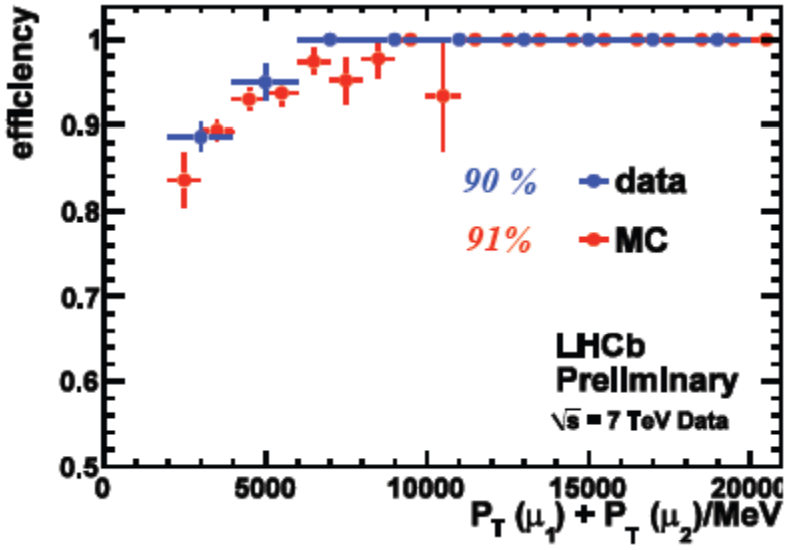


ary and

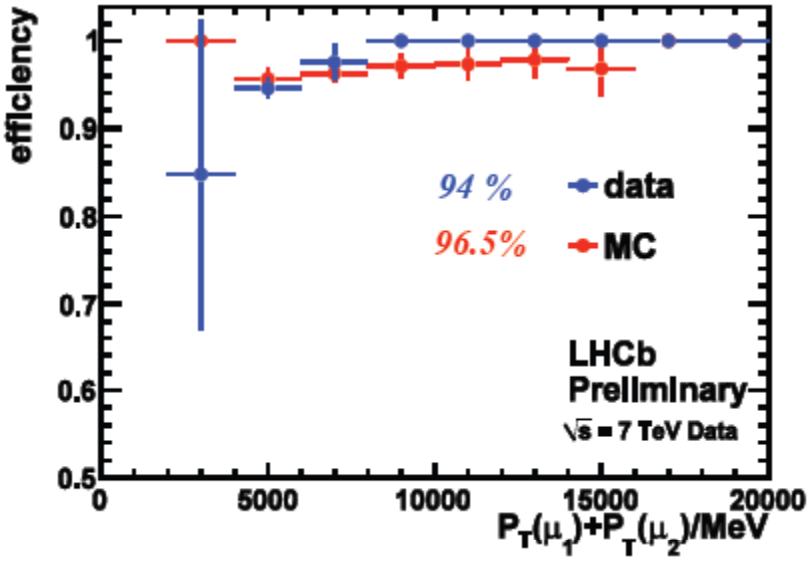
Trigger Efficiencies

- *Measure performance of L0*HLT1 (using lifetime unbiased HLT1 lines) for J/ψ→μμ*
- *Transport results to harder p_t spectrum of B_s→μμ*

L0 x HLT efficiency for J/ψ



HLT efficiency for Bs→μμ



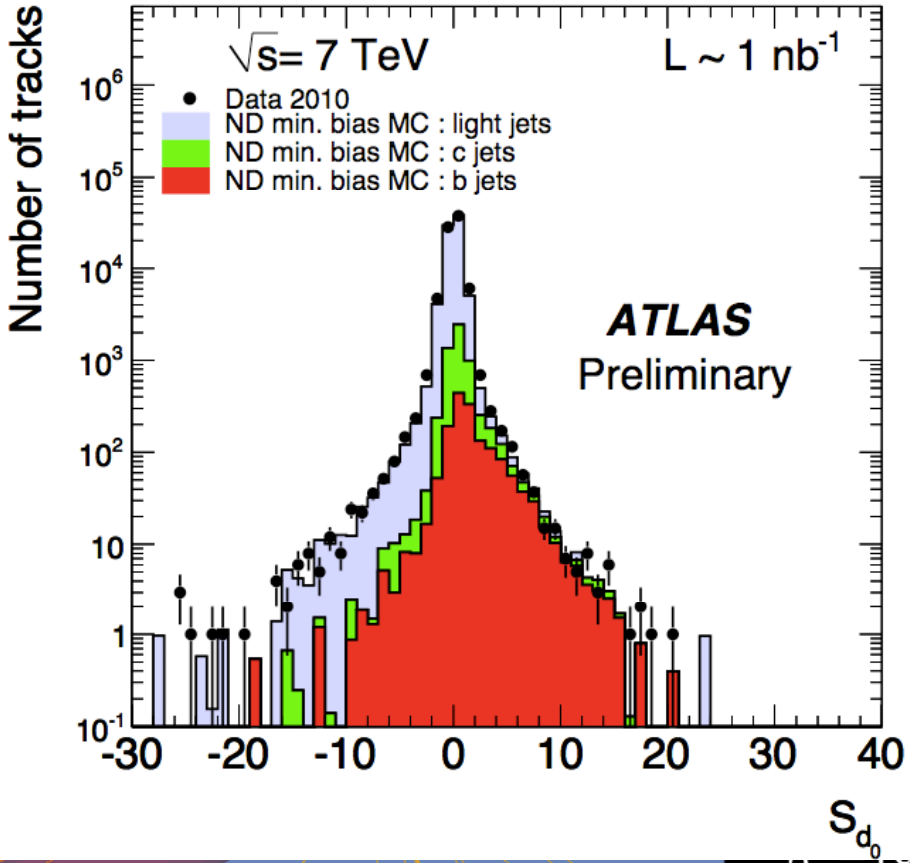
Data agree well with MC

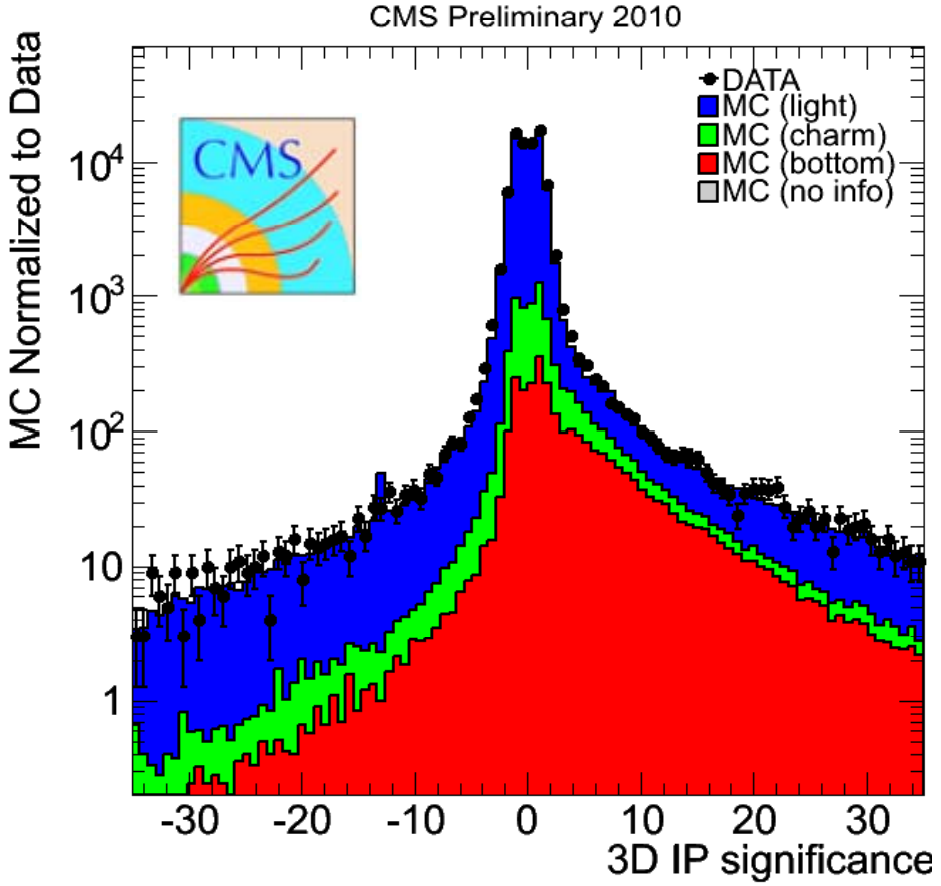
LHCb trigger concept has been proven with data !!!

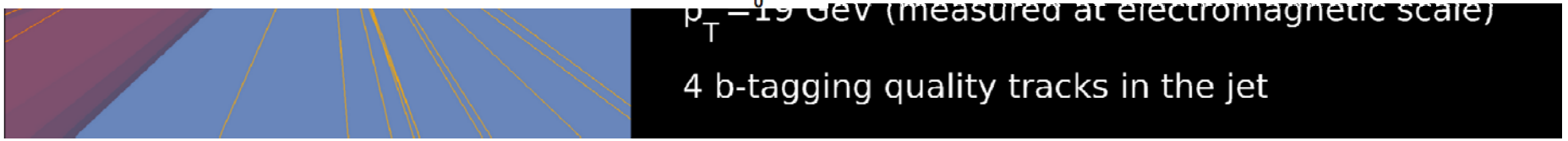
LHCb is currently running with the pile-up close to expected at nominal conditions

b - tagging


ATLAS
EXPERIMENT
http://atlas.ch
Run 152166
Event 817271
b-tagged jet in 7 TeV collisions
Si strips

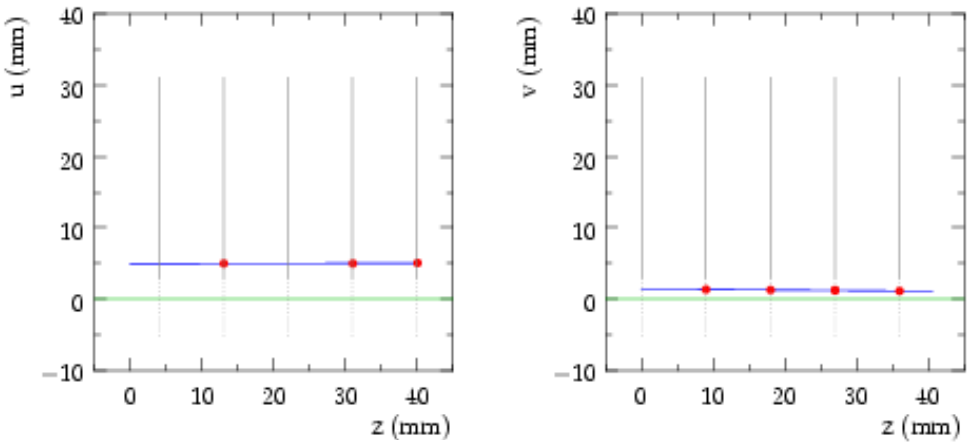

√s= 7 TeV
L ~ 1 nb-1
Data 2010
ND min. bias MC : light jets
ND min. bias MC : c jets
ND min. bias MC : b jets
ATLAS
Preliminary
Number of tracks
Sd0

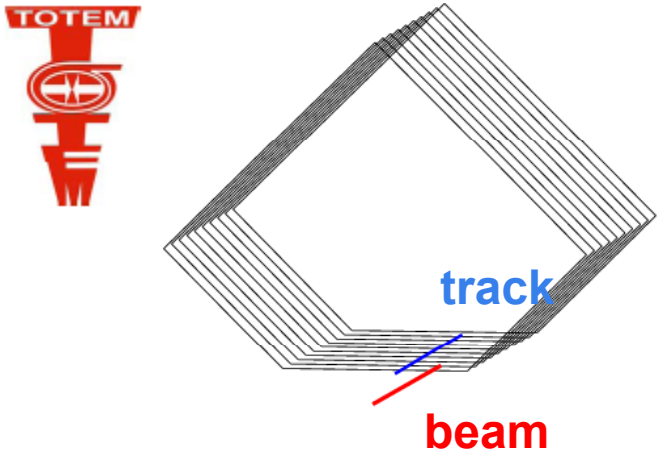

CMS Preliminary 2010
CMS
DATA
MC (light)
MC (charm)
MC (bottom)
MC (no info)
MC Normalized to Data
3D IP significance

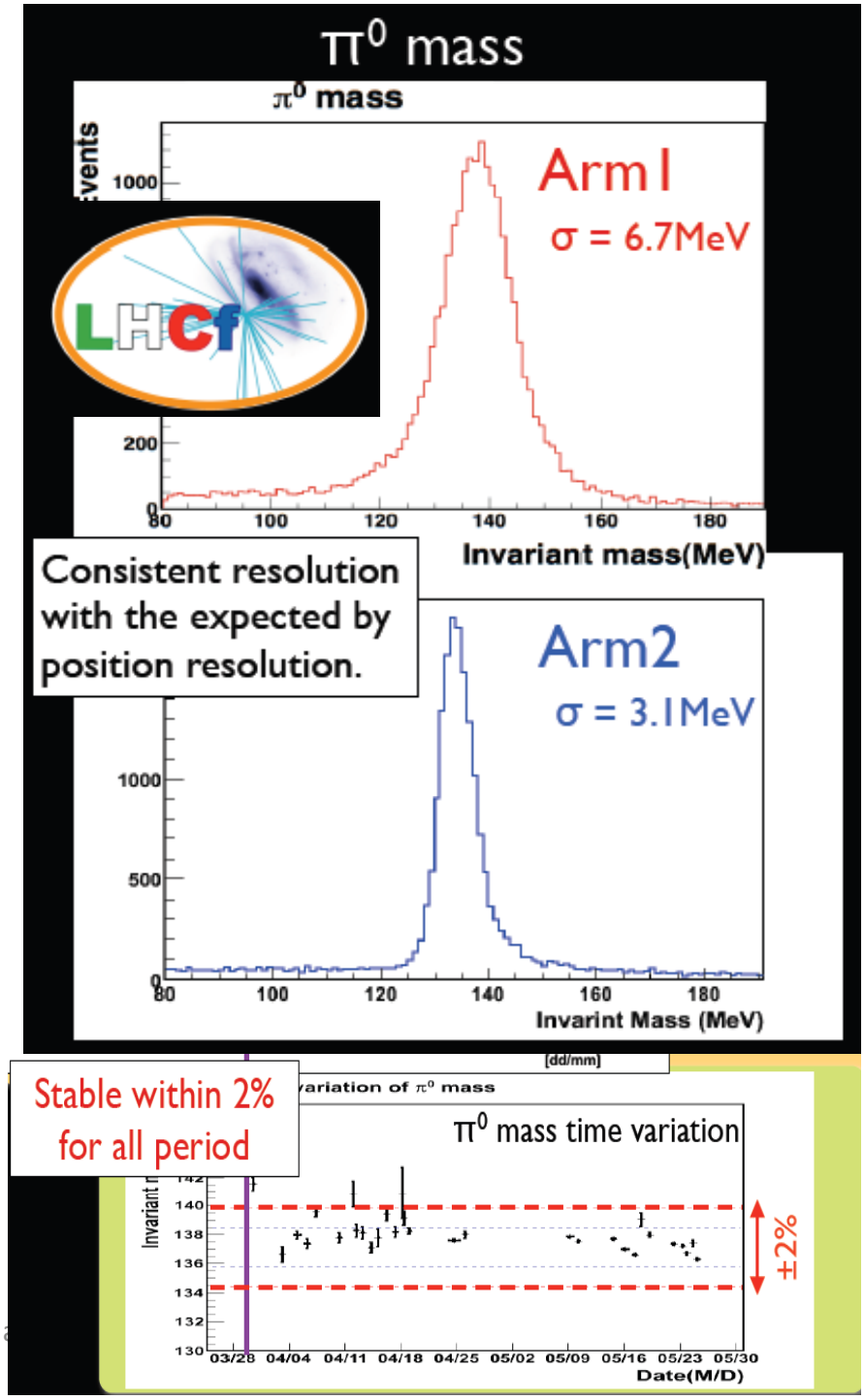

pT ~19 GeV (measured at electromagnetic scale)
4 b-tagging quality tracks in the jet

Forward Detector Experiments

A first track in the RP detectors

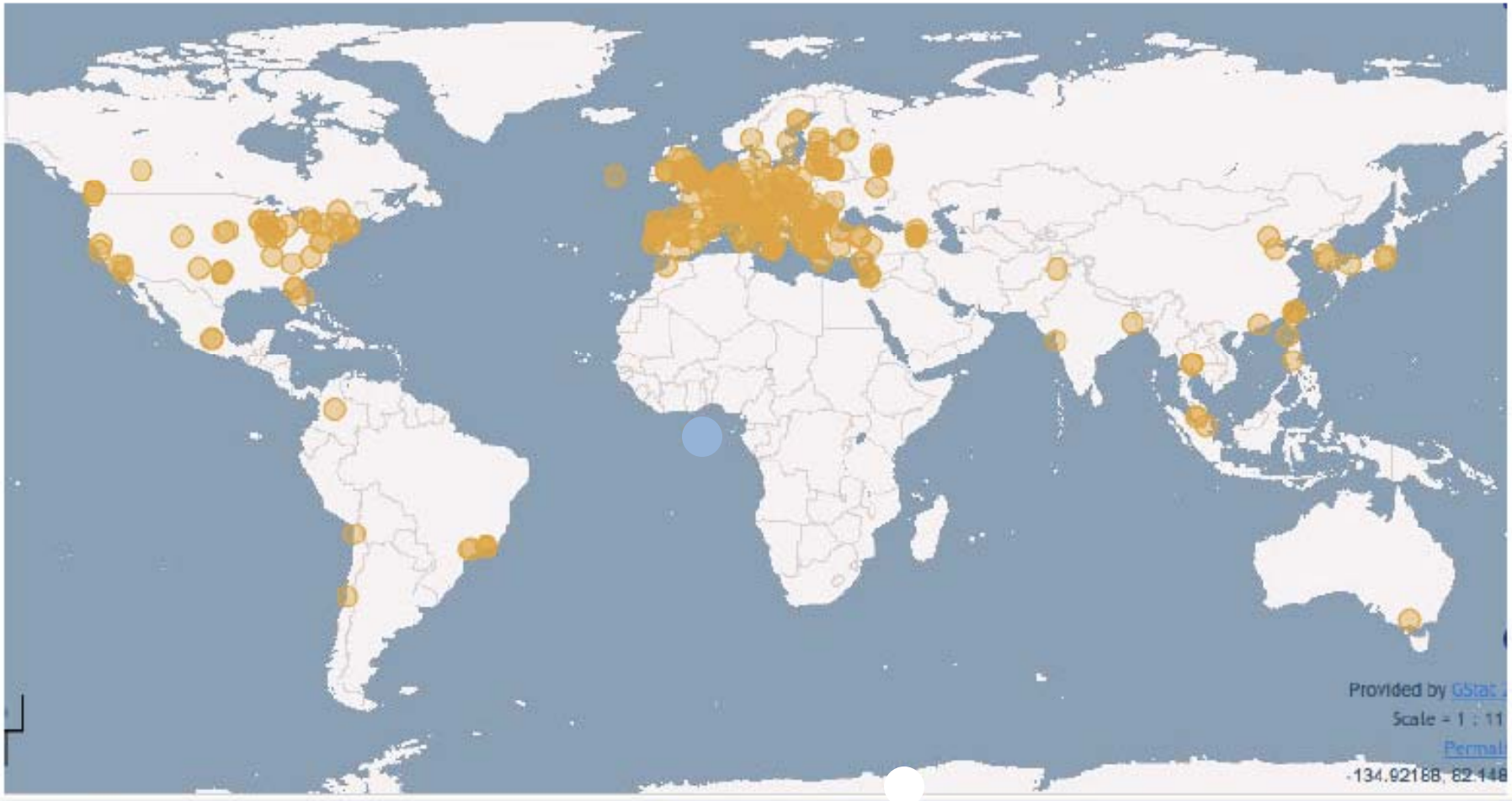






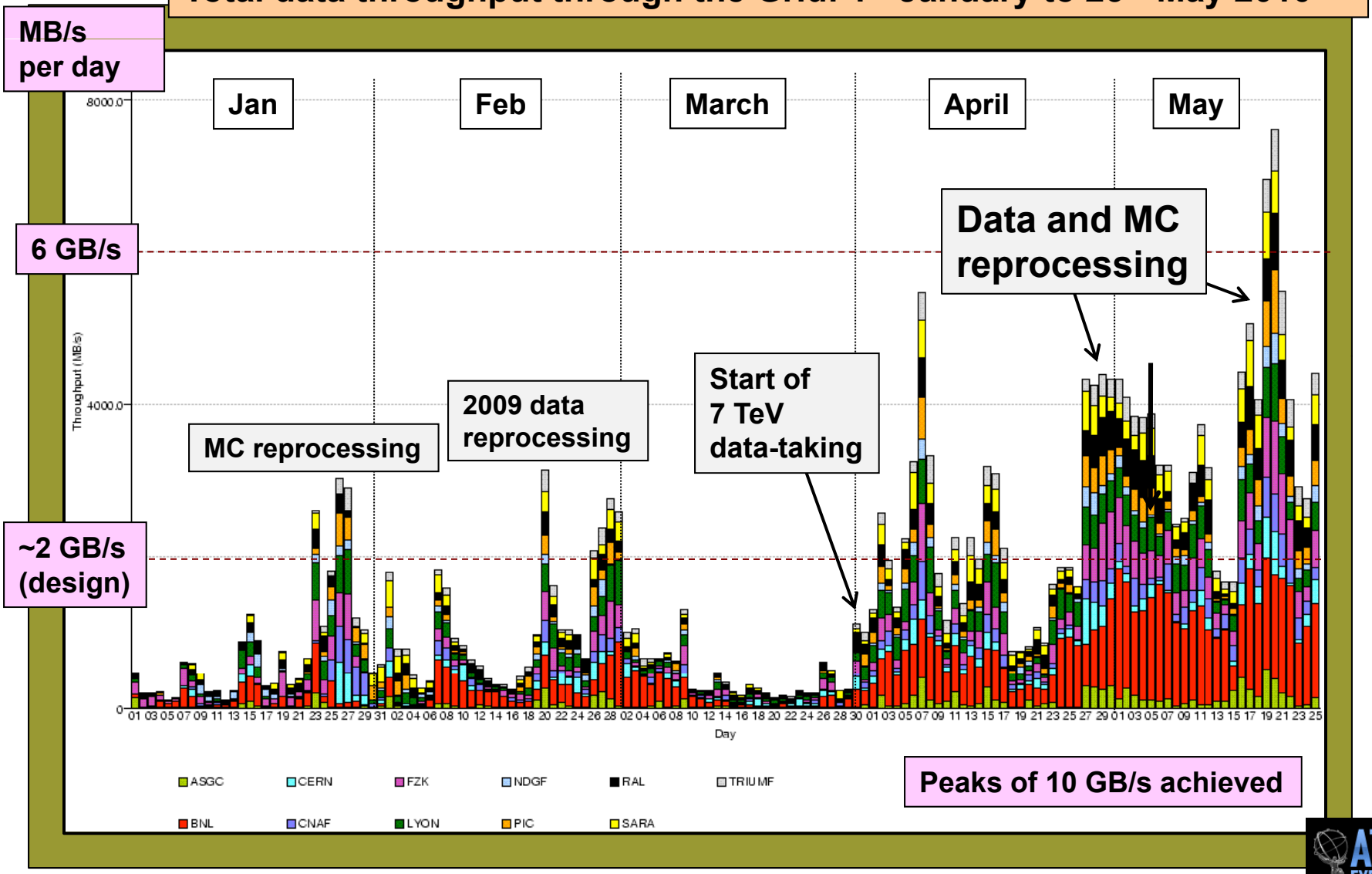
Today's WLCG

- More than 170 computing facilities in 34 countries
  - More than 100k Processing Cores
  - More than 50PB of disk



Worldwide data distribution and analysis

Total data throughput through the Grid: 1st January to 25th May 2010



GRID-based analysis in April-Mai 2010:
~ 900 different users, ~ 6 million jobs completed; > 45 billion events analysed

ATLAS EXPERIMENT http://atlas.ch

To sum up the commissioning part:

(Only a tiny fraction of all the many results could be mentioned)

It is not exaggerated to state that never in the past experiments have been ready to such a great extent when starting up operation with beams

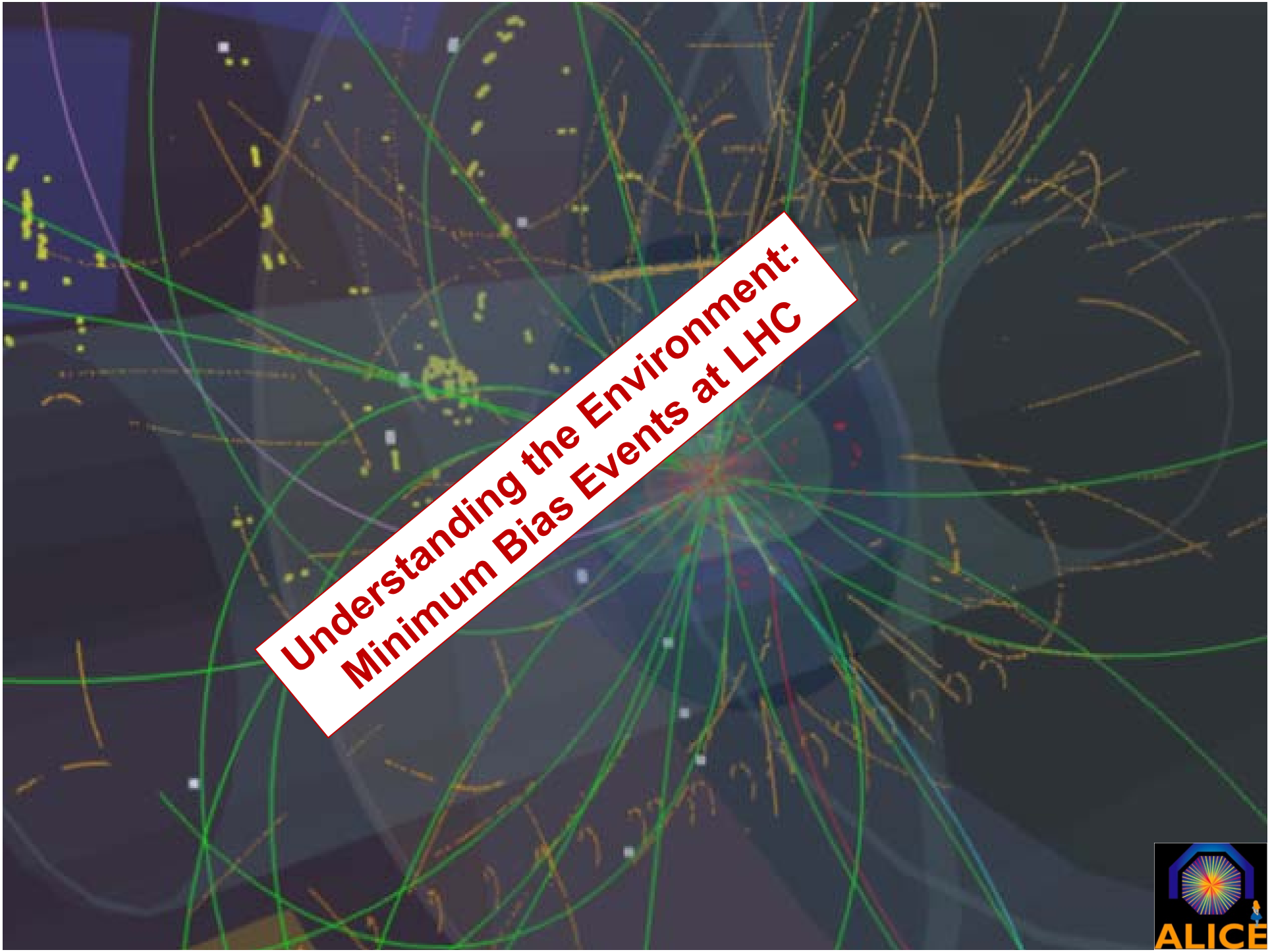
- The complex detector hardware is working at a remarkable level, including efficient data taking (trigger, DAQ, operation…)

- A long history of test beam studies and detector simulations result in a great understanding of the instrumentation

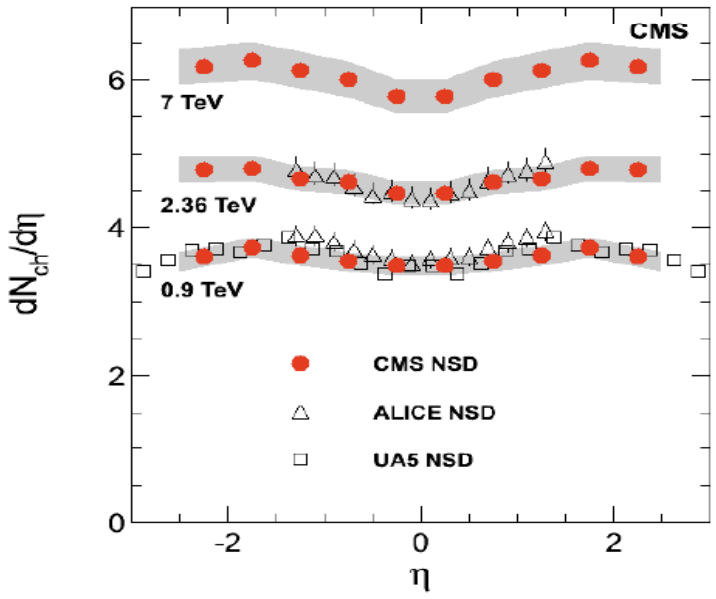
- The experiments are successfully exploiting huge amounts of cosmics data from the last couple of years

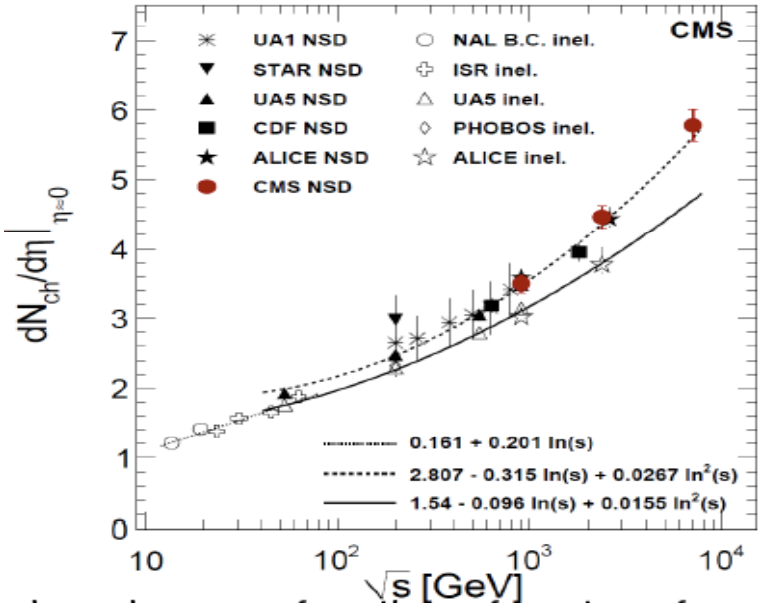
The collision data is then already used at the 'fine-tuning' stage of the commissioning

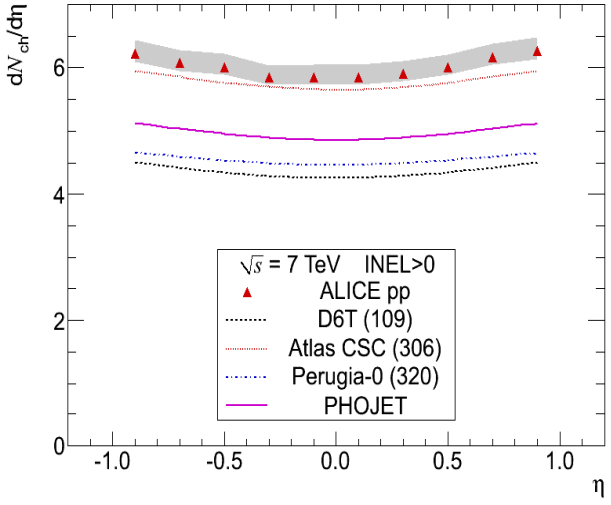
Last but not least, software and computing are working smoothly, and wLCG delivers! (All this was by far not obvious at the onset of the LHC project!)

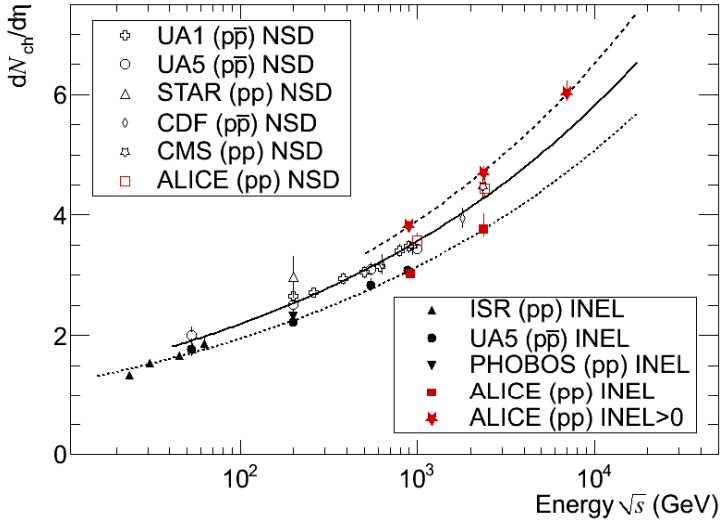

Understanding the Environment:
Minimum Bias Events at LHC
ALICE

Global minimum bias results from ALICE and CMS



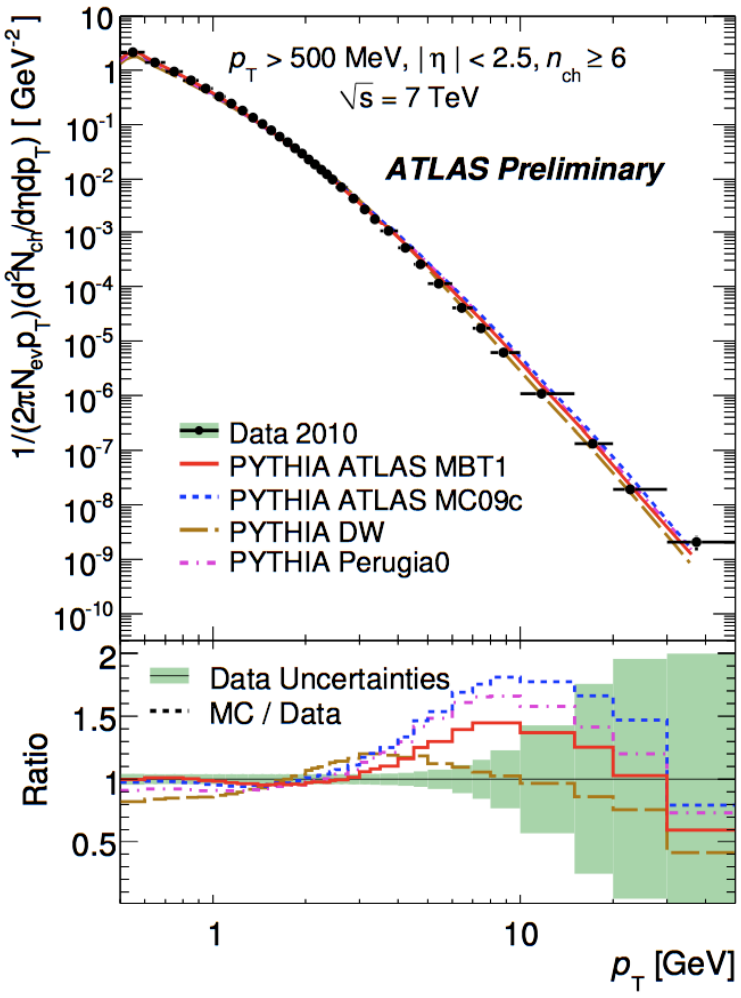


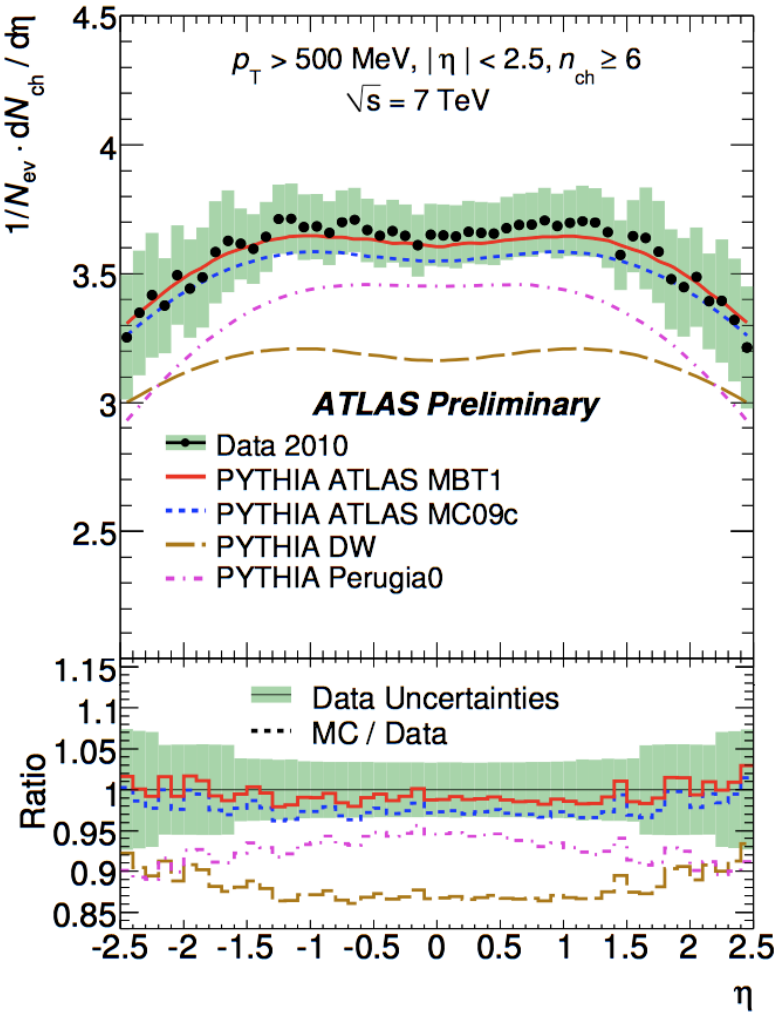


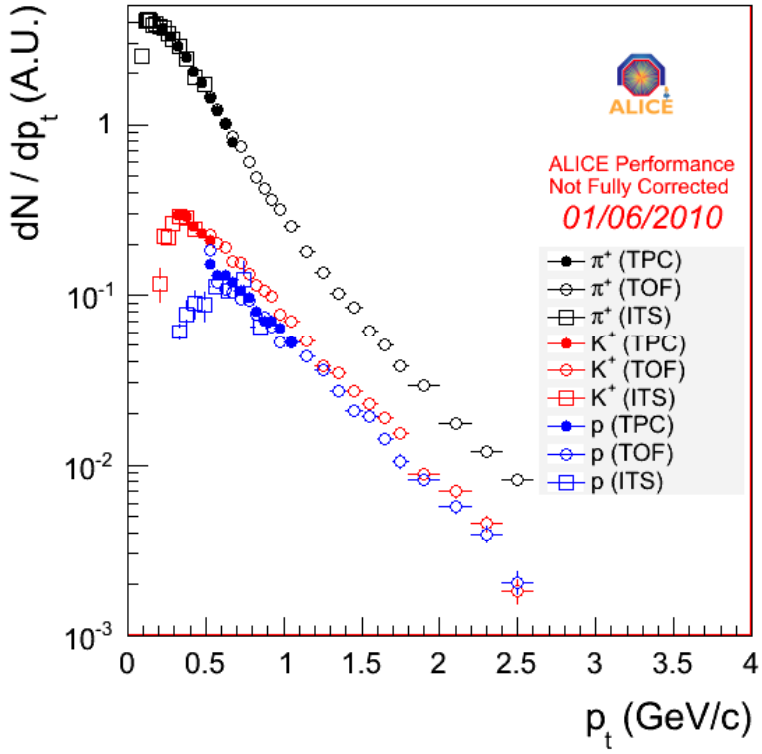


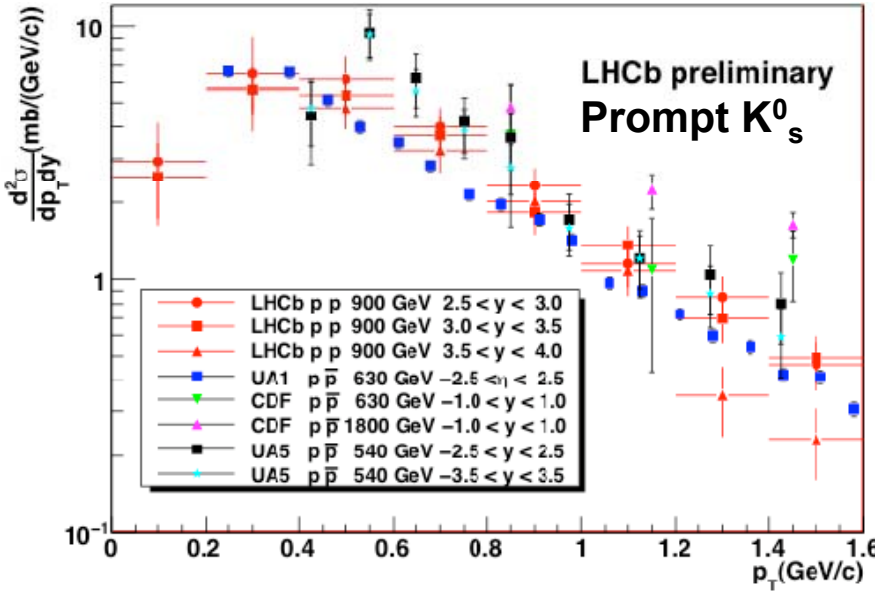
Data with minimal model dependence can be used for detailed MC tuning

Used for the tune
ATLAS UE data at 0.9 and 7 TeV
ATLAS charged particle densitites at 0.9 and 7 TeV
CDF Run I underlying event analysis (leading jet)
CDF Run I underlying event "Min-Max" analysis
D0 Run II dijet angular correlations
CDF Run II Min bias
CDF Run I Z pT

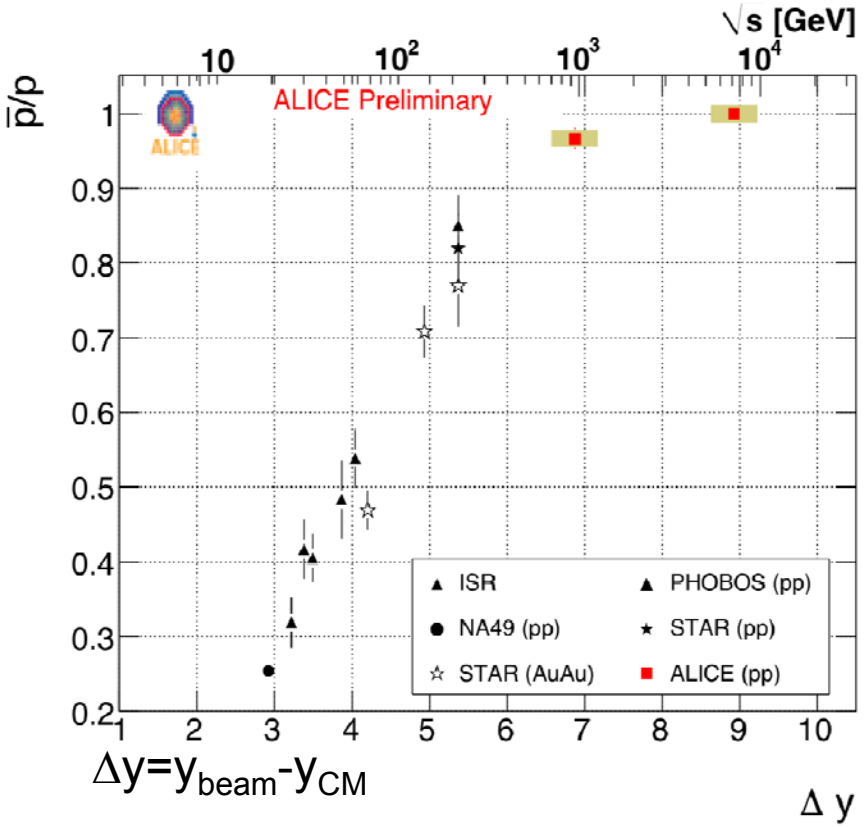




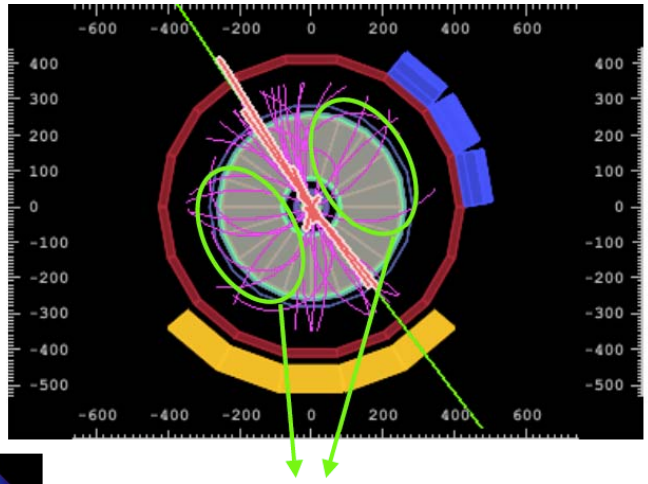


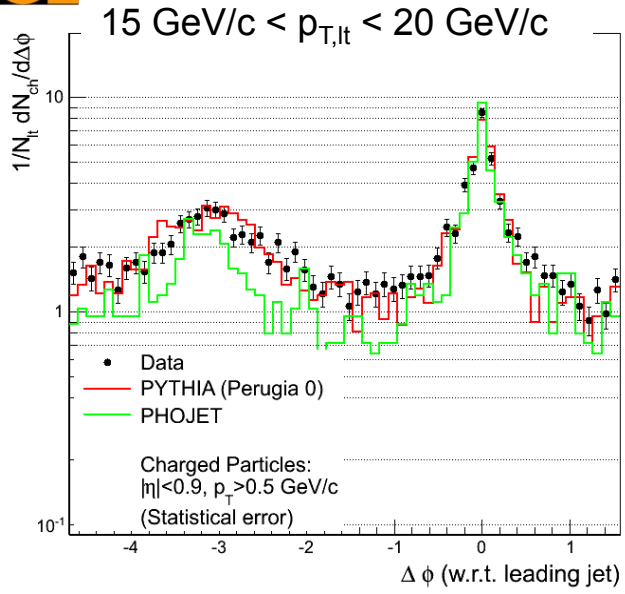


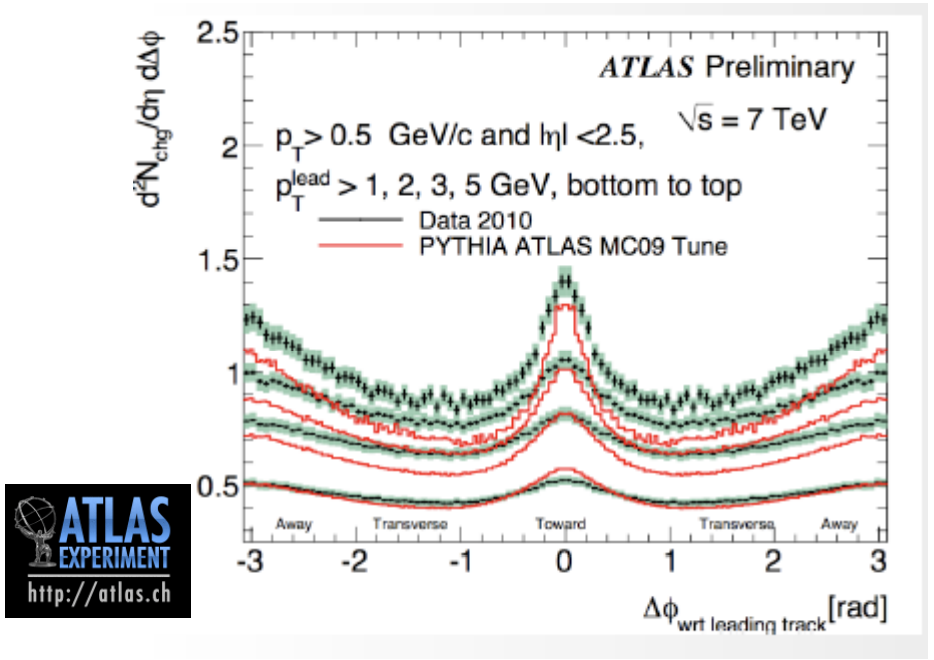
Examples of detailed measurements with particle identification

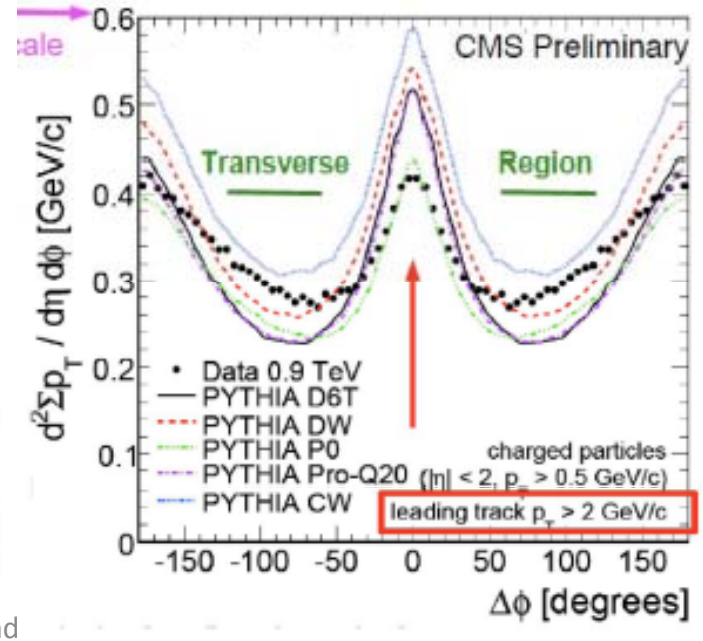


Underlying event studies

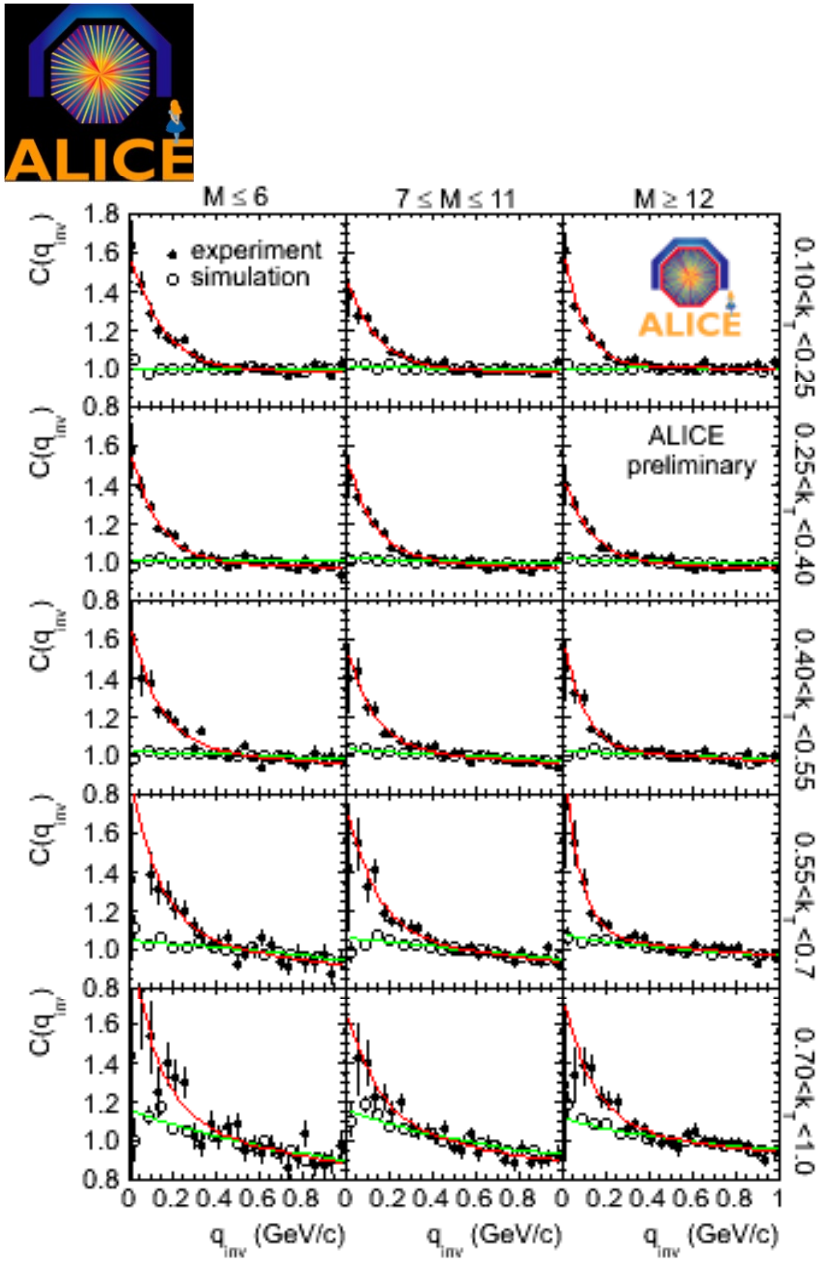




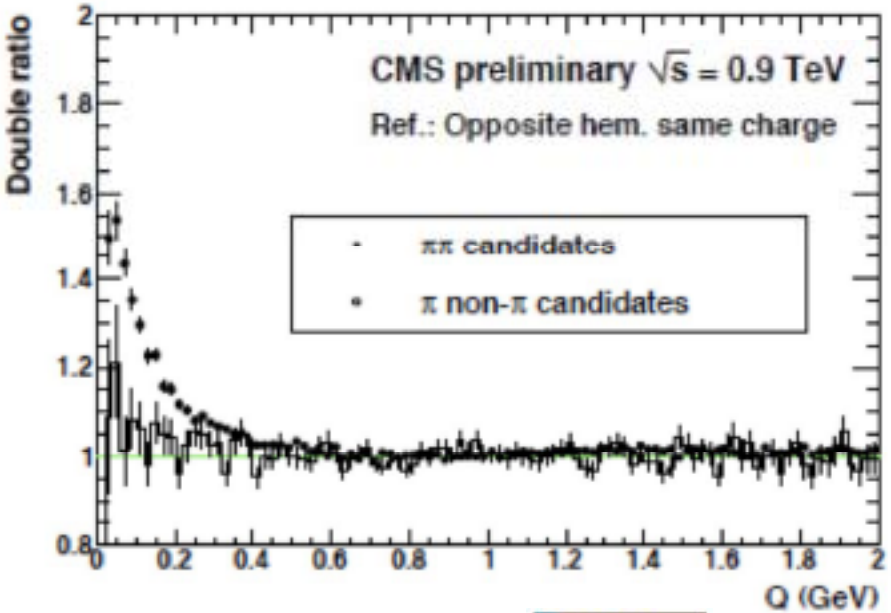




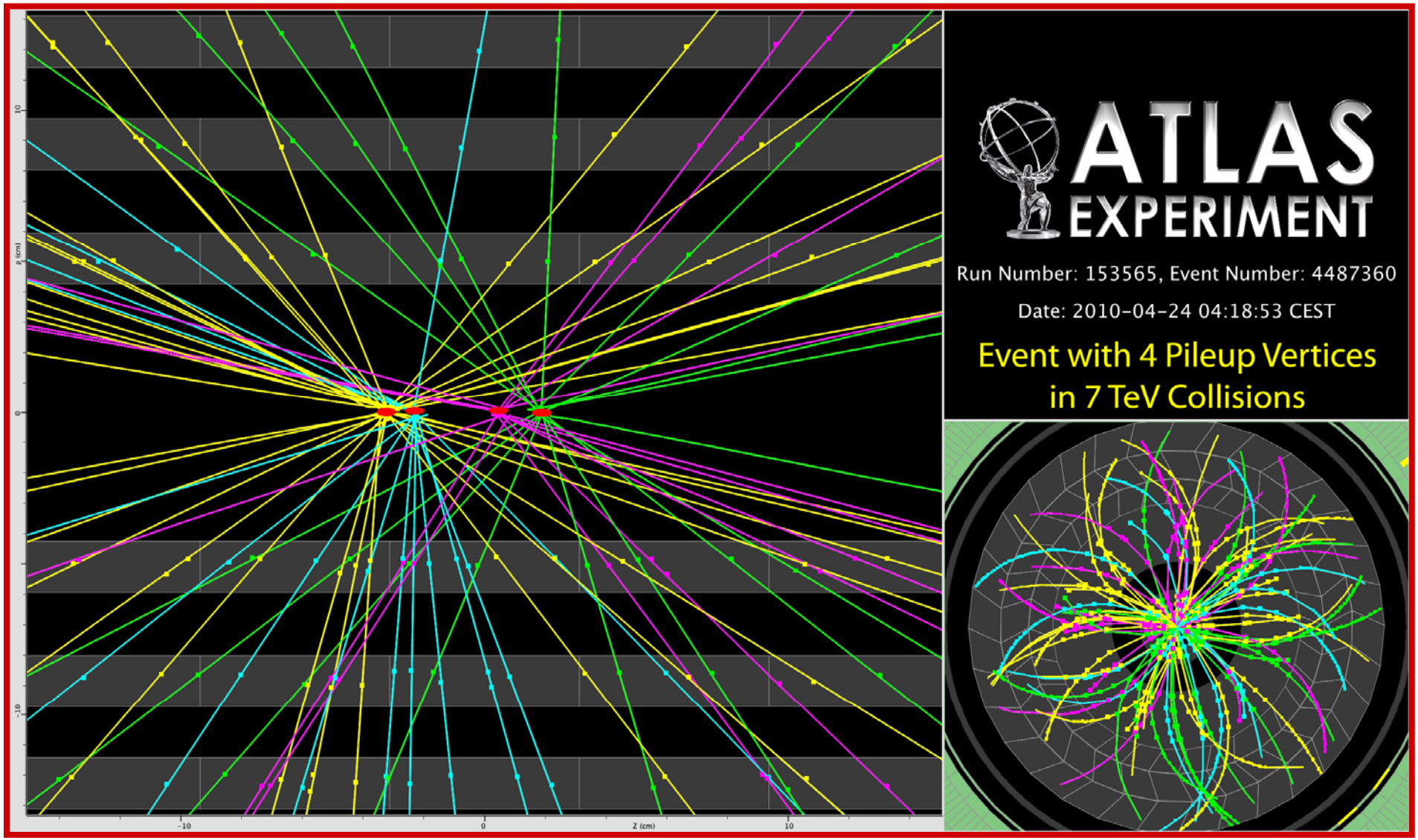
imental Summary and



Correlations
Bose-Einstein enhancement
for pion-pairs, as an example

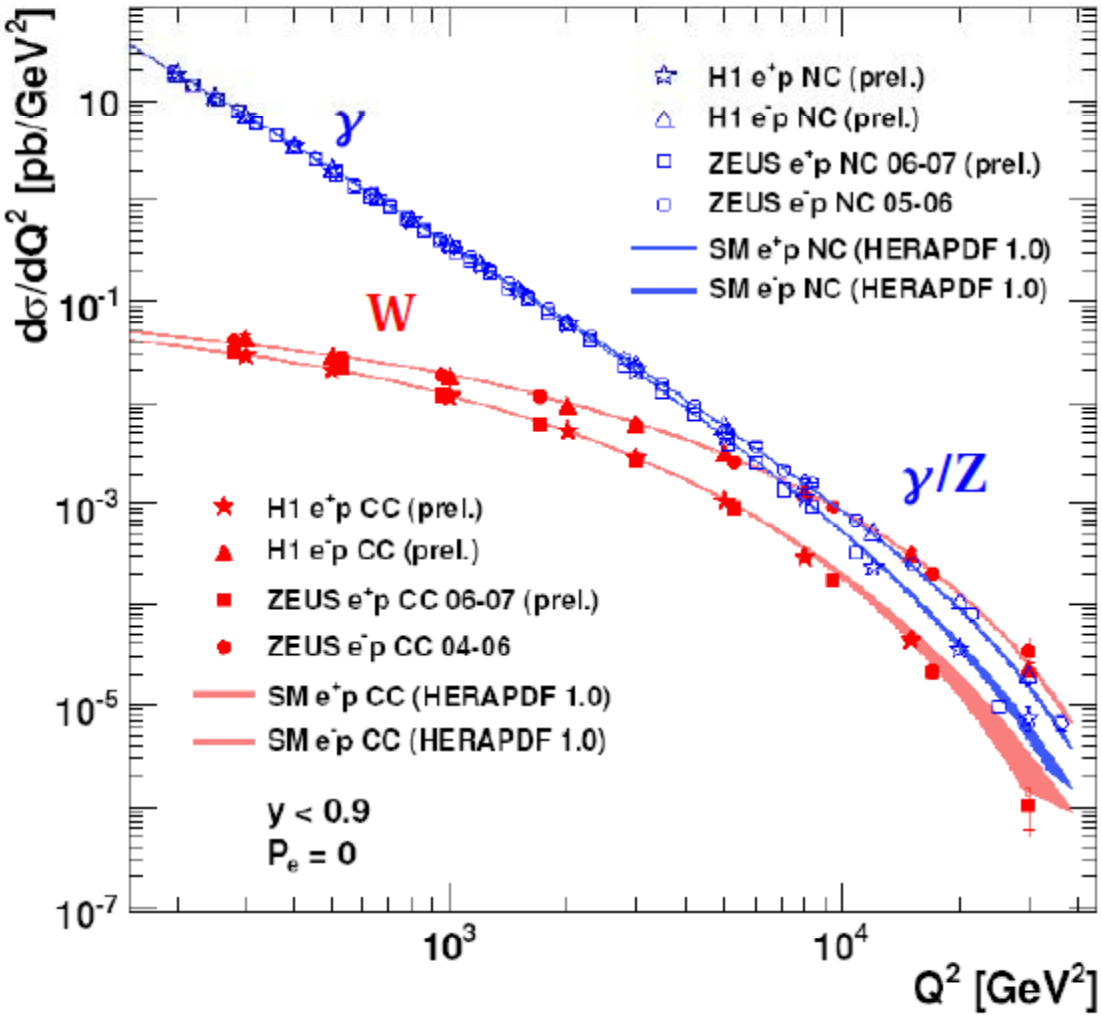


Preparing for the future : pile-up reconstruction
4 pp interactions in the same bunch-crossing



The HERA experiments provide a very major contribution with their structure functions to understand the physics at LHC (and Tevatron)

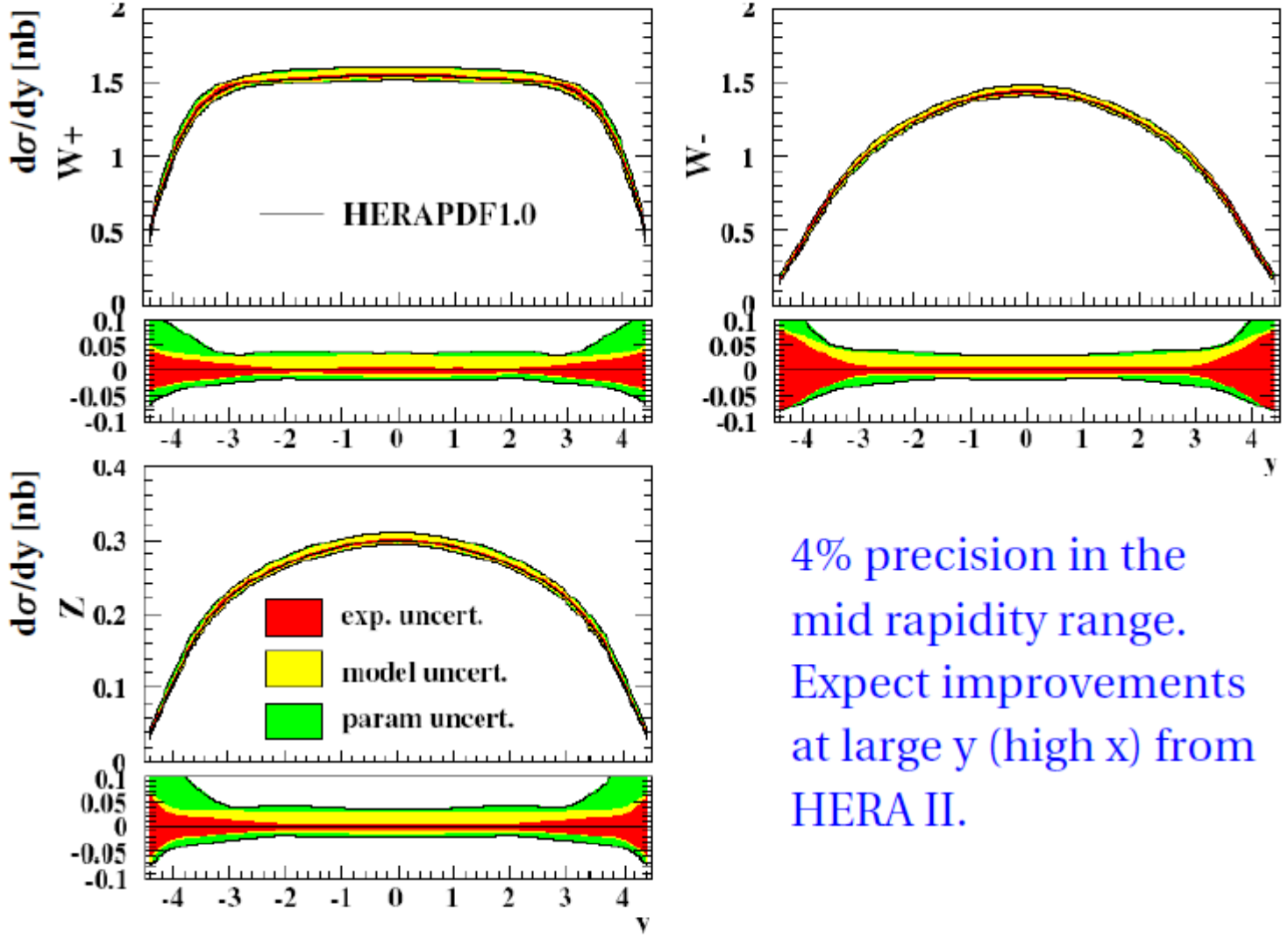
$e^+ p$ and $e^- p$ cross sections vs Q^2



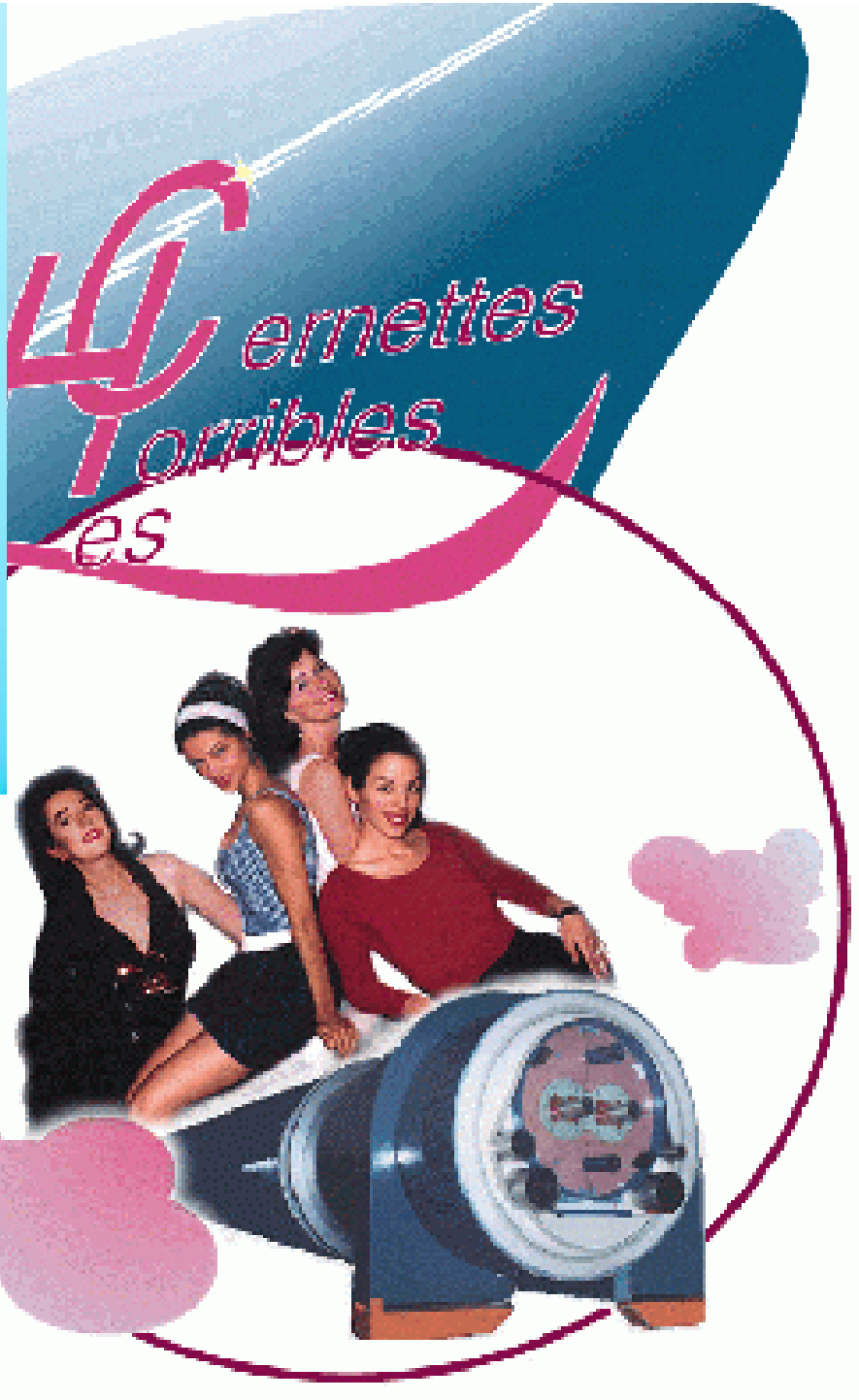
- Well described over 6 orders of magnitude.
- Destructive (e^+) and constructive (e^-) γZ interference in Neutral Current.
- Charged Current:
  - e^- u dominates,
  - e^+ d is suppressed.
- Electroweak unification at $Q^2 \sim m_W^2$.

W and Z with HERAPDF1.0

LHC at 14 TeV



4% precision in the mid rapidity range. Expect improvements at large y (high x) from HERA II.



The first picture on the Web in 1992 !

Collision energy

Tevatron ($p\bar{p}$)

1.96 TeV

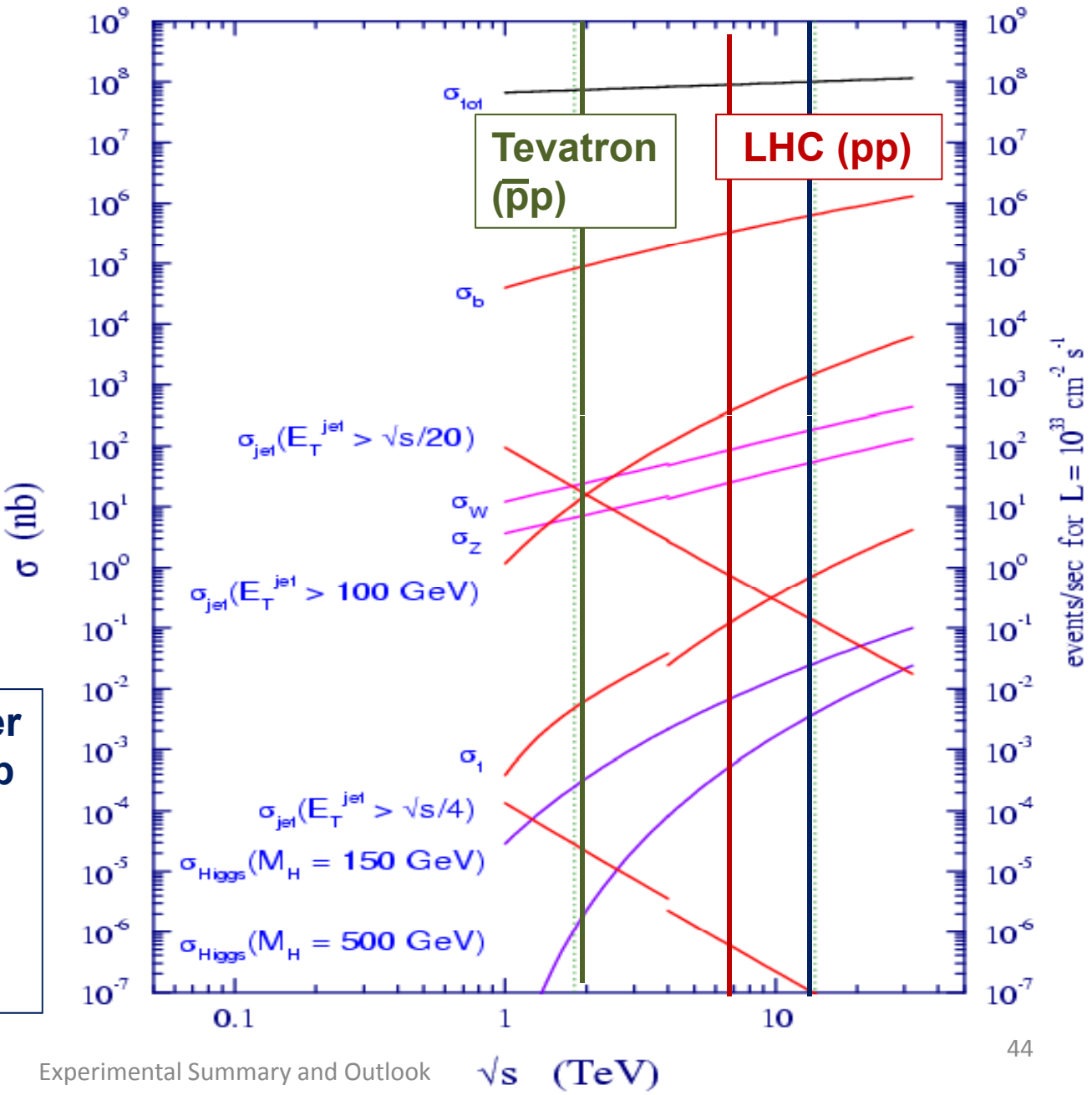
LHC (pp)

initially 7 TeV
later 14 TeV

The other key parameter for setting the road map for discoveries is the integrated luminosity

$$N_{events} = \sigma \int L\, dt$$

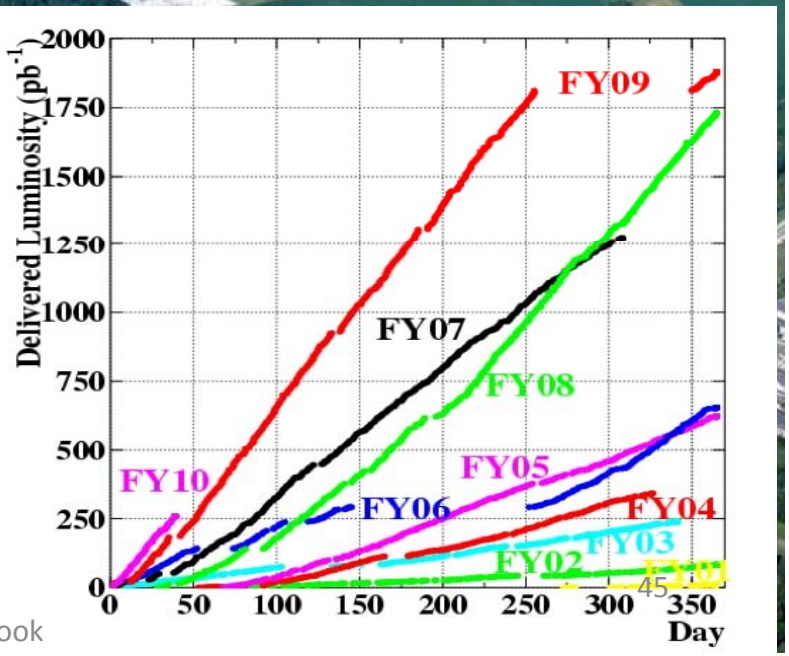
Some bench-mark cross-sections



The Tevatron at Fermilab is performing in a superb way, and has still a major potential for great physics in the near future

CDF

D0

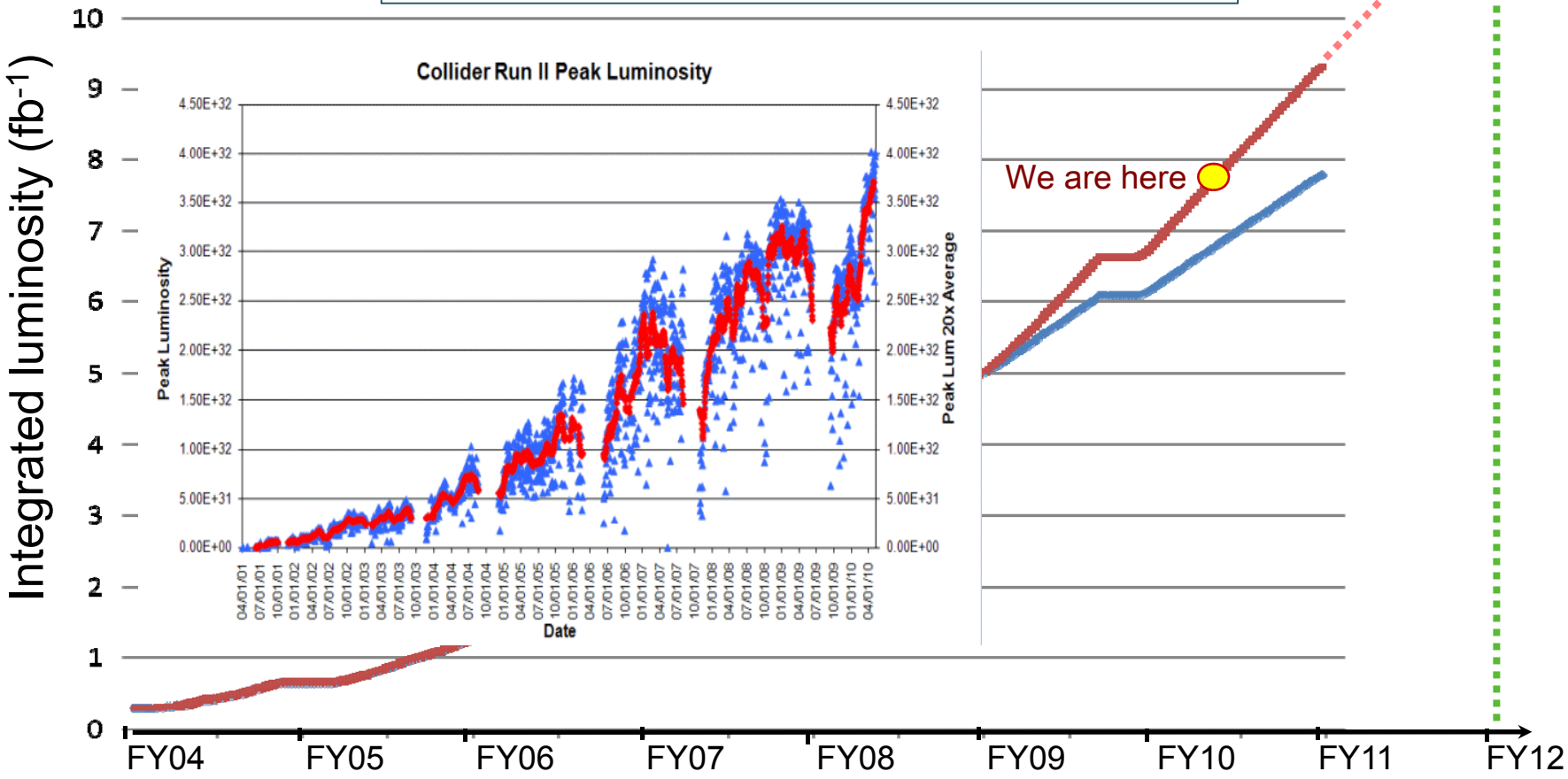


The Tevatron is a very mature machine with well understood detectors operated by collaborations with highly developed analysis skills

Projection for the Tevatron

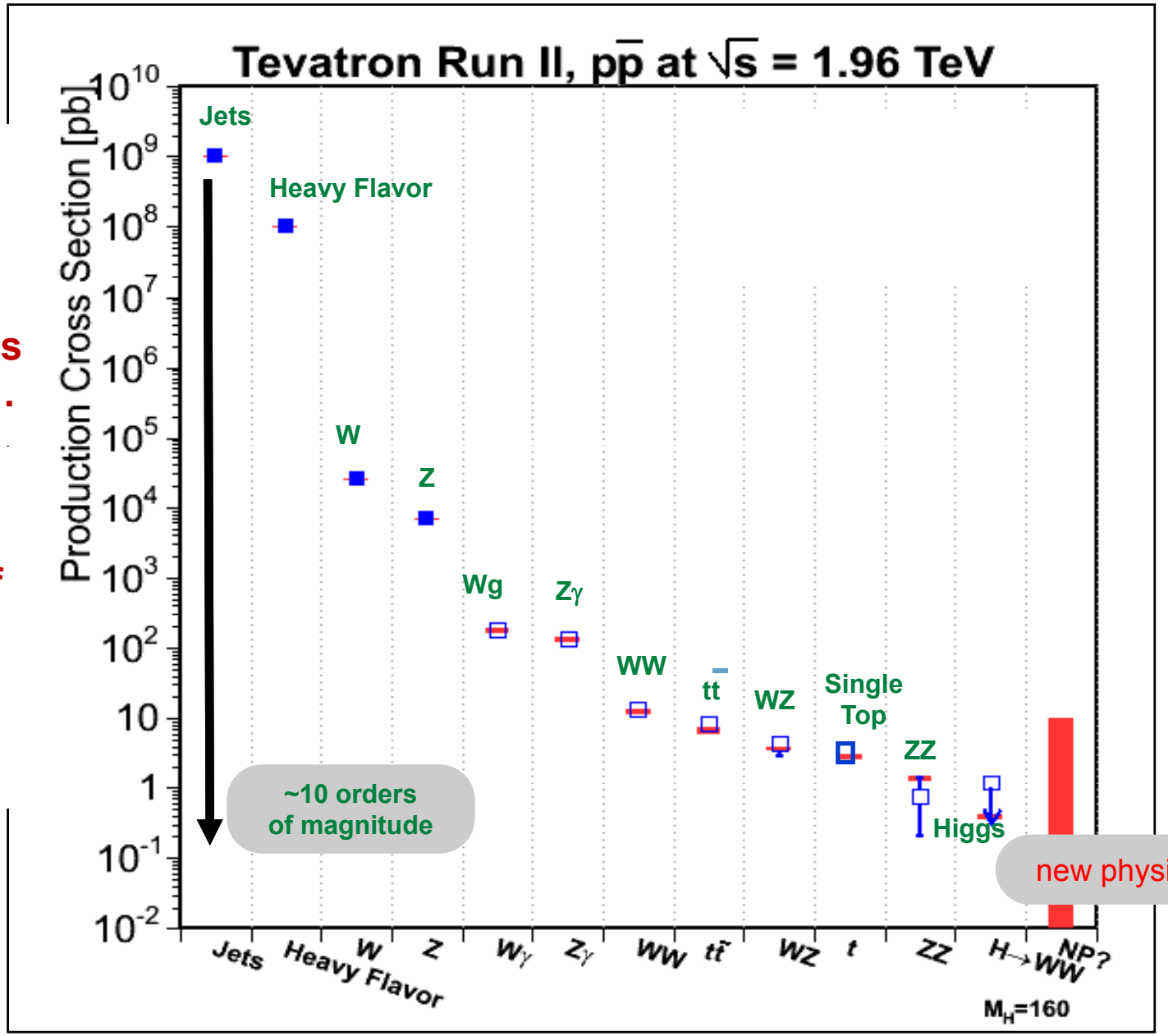
Expect about 2 fb^{-1} per year from now on → **~12 fb^{-1}**

→Reach at the end of 2011 some 10 – 12 fb^{-1} analyzable/delivered integrated luminosity



The Tevatron experiments have explored an impressive range of physics over the years…

…both in direct observations of processes as well as in precision measurements



Lake of Geneva

CMS

LHCb

Airport

ALICE

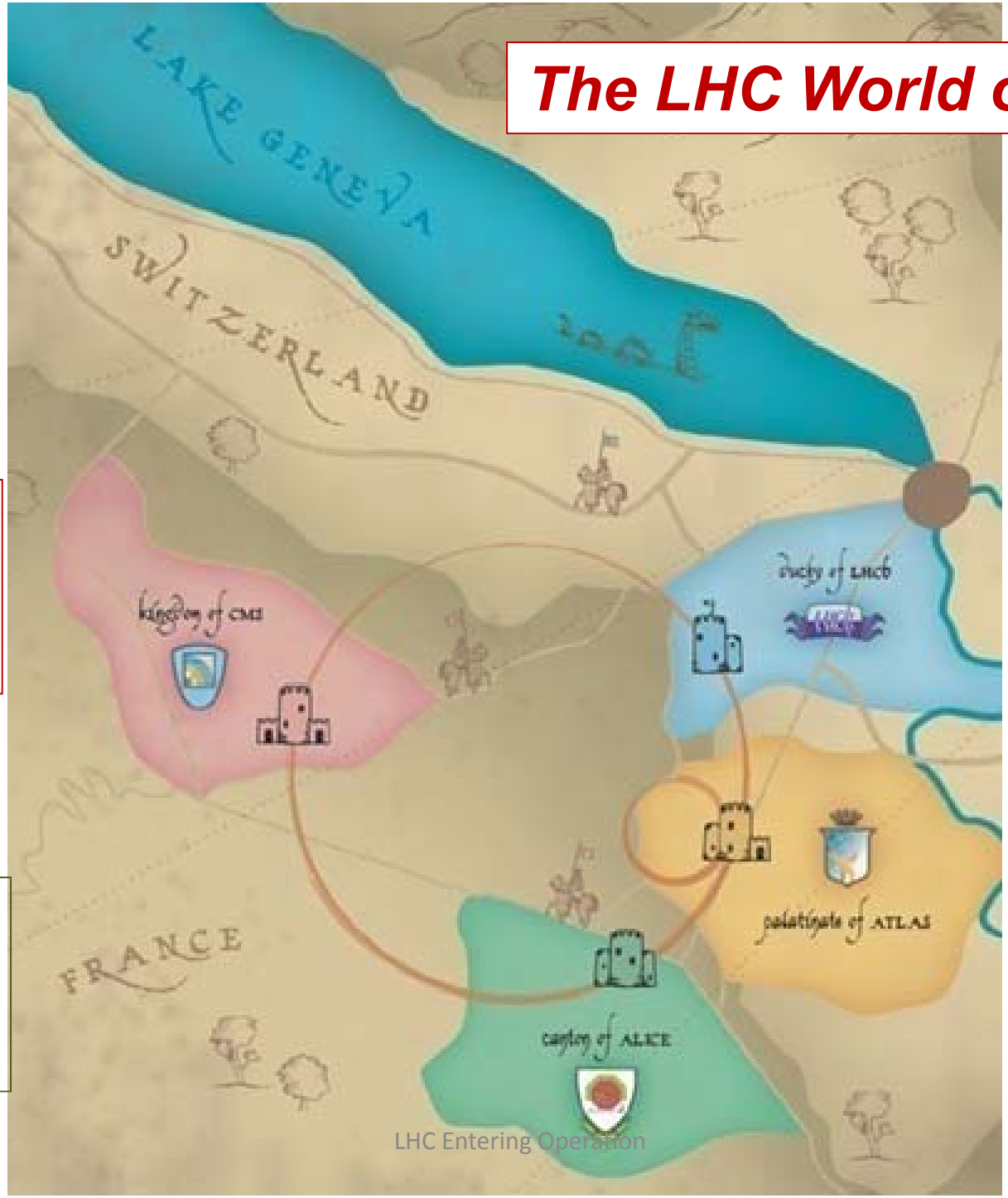
ATLAS

The Large Hadron Collider LHC and its sophisticated experiments have finally only just entered the scene as active players...

CERN

The LHC World of CERN

Plus smaller
local earldoms
LHCf (point-1)
TOTEM (point-5)
Moedal (point-8)



CMS
2900 Physicists
184 Institutions
38 countries
550 MCHF

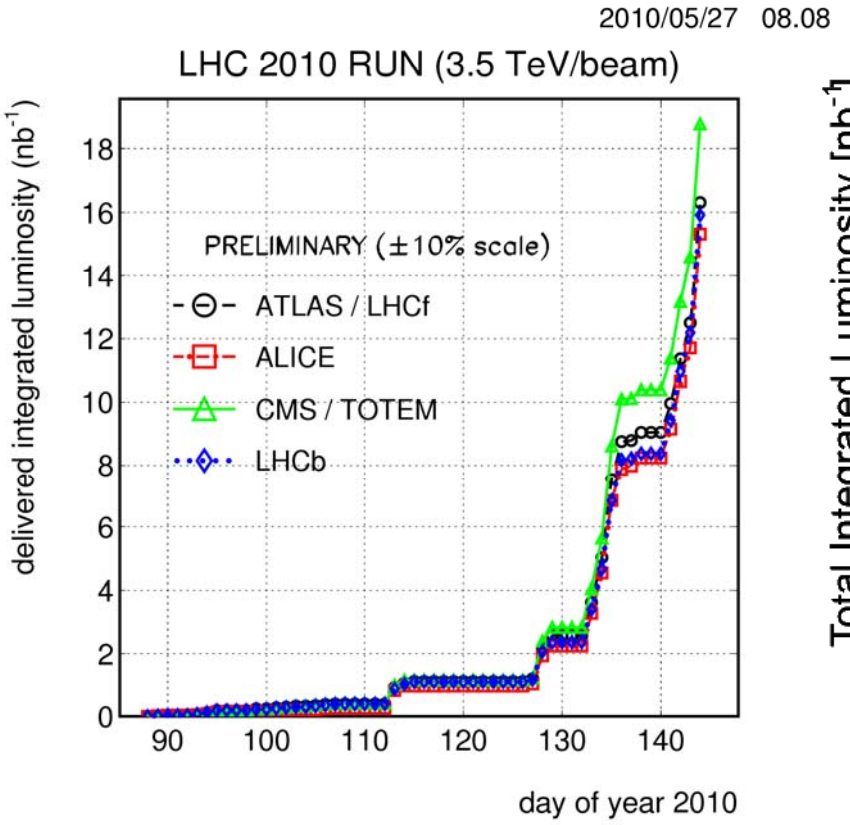
LHCb
730 Physicists
54 Institutions
15 countries
75 MCHF

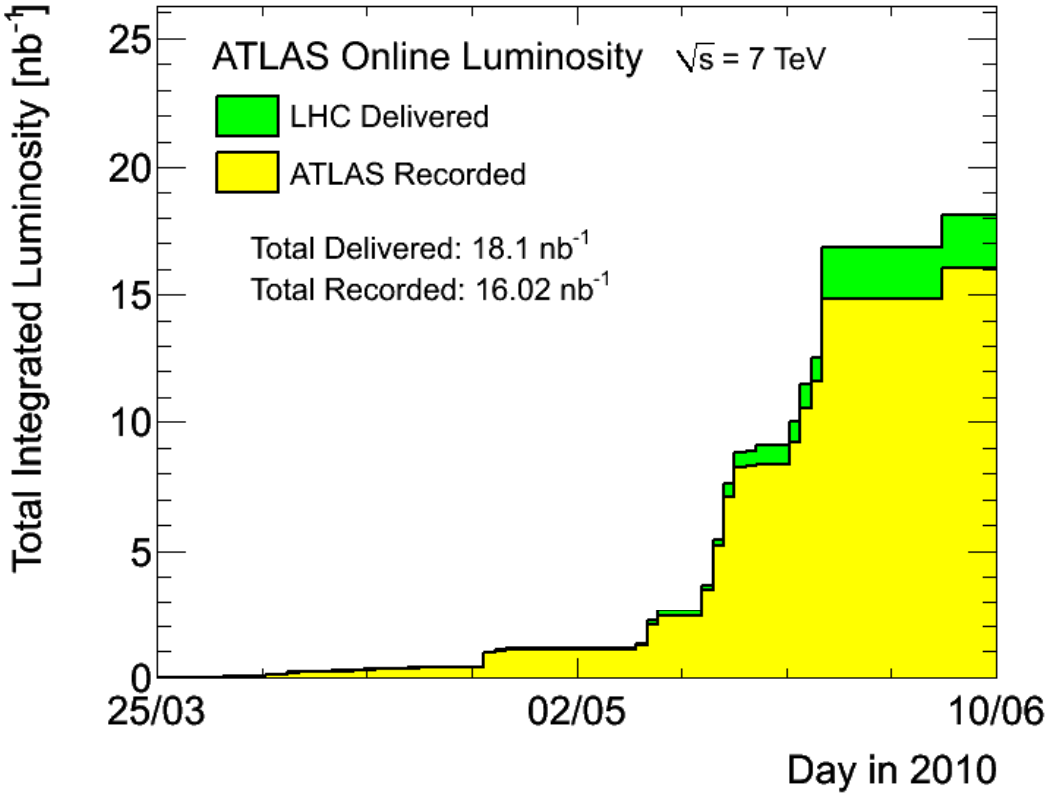
ATLAS
2900 Physicists
173 Institutions
37 countries
550 MCHF

ALICE
1000 Physicists
105 Institutions
30 countries
150 MCHF

(All numbers are approximate…)

LHC at 7 TeV: the still very young luminosity history





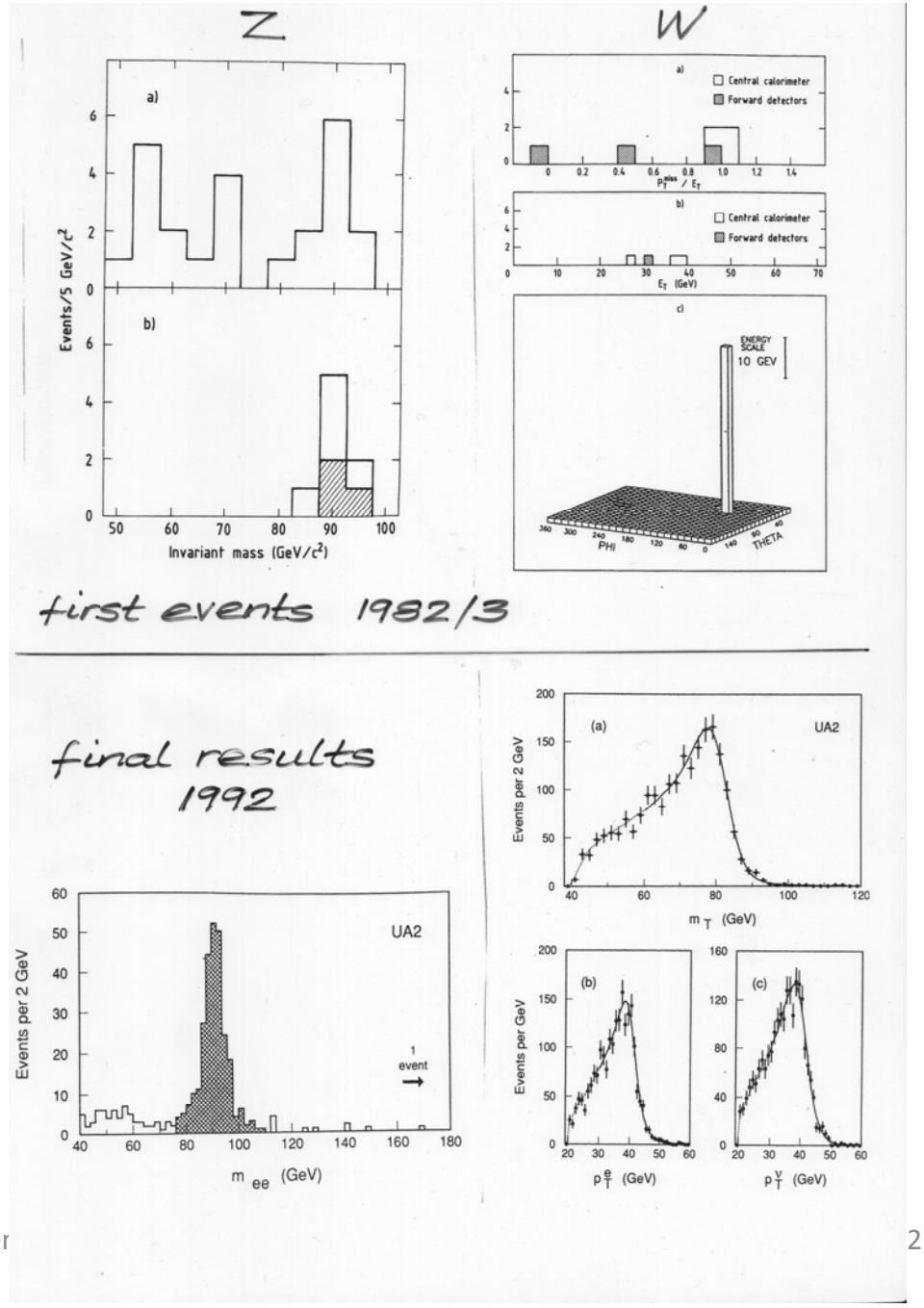
Road Map of Expected Hadron Collider Performances

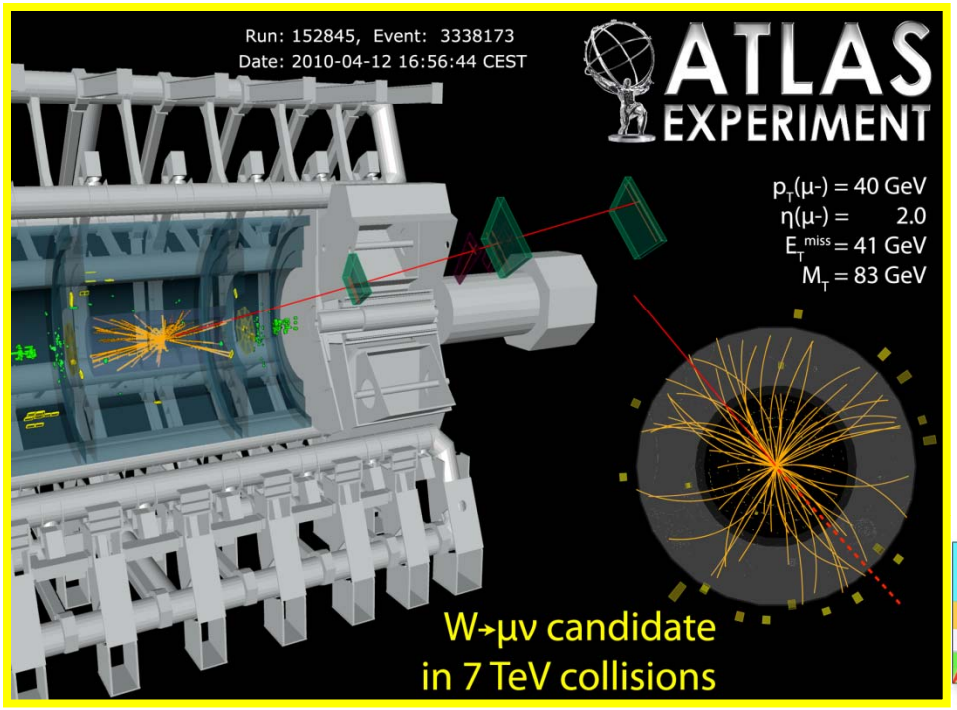
(All the LHC details/assumptions can be found in today's talk of M Lamont)

Now	**Tevatron**	**2 TeV**	**7 fb^{-1} (analysed)**
	LHC	**7TeV**	**20 nb^{-1}**
End 2011	**Tevatron**	**2 TeV**	**10 fb^{-1}**
	LHC	**7 TeV**	**1 fb^{-1}**
End 2014	**LHC**	**14 TeV**	**15 fb^{-1}**
End 2016	**LHC**	**14 TeV**	**50 fb^{-1}**
Early 2020ies	**LHC**	**14 TeV**	**500 fb^{-1}**
2030	**(s)LHC**	**14 TeV**	**3000 fb^{-1} (ultimately…)**

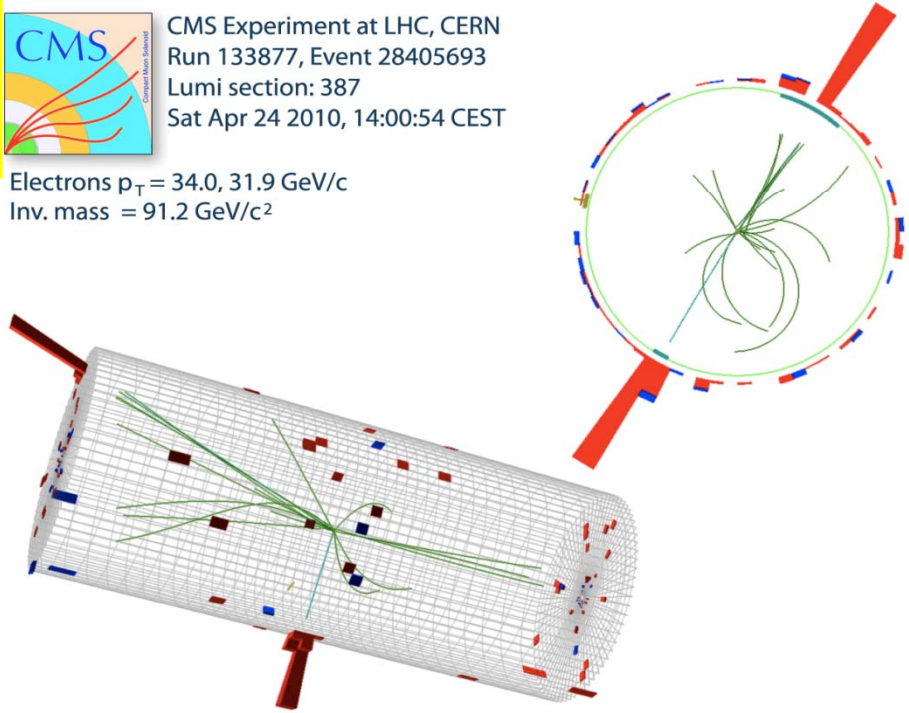
(These are round numbers and estimates, just to give a rough idea…)

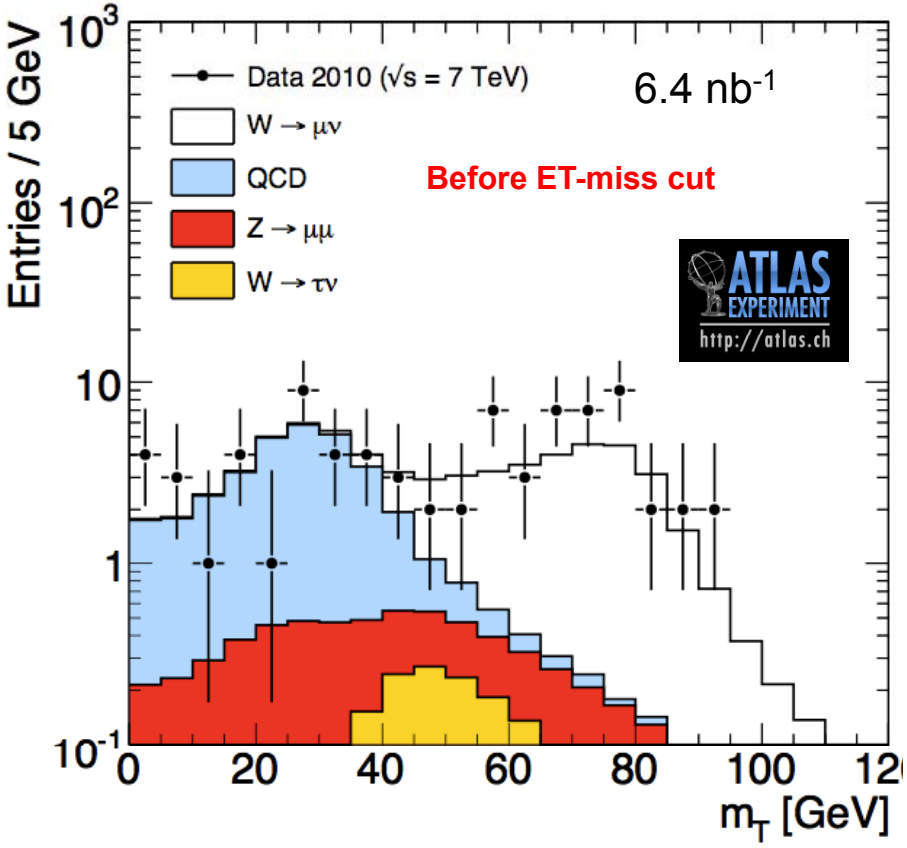
Physics and Outlook



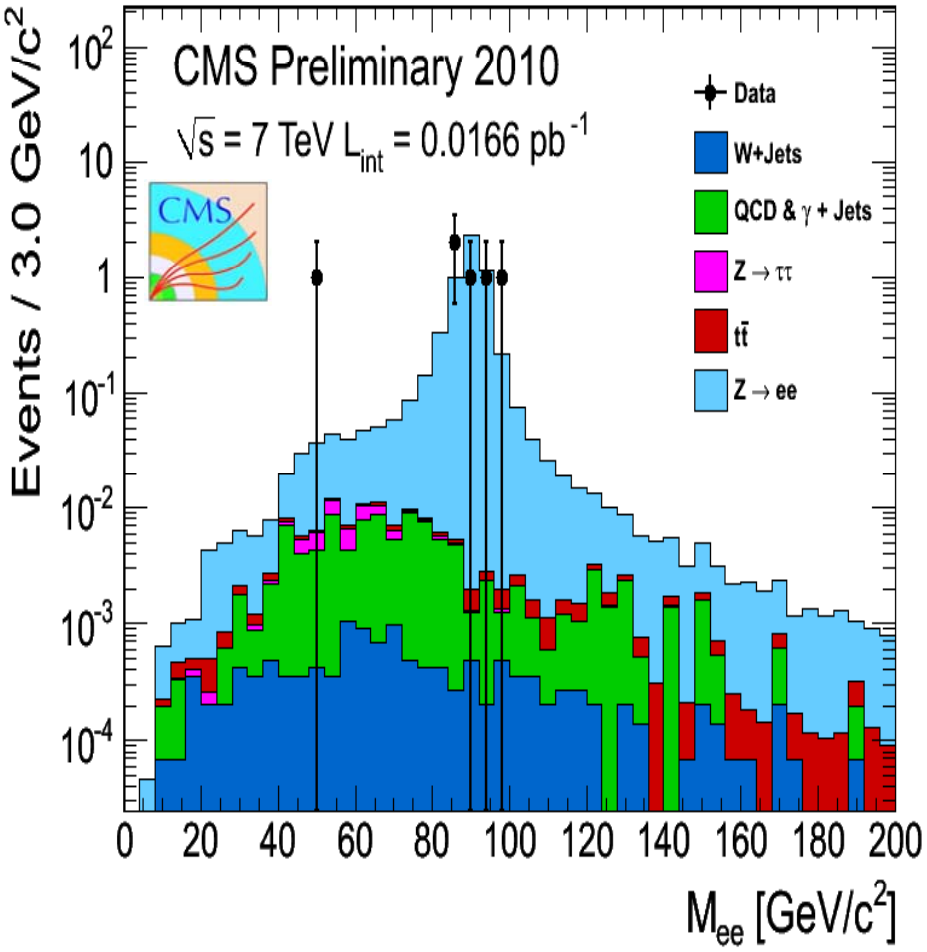


At the LHC we just enter the era of the W and Z …

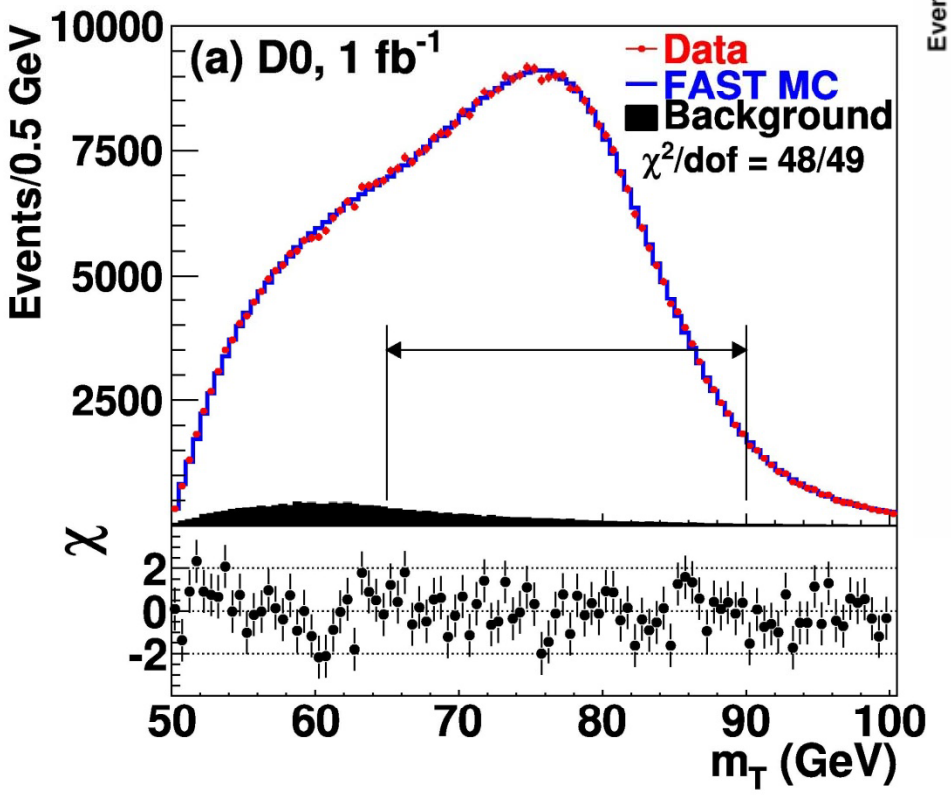




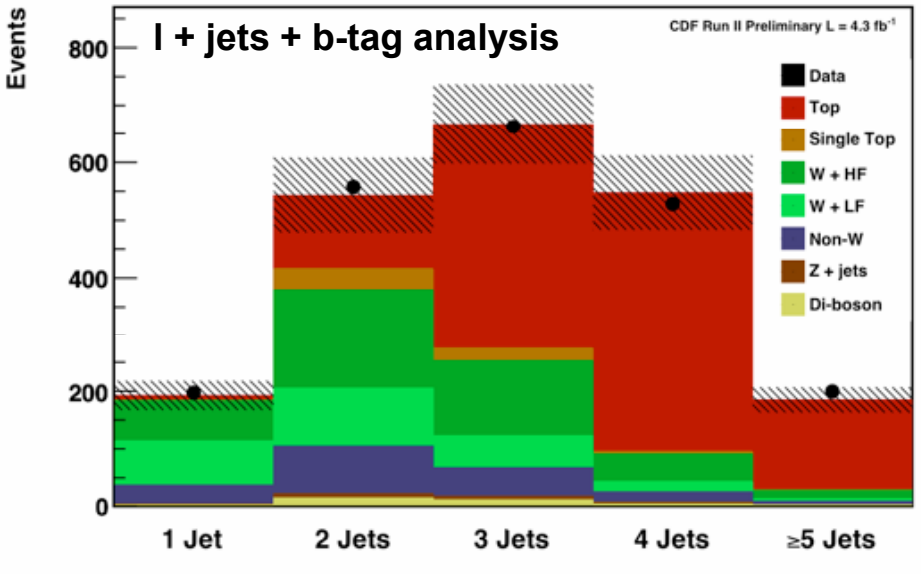
Analyses and measurements of W and Z productions at LHC have only just started …

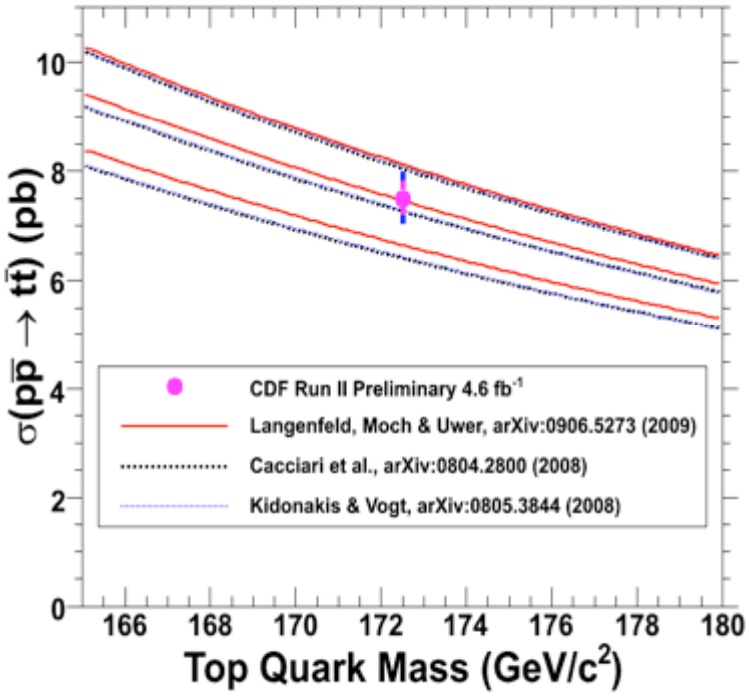


Observed	40
Expected	28.7 ±0.5(stat)±3.9(syst)±5.7(lumi)
Signal	25.9±3.6(syst) ±5.2(lumi)
Background	2.8±0.5(stat) ±0.8(syst) ±0.6(lumi)

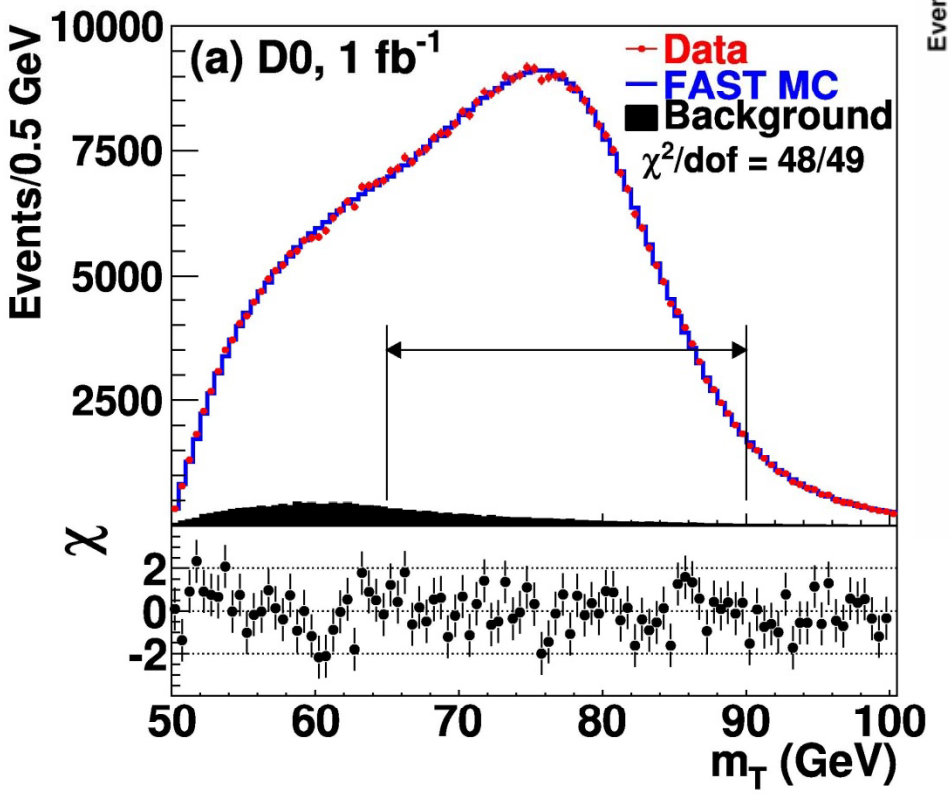


499830 W → eν candidates

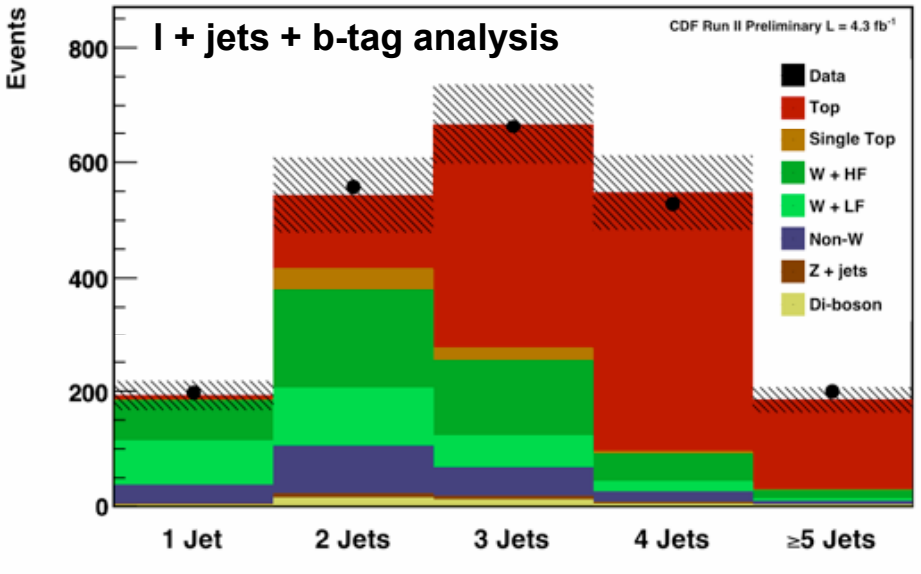


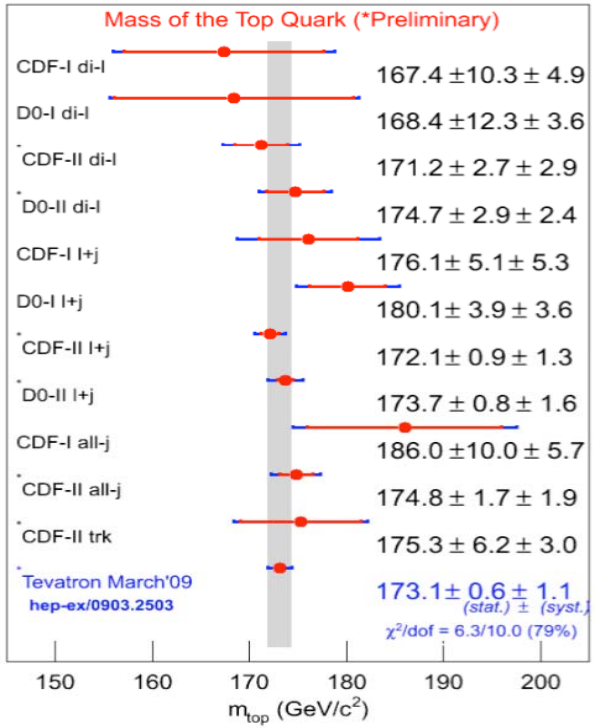


Whereas W, Z, and top analyses are in a very mature and advanced state at the Tevatron, giving a wealth of detailed QCD and EW measurements

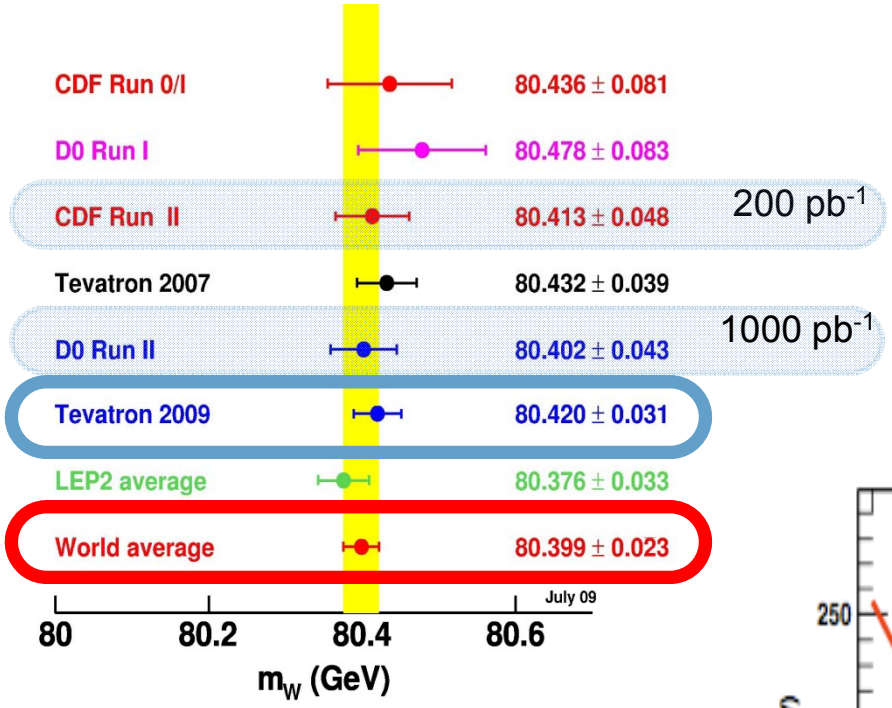


499830 W → eν candidates

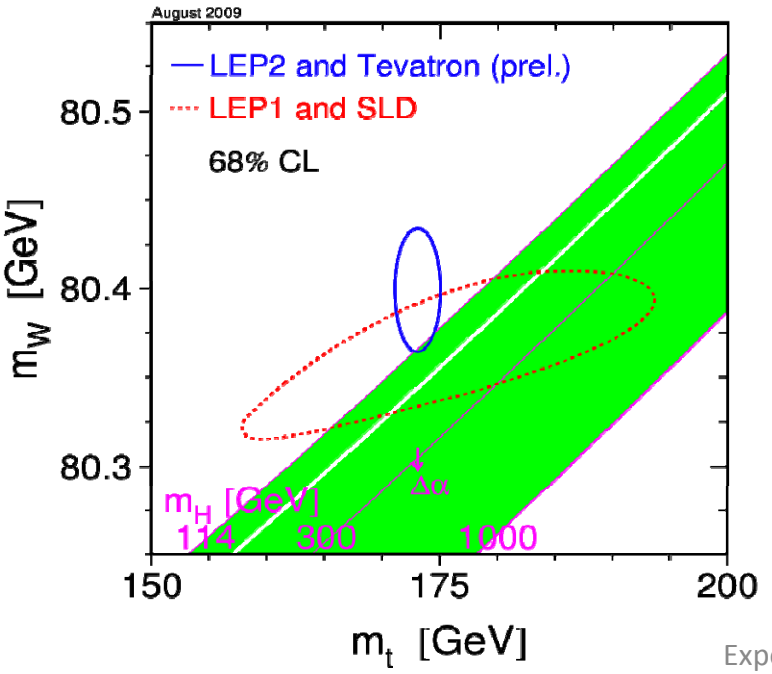


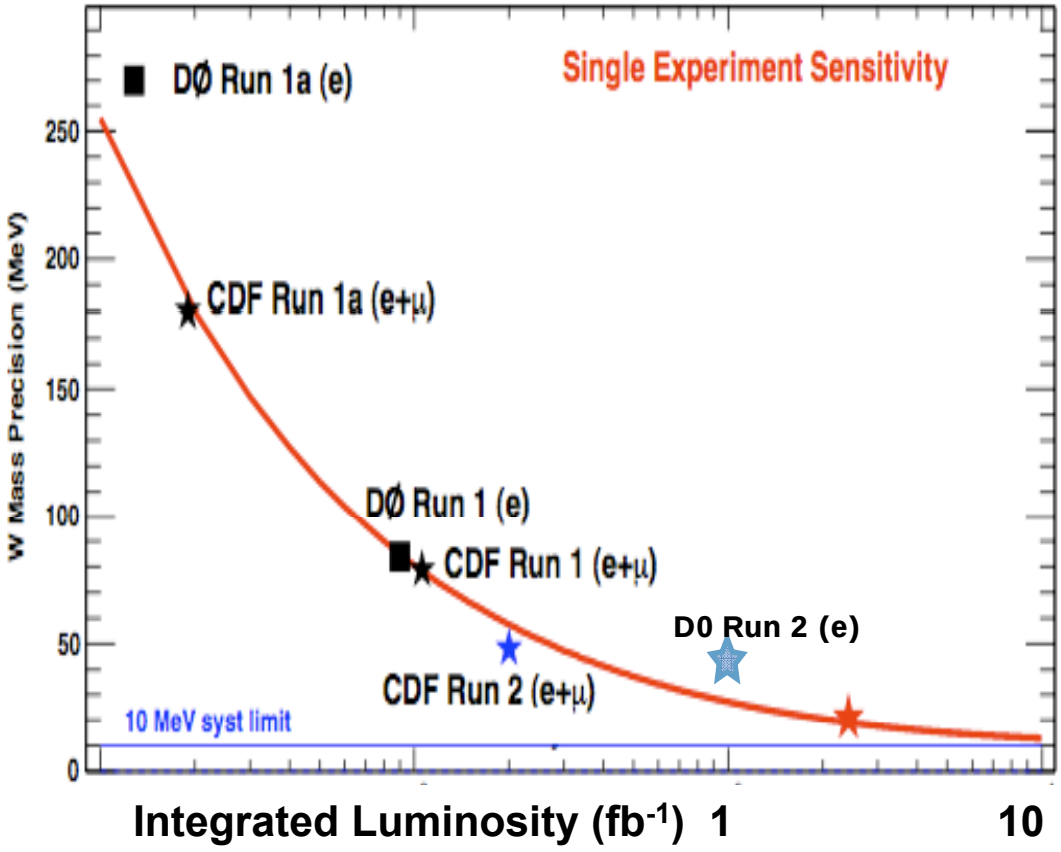


Whereas W, Z, and top analyses are in a very mature and advanced state at the Tevatron, giving a wealth of detailed QCD and EW measurements

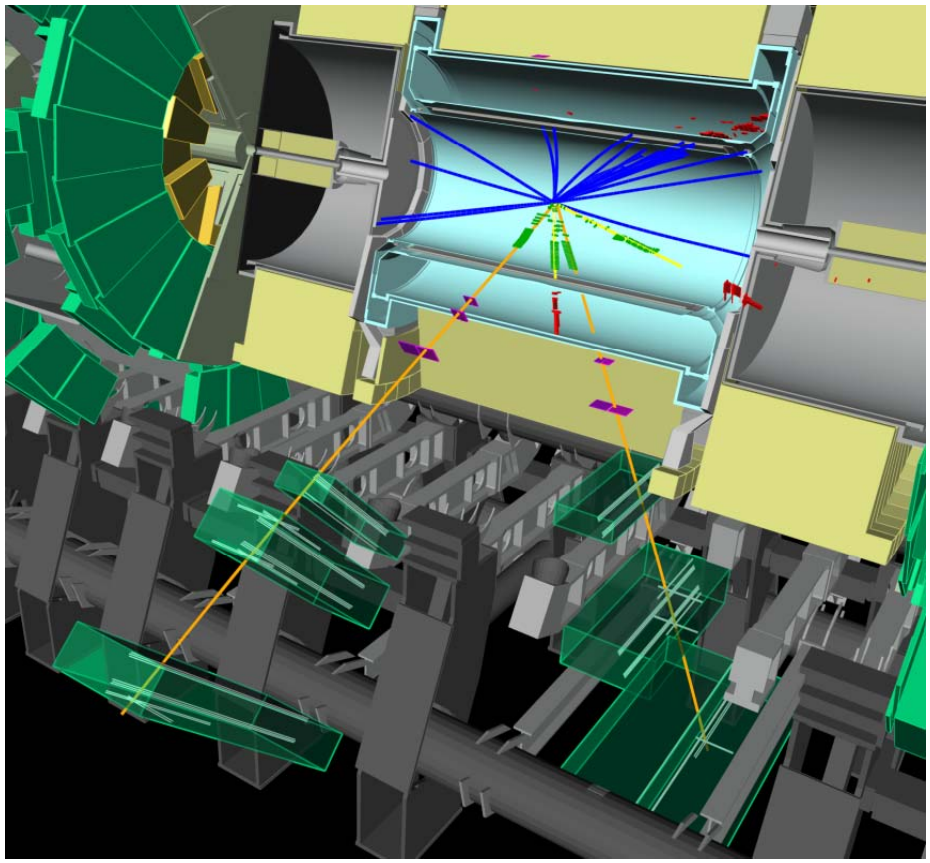


There will be a long way for LHC to match theTevatron W and top mass measurements, our preferred example of precision measurements testing the (consistency of the) Standard Model and Higgs hypothesis

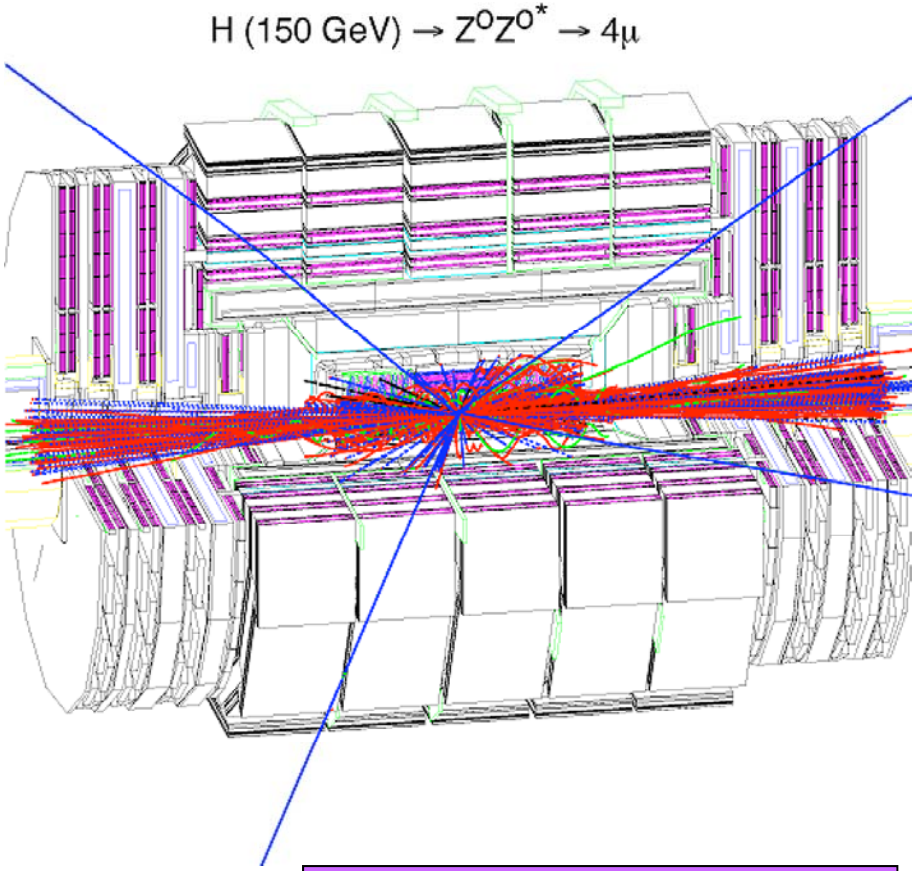




Higgs search



Simulation of a 130 GeV mass H → μμ ee event in ATLAS



Simulation of a 150 GeV mass H → μμ μμ event in CMS

CDF/D0 at HCP2009:

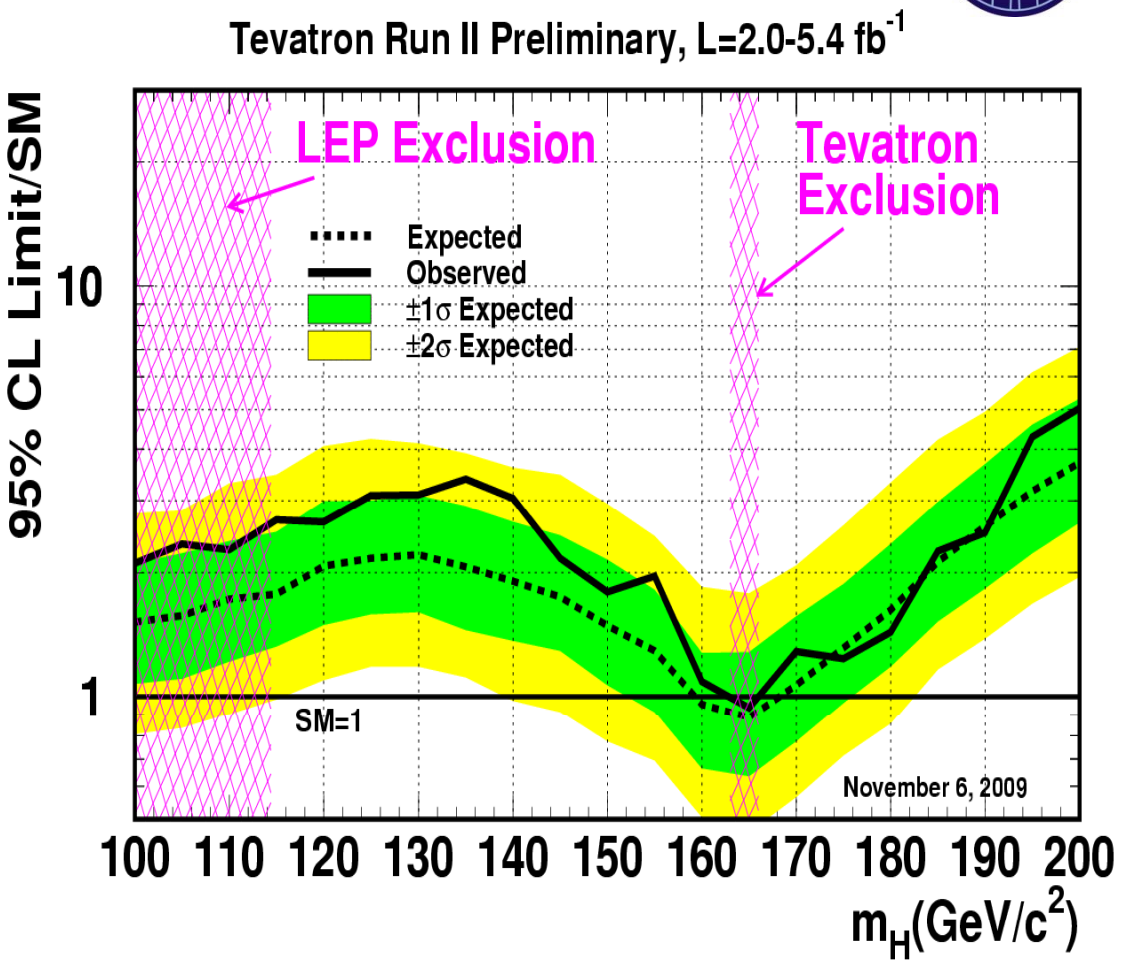
Great results from both experiments in both low and high-mass sectors

SM Higgs exclusion in the range 163-166 GeV @95% CL

Expected exclusion range 159-168 GeV

Better than 2.2xSM sensitivity at all masses below 185 GeV

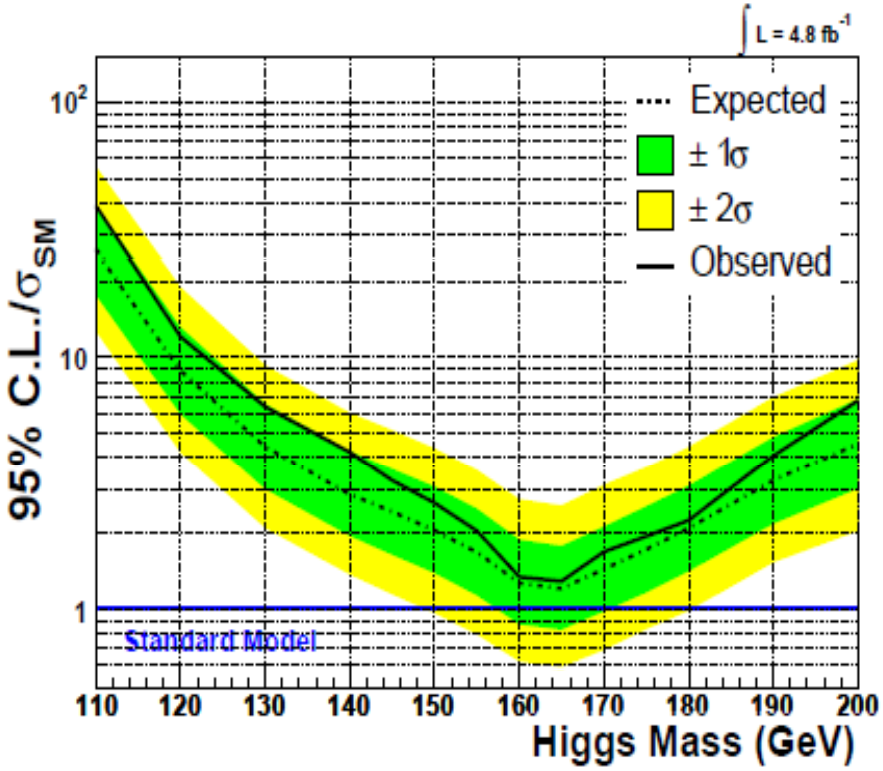
Stay tuned for further Tevatron improvements in Higgs searches



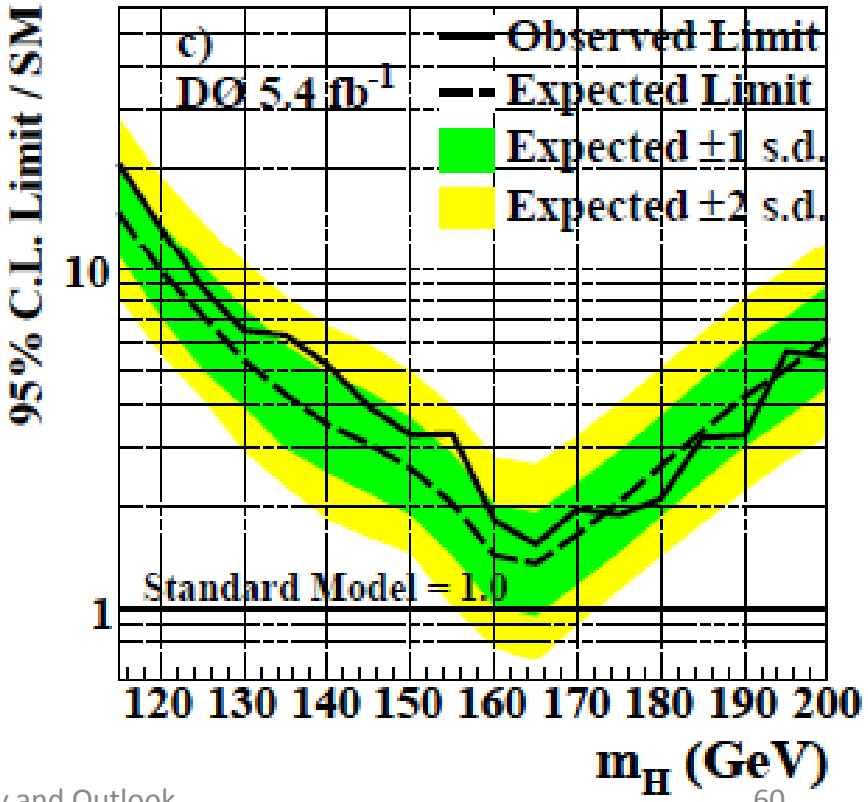
Both experiments have recently released new analyses for H → W^+W^- which dominate the mass region around 160 GeV

Basically both searched for two oppositely charged isolated leptons (e or μ), and made sophisticated multi-variable analyses

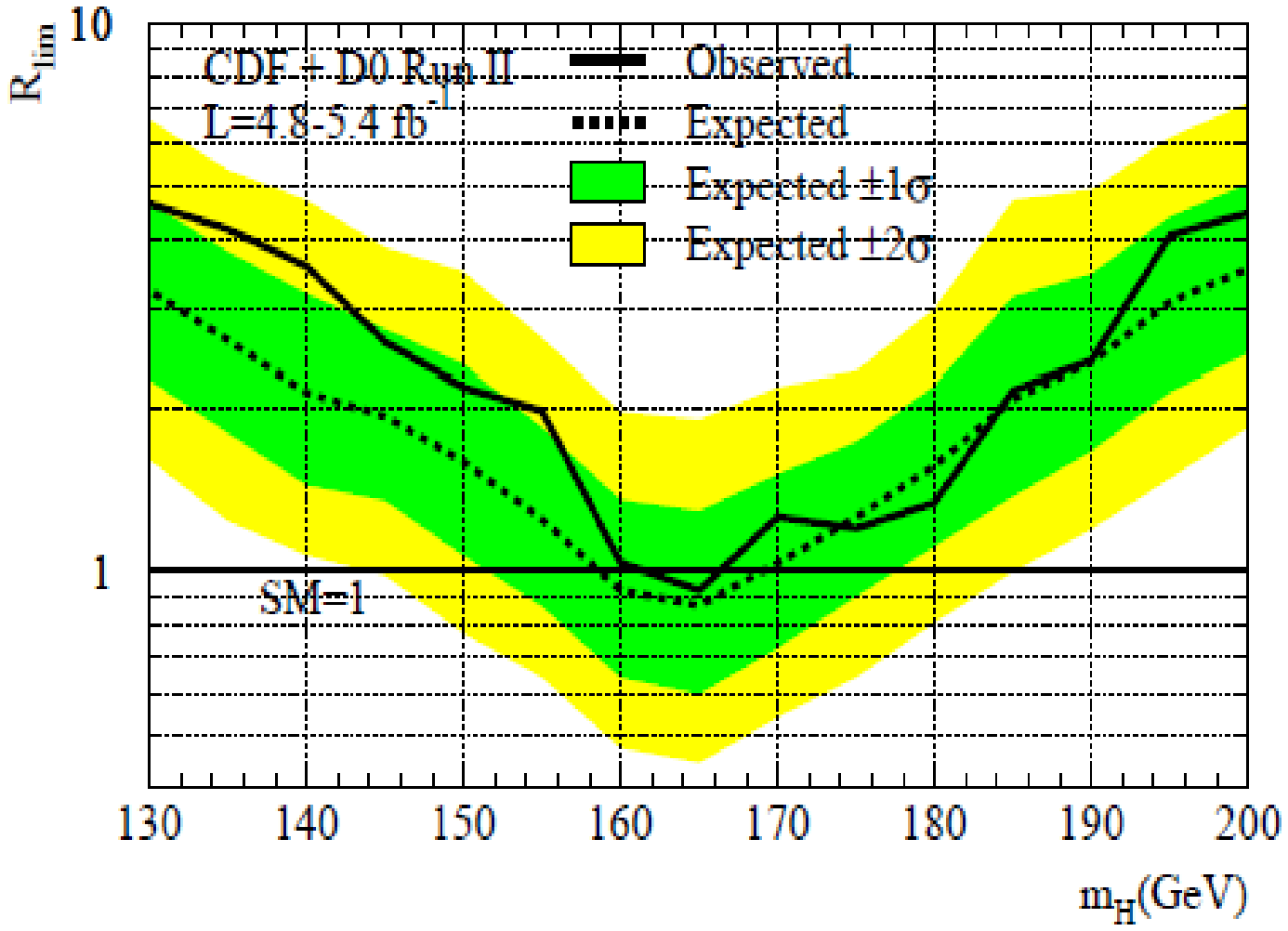
Classified events according to 0, 1, and 2 or more jets, and topology (included also same sign leptons for WH and ZH production)



Classified events according to ee, eμ, and μμ

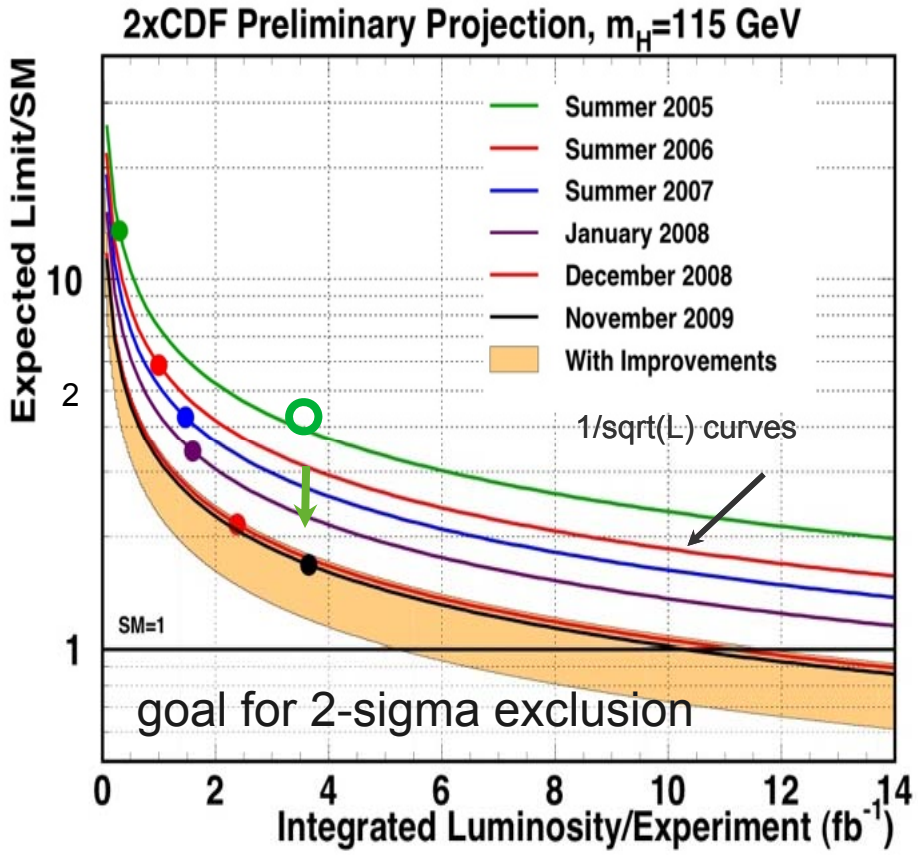


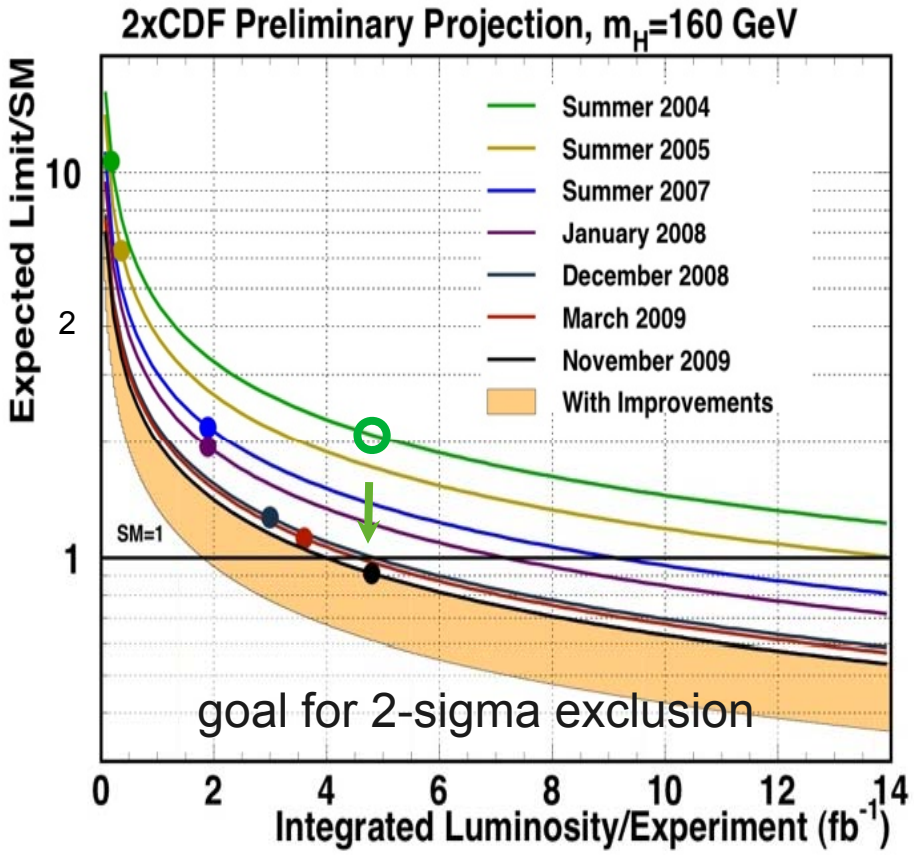
The new combined result published recently sets a new combined 95% CL exclusion for 162 – 166 GeV



Combining the two experiments at this advanced stage turns out to be very powerful for the Tevatron (… what about LHC?)

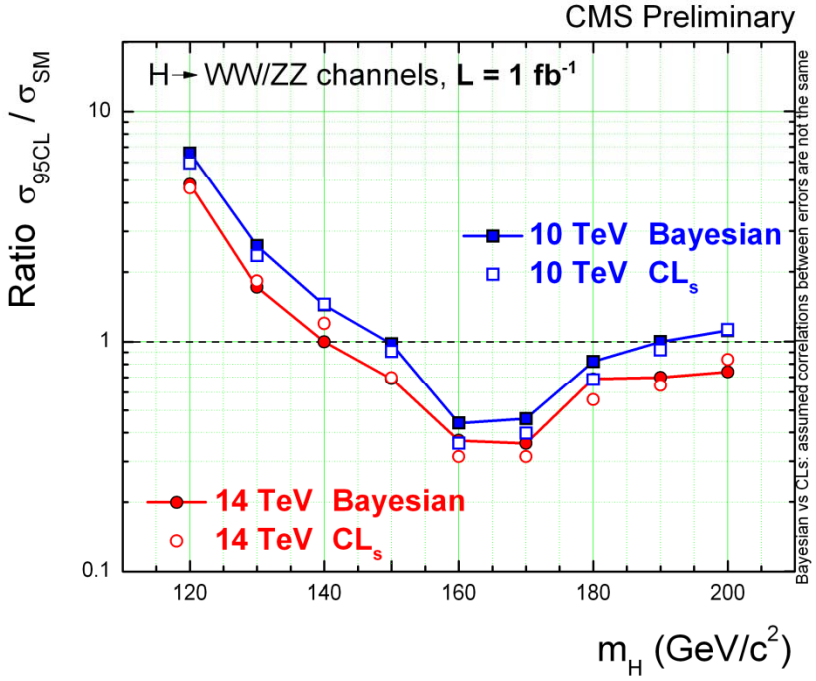
Tevatron Higgs Search Progress



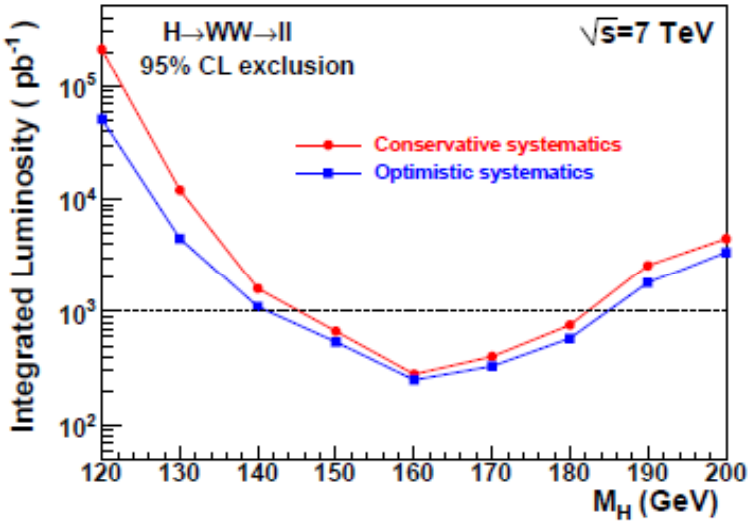


The first physics run with 7 TeV at the LHC, with the goal of 1 fb^{-1} towards the end of 2011, will be just 'catching up' the Tevatron

One can expect for the end of 2011 that ATLAS and CMS can exclude each the mass range 145 – 180 GeV, and that combined they could reach a 4.5 σ signal at a mass of 160 GeV

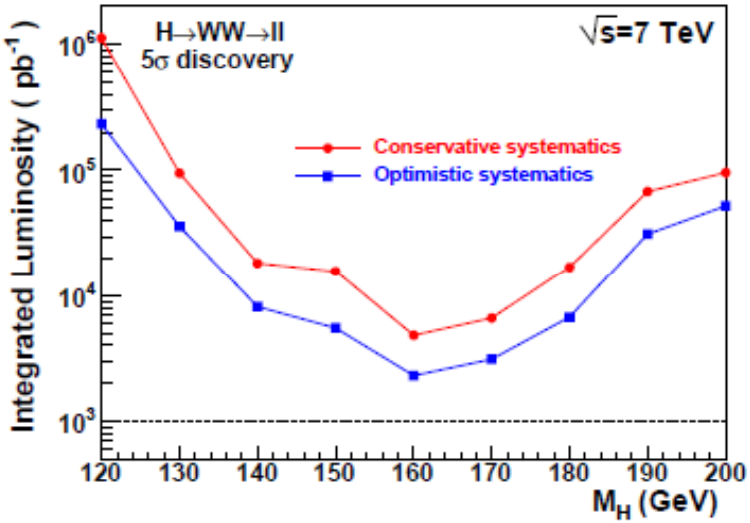


(work in progress…)



95% C.L. Exclusion

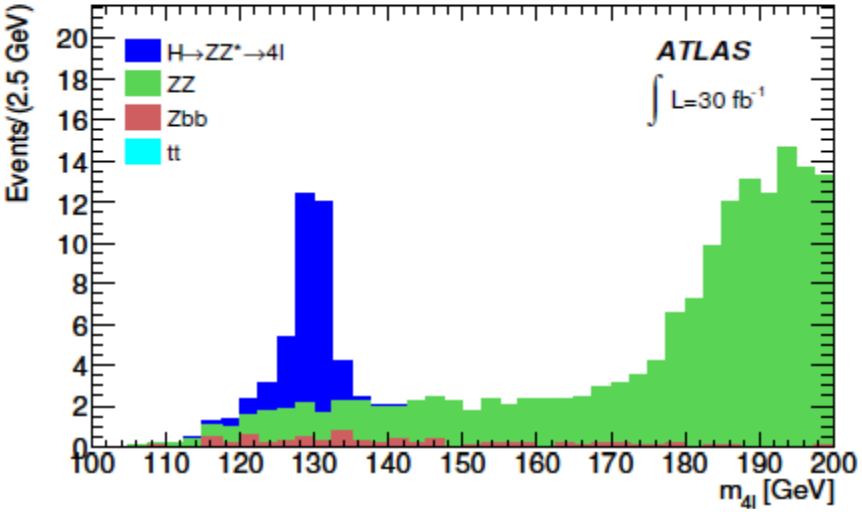
(work in progress…)

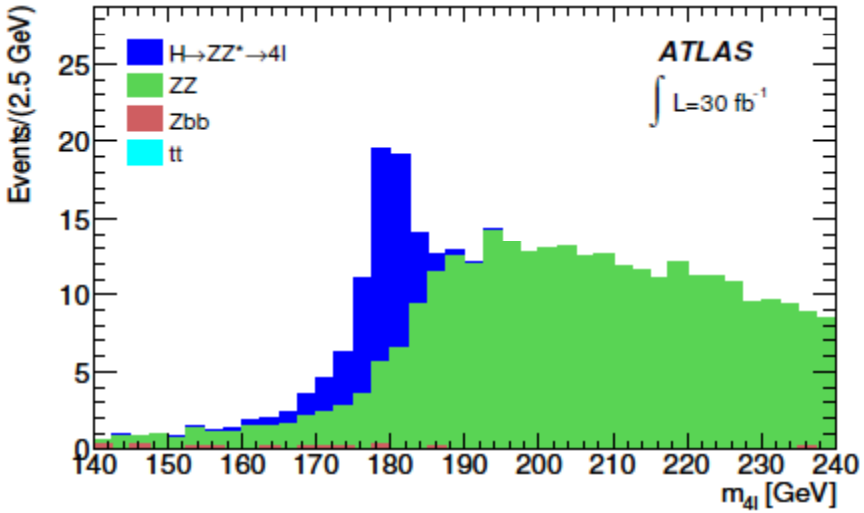


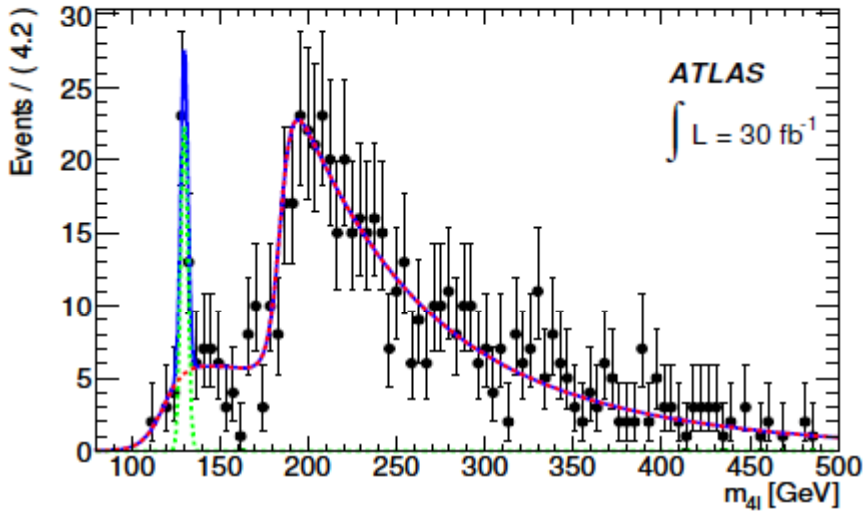
5σ Discovery

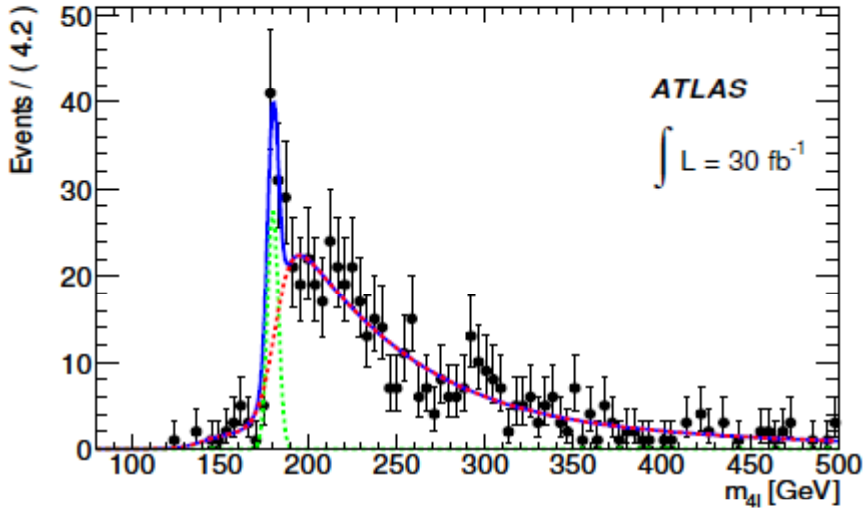
Higgs searches in the years 2014 and after …

14 TeV







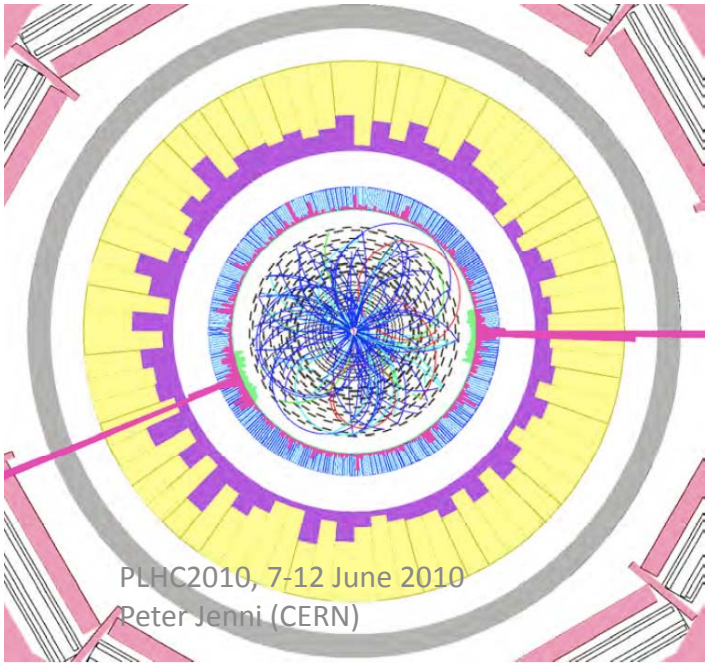


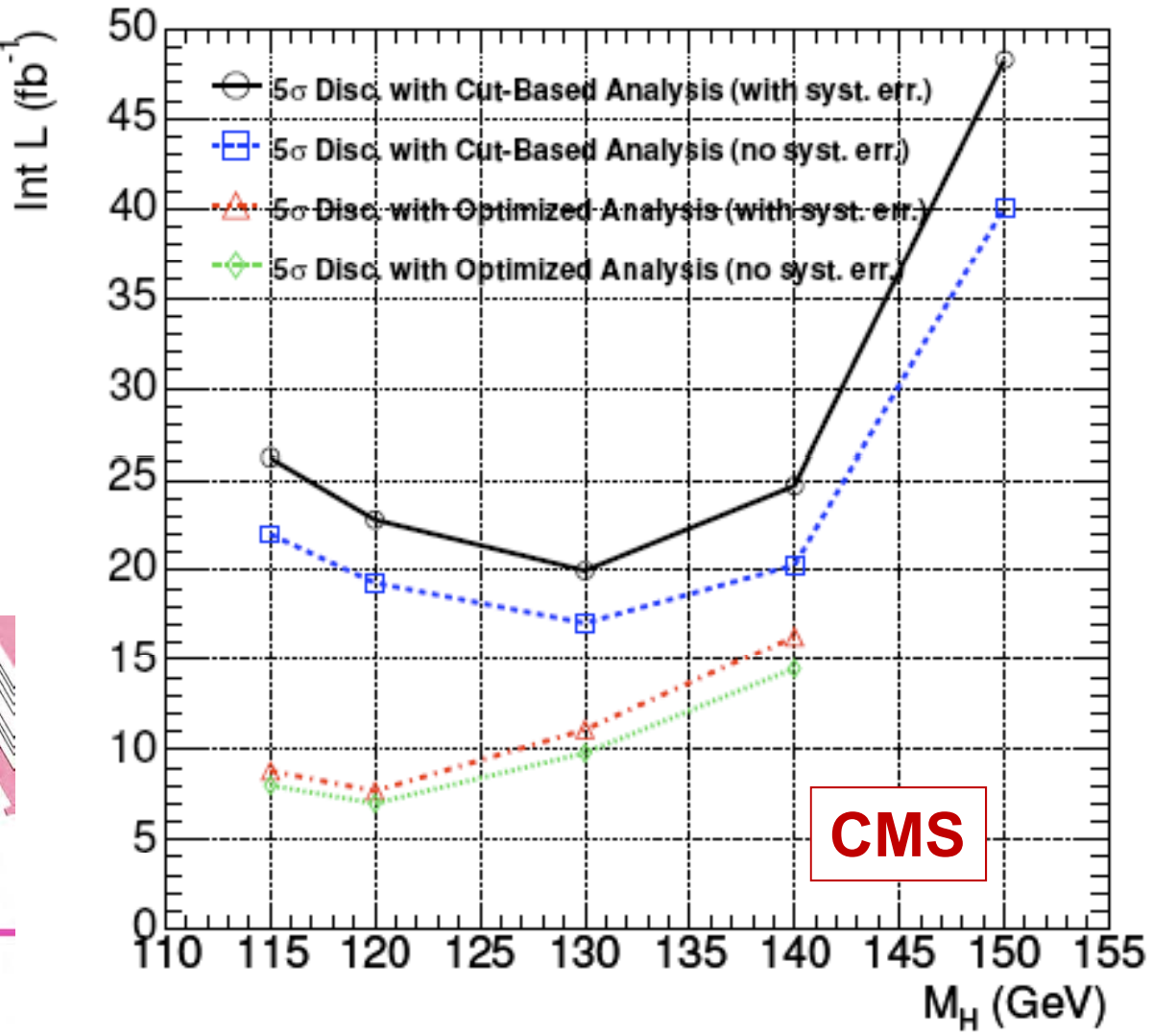
Examples for the 'gold-plated' 4 lepton channels (maybe sometimes in 2015), shown as smooth histogrammes and as a typical experimental distribution

Example of another channel for the low mass region

$H \rightarrow \gamma\gamma$

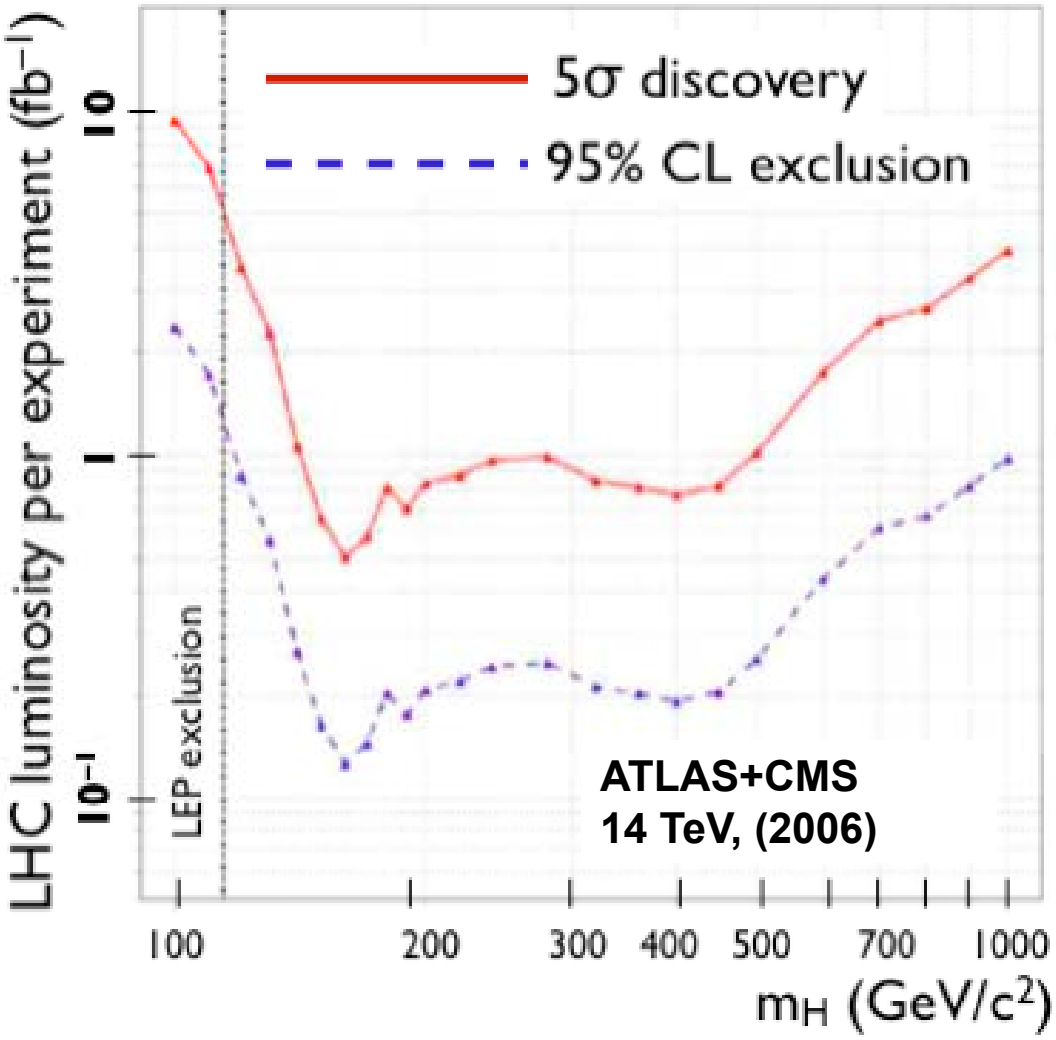
Optimized analysis: discovery with ~ 10 fb^{-1}





Summing up the Higgs search at the LHC with an old plot (still ~ valid)

→Around 2015 we should be able to conclude…

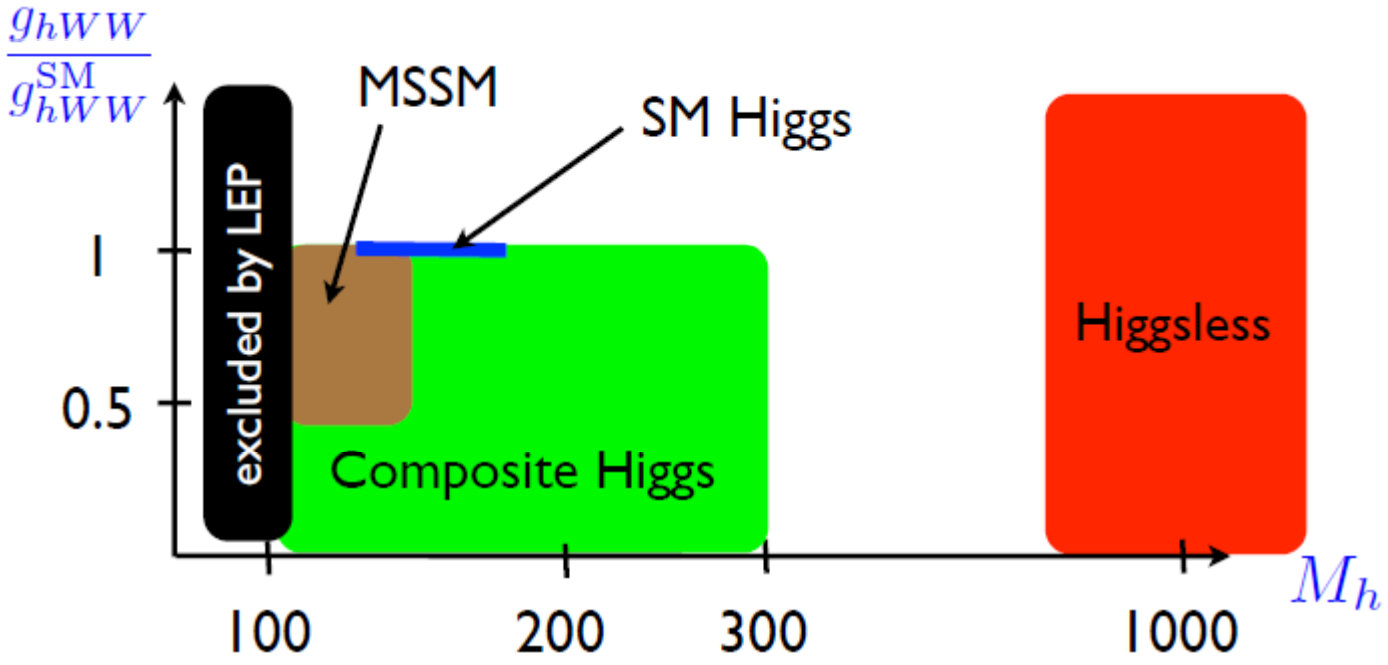


From Alex Pomarol:

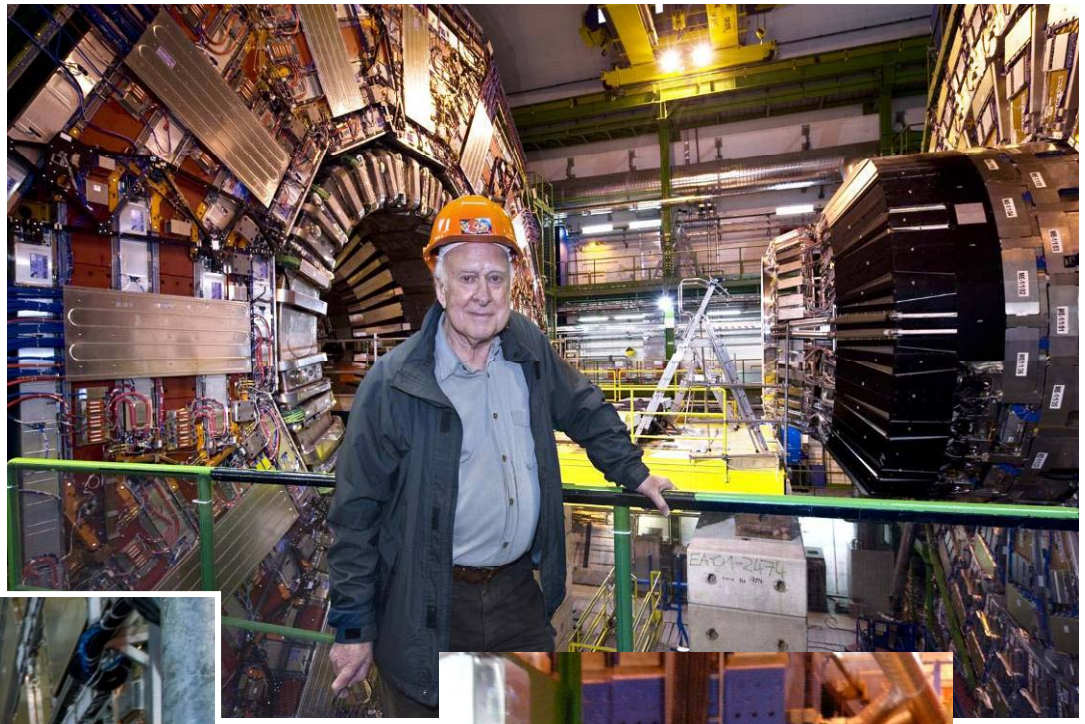
When a **Higgs-like** state is found, it will crucial to determine its role in EWSB

e.g. where it **sits** in this plane!

A rough perspective of different theoretical scenarios:



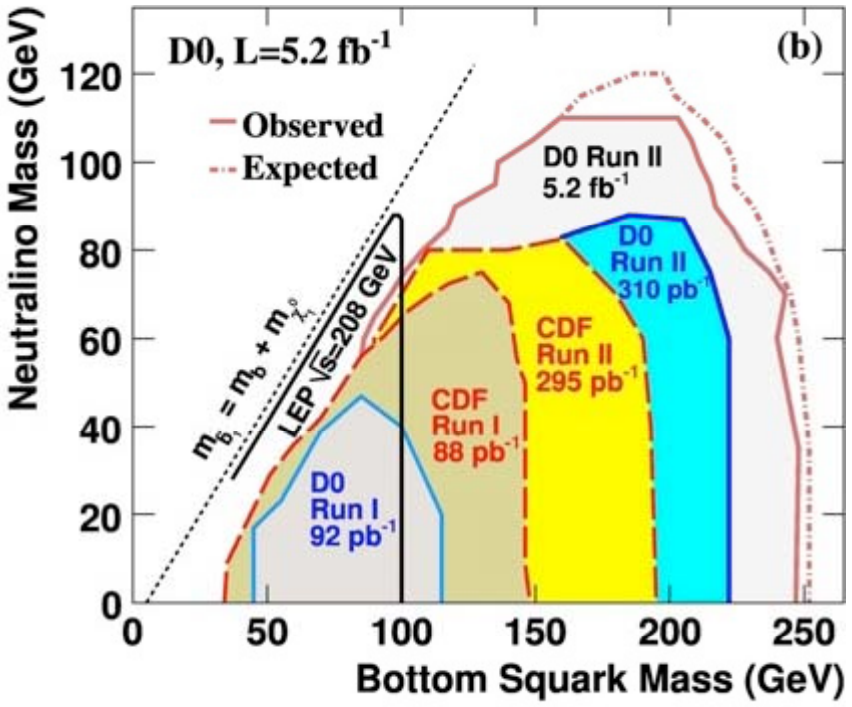
The first "Higgs" events observed jointly in CMS and ATLAS … (April 2008)

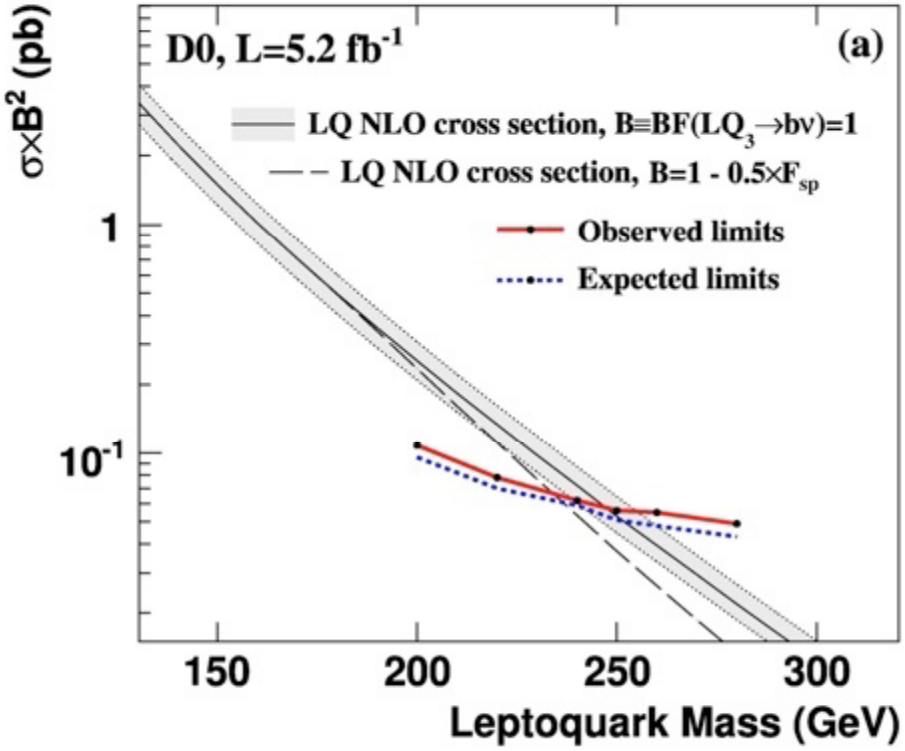


somewhat later, even in ALICE…

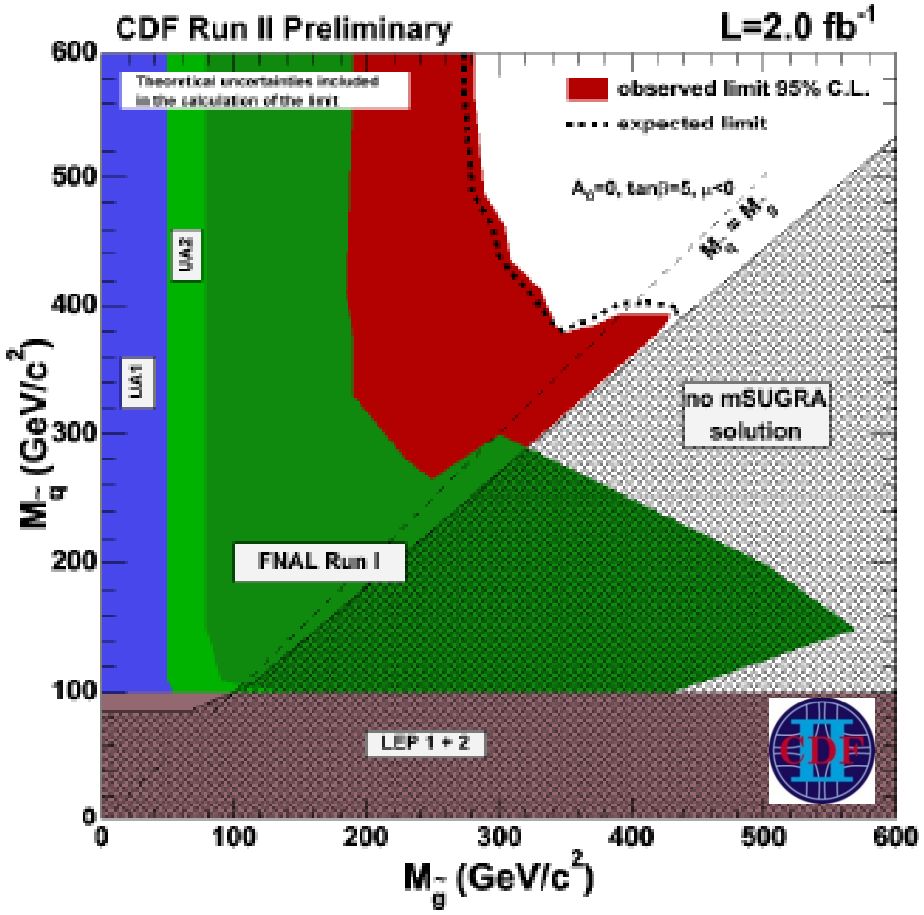
A very impressive spectrum of sophisticated searches have been reported from the Tevatron experiments, there is no way to do any justice here for this excellent work!

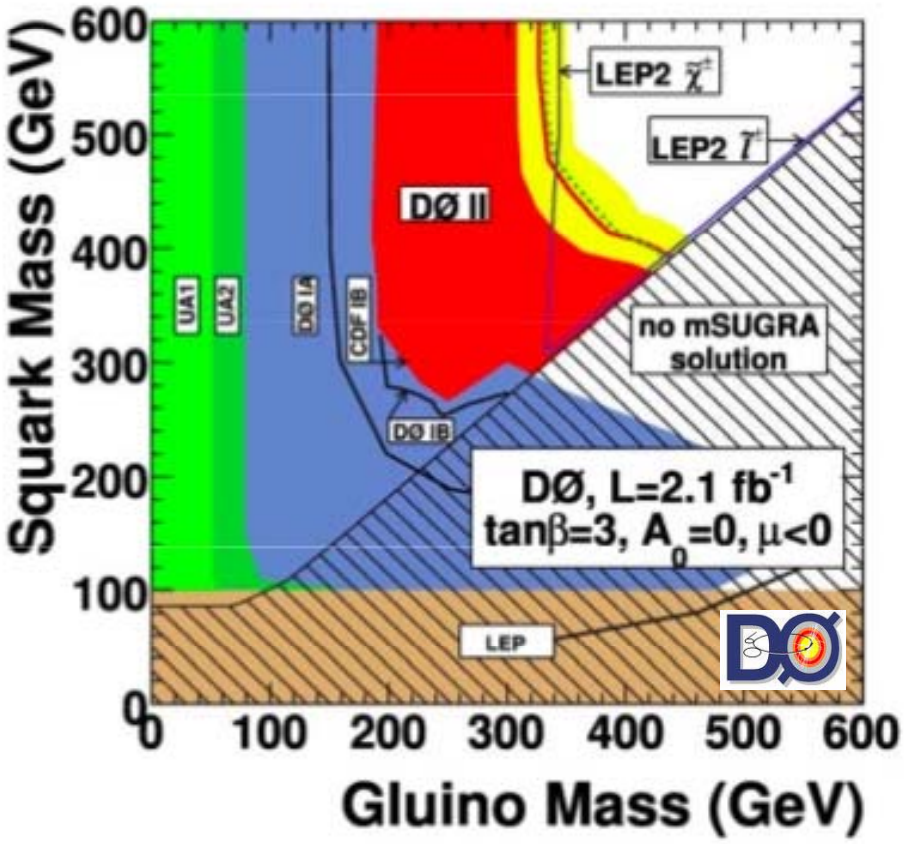
Just a few examples, which however also illustrate that it will be very difficult to push these searches much further, the LHC will have a much easier time thanks to the higher energy…





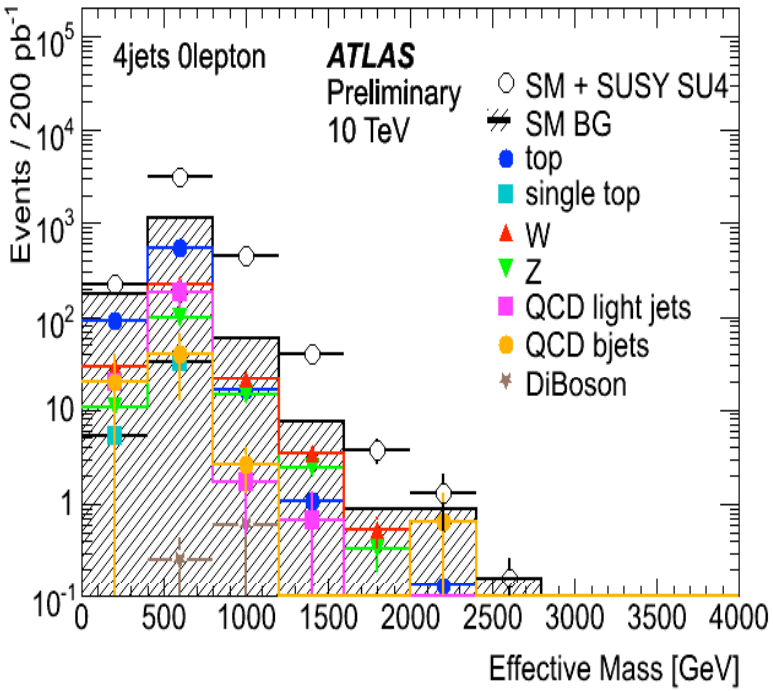
The Tevatron experiments have made very detailed studies investigating a large variety of possible signatures for SUSY

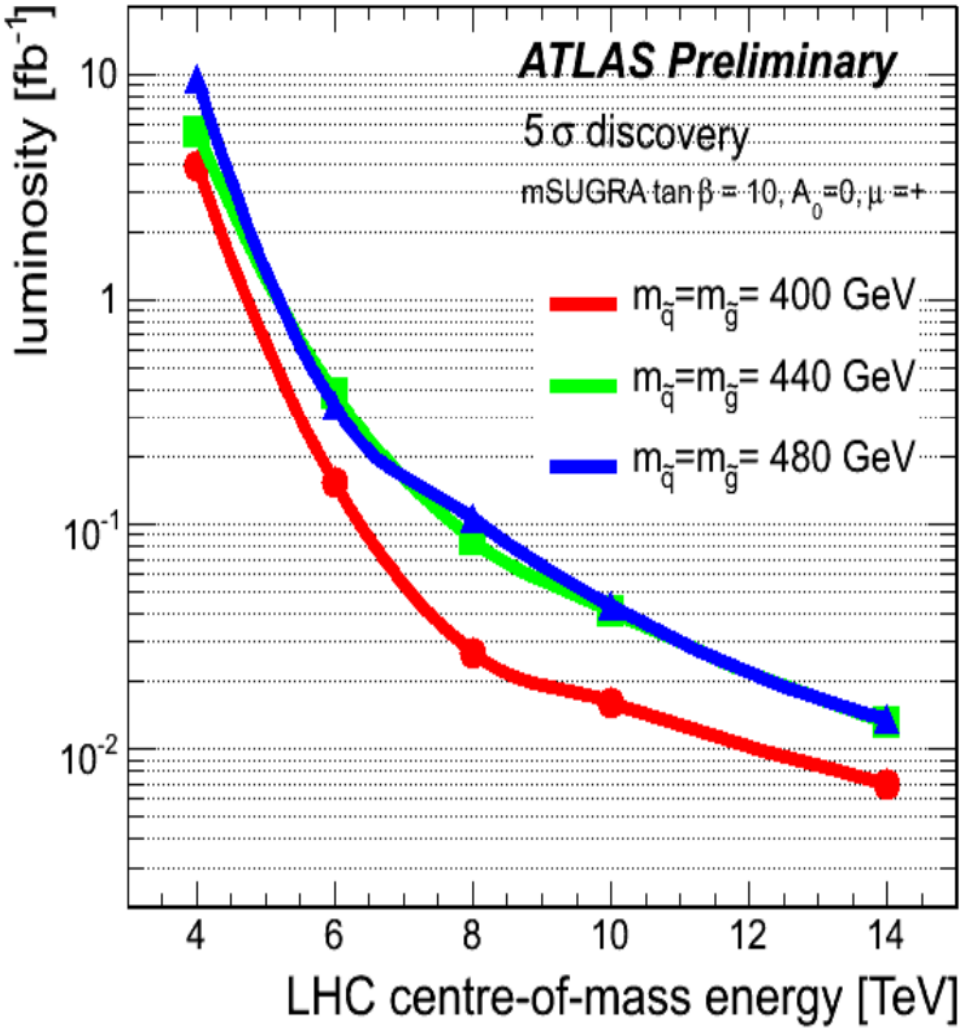




Exclusion plots (95% CL) for the most basic searches for squarks and gluinos

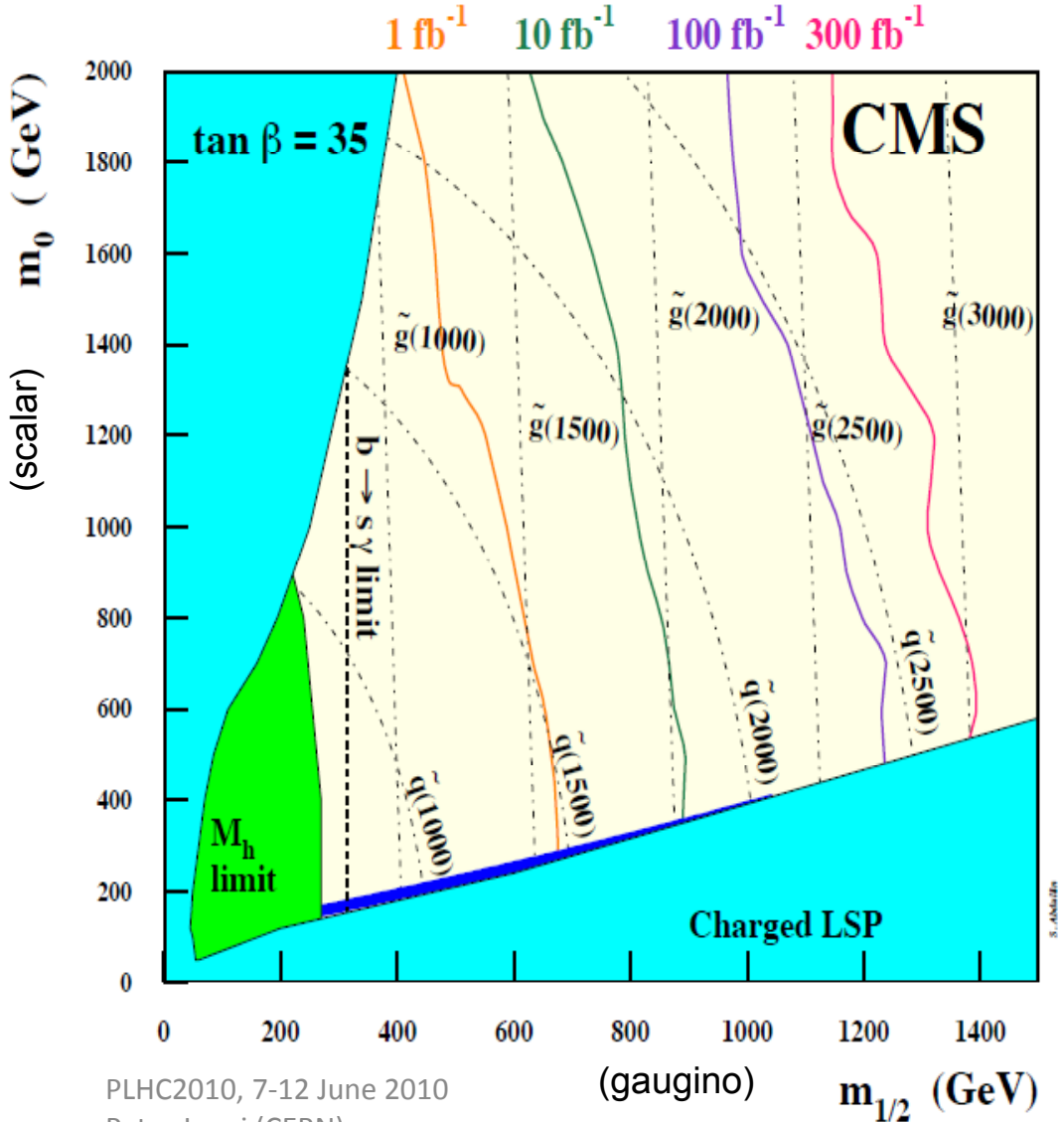
The initial LHC running will already match (maybe exceed) end 2010 the Tevatron reach

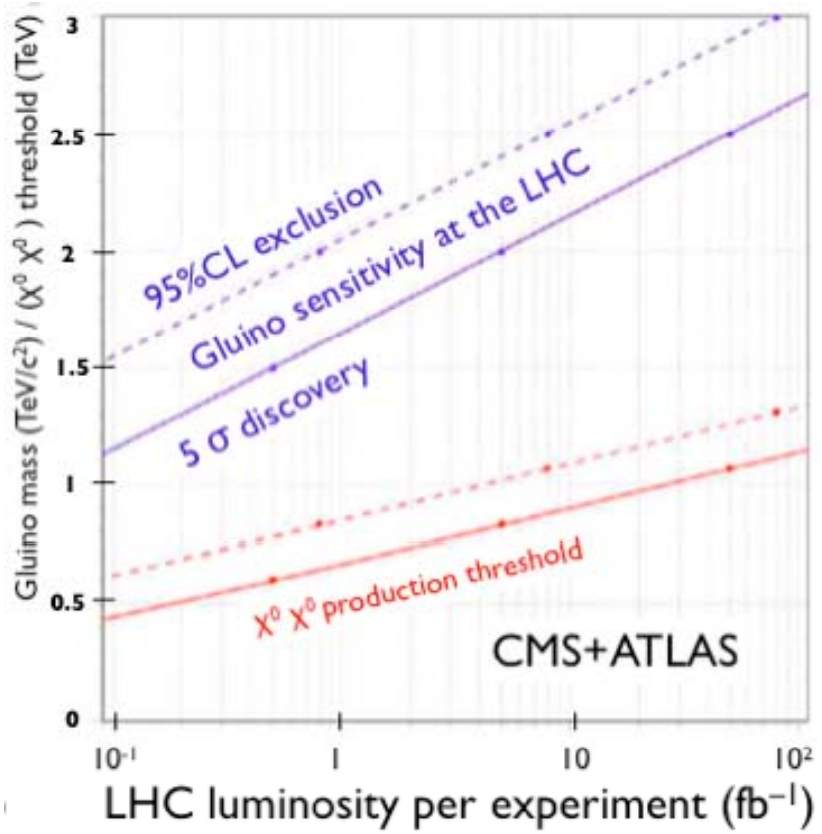




A typical example; note that the missing transverse energy performance enters directly the 'Effective Mass', detectors must be well understood for these measurements

Ultimate discovery reach for SUSY particles at the LHC (indicative plots, model-dependent…)

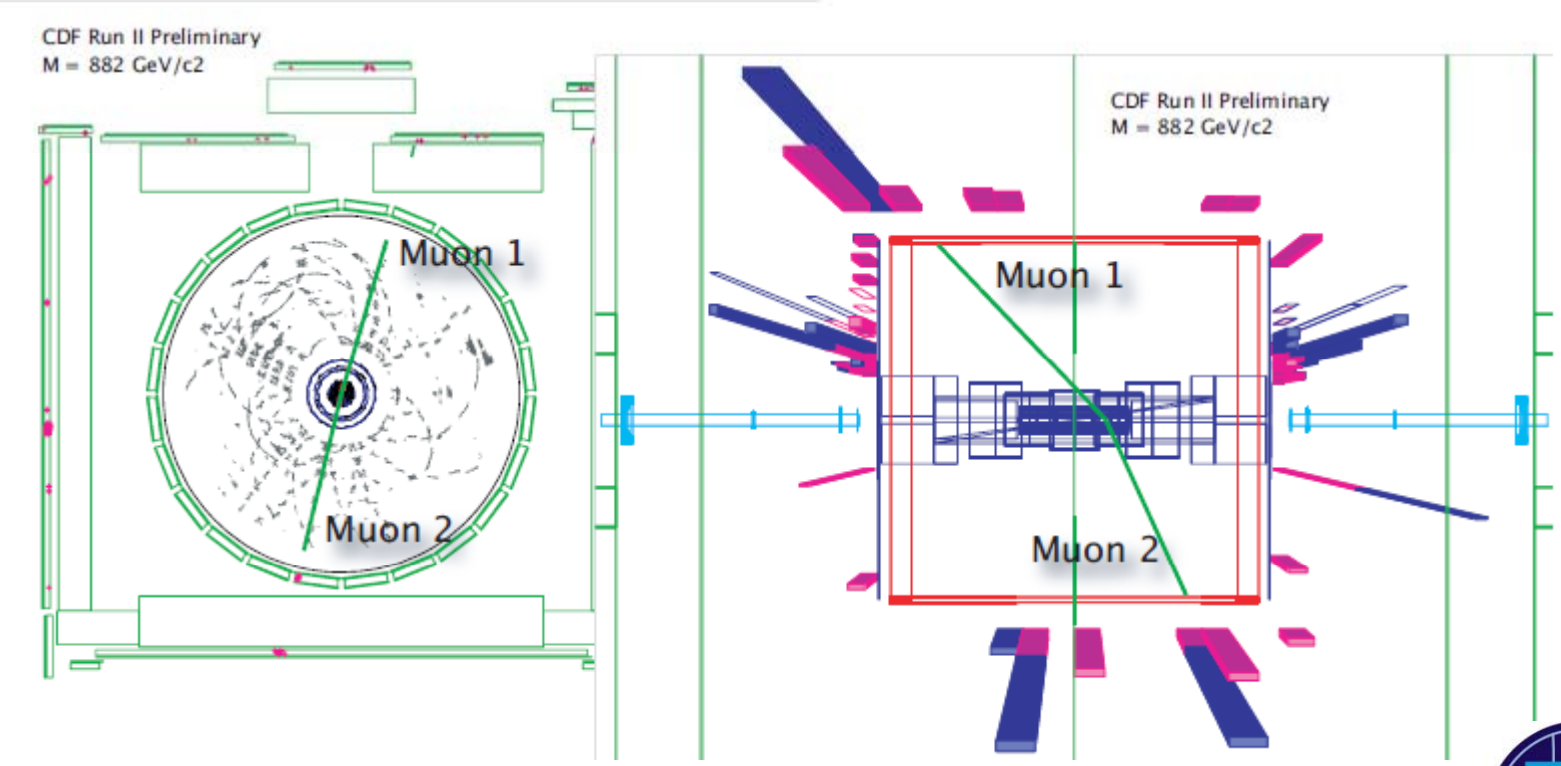




The mass scale probed for squarks and gluinos will be typically 2.5 TeV by 2017

CDF di-muon peak search

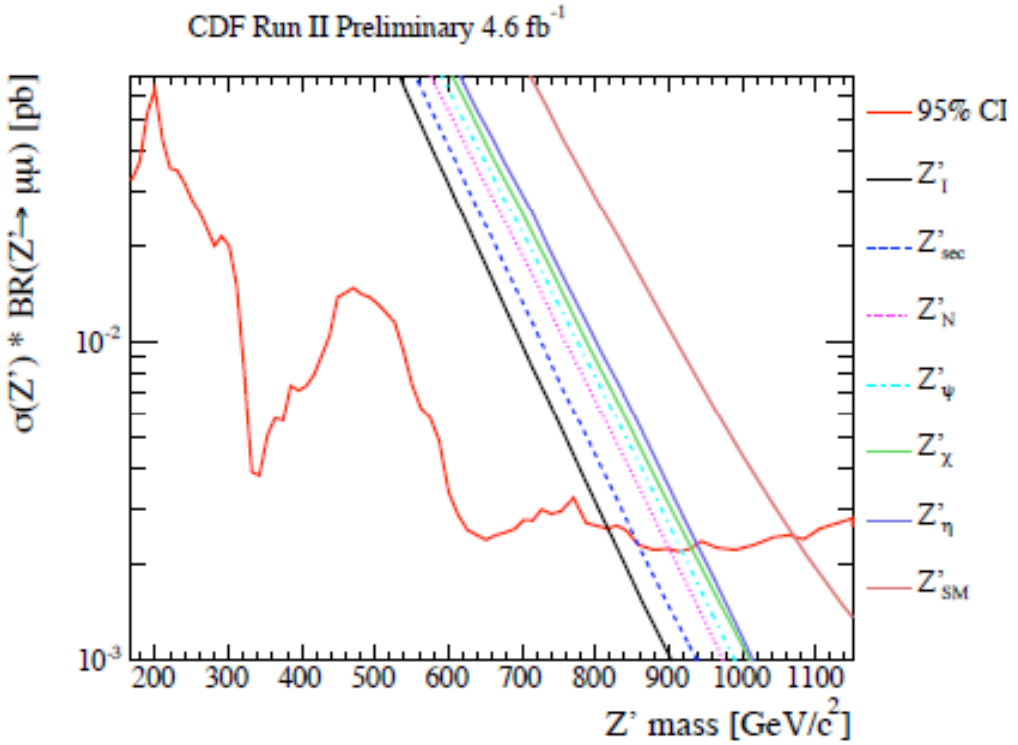
highest mass event: $m_{\mu\mu}$ = 882 GeV



CDF: $Z' \rightarrow \mu^+\mu^-$, 4.6/fb

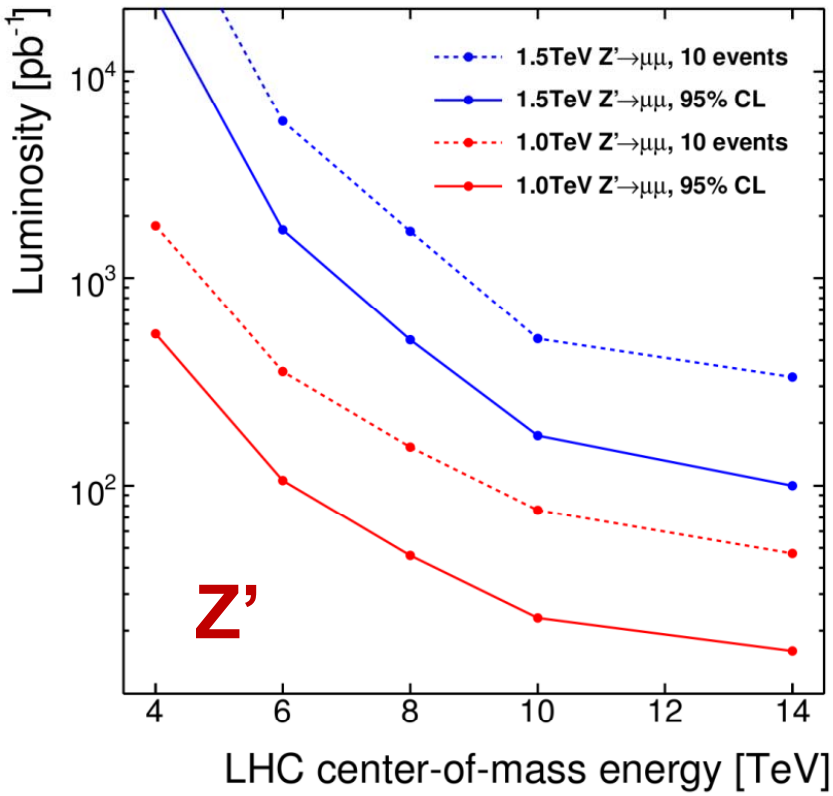
- No excess observed;
- Set limits in terms of several Z' models
- $Z'_{SM} > 1071$ GeV

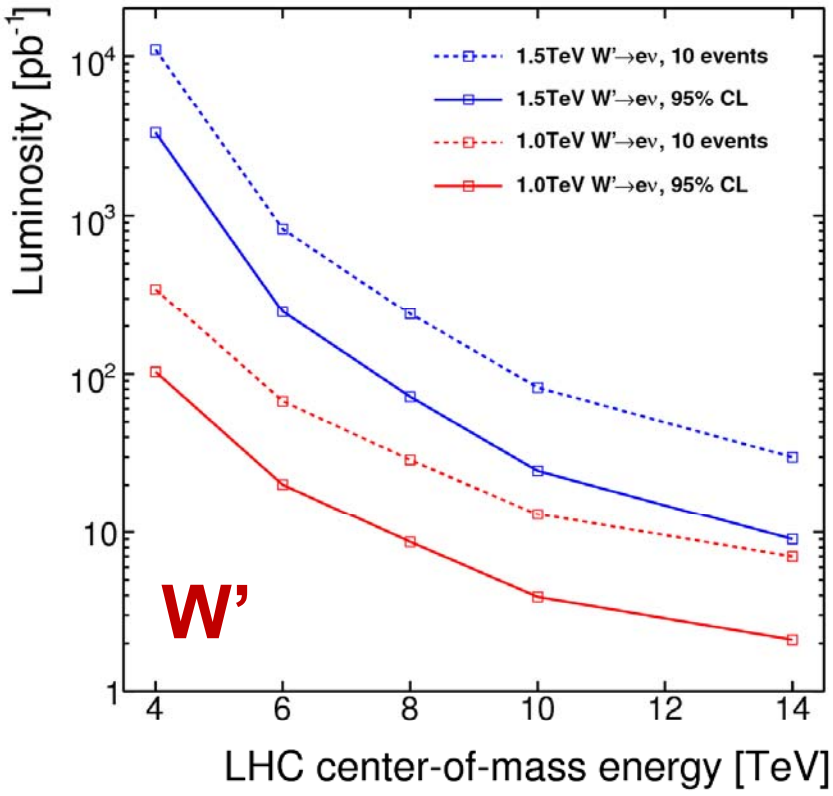
- data "best fit":
  - consider fit of signal fraction (number of Z') and mass as 2d fit
- best fit at m=190 GeV, sz=1.3%
  - p-value 16%



Model	Mass Limit (GeV/c^2)
Z'_I	817
Z'_{sec}	858
Z'_N	900
Z'_ψ	917
Z'_χ	930
Z'_η	938
Z'_{SM}	1071

The LHC experiments will have access to the 1 TeV mass range very early on, still this year (2010)

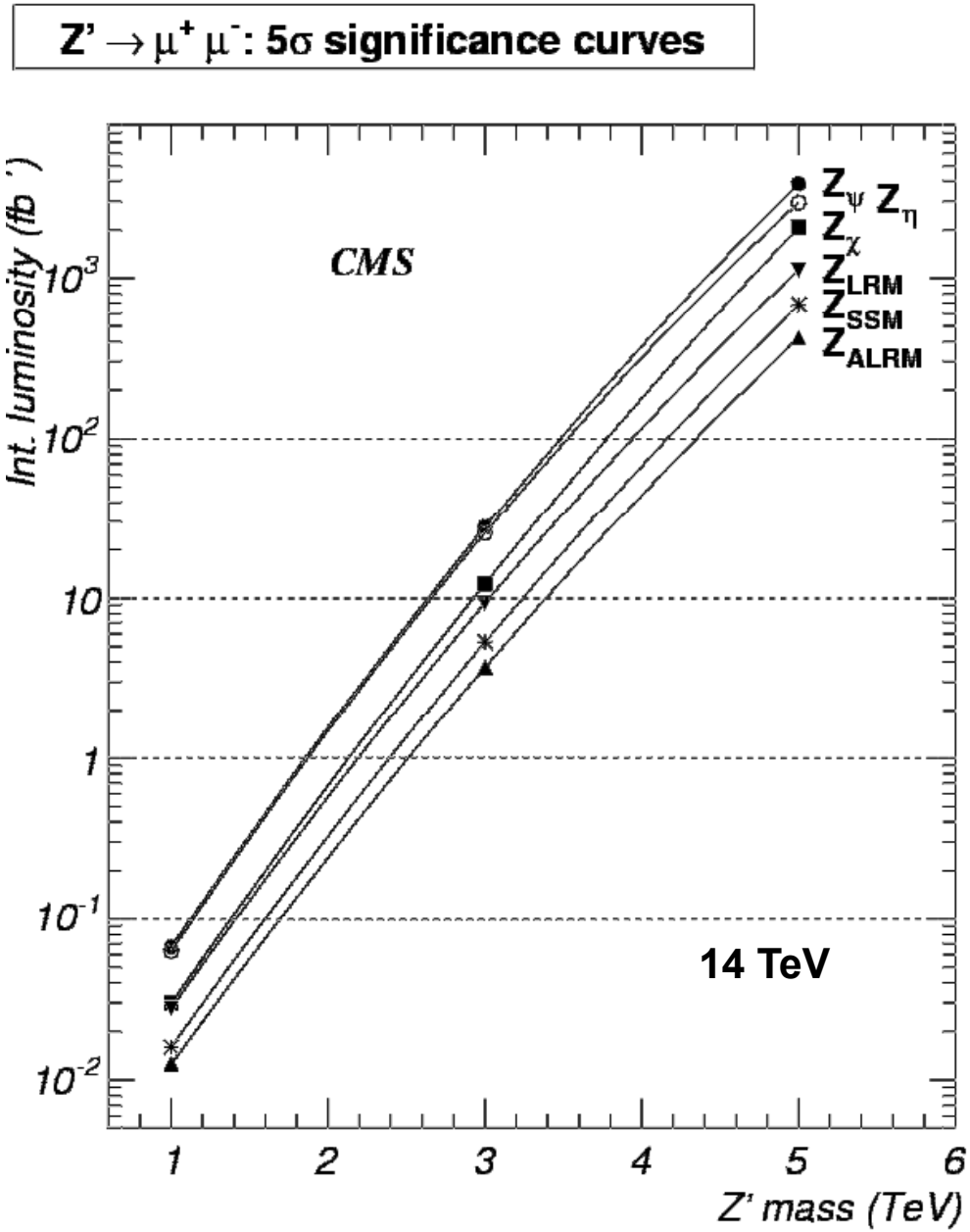




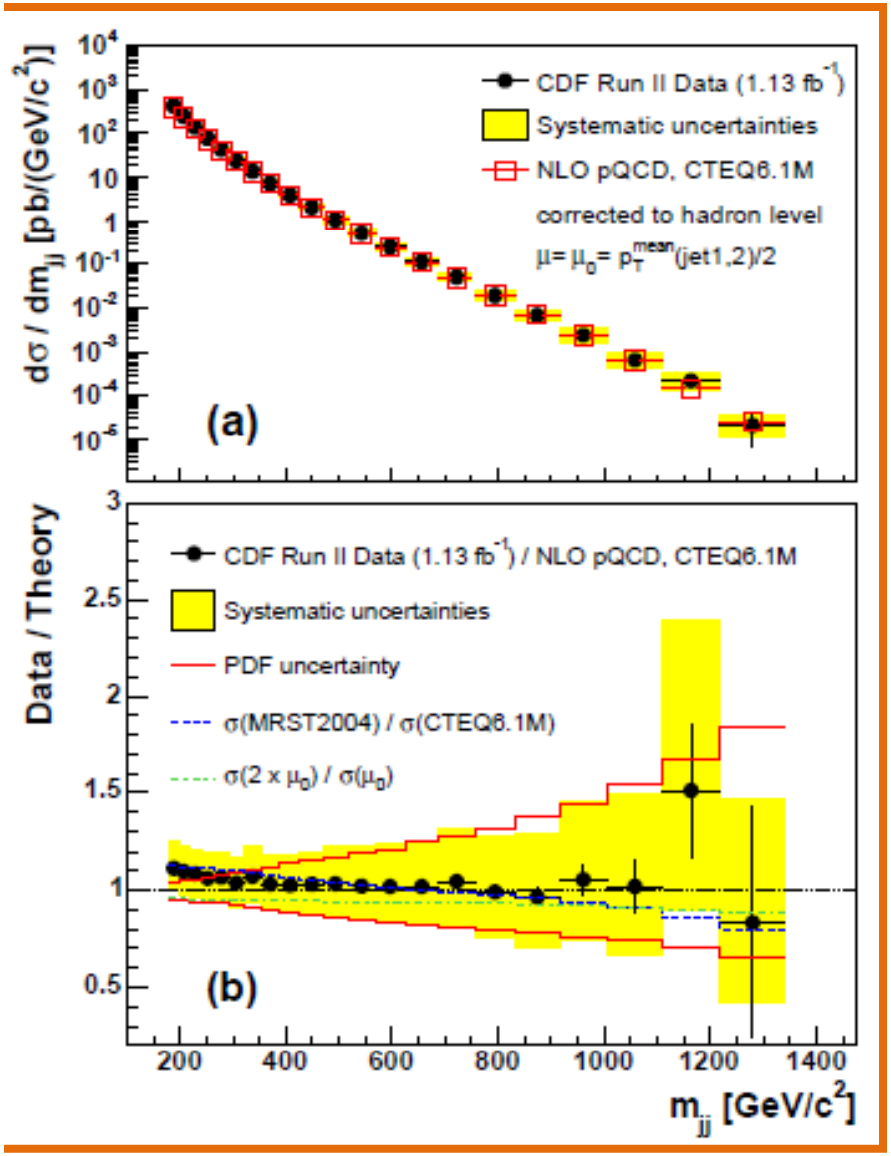
Discovery potential for ATLAS and CMS for the end of 2011, with 1 fb^{-1} at 7 TeV: up to 1.5 TeV for Z' and up to 1.9 TeV for W'

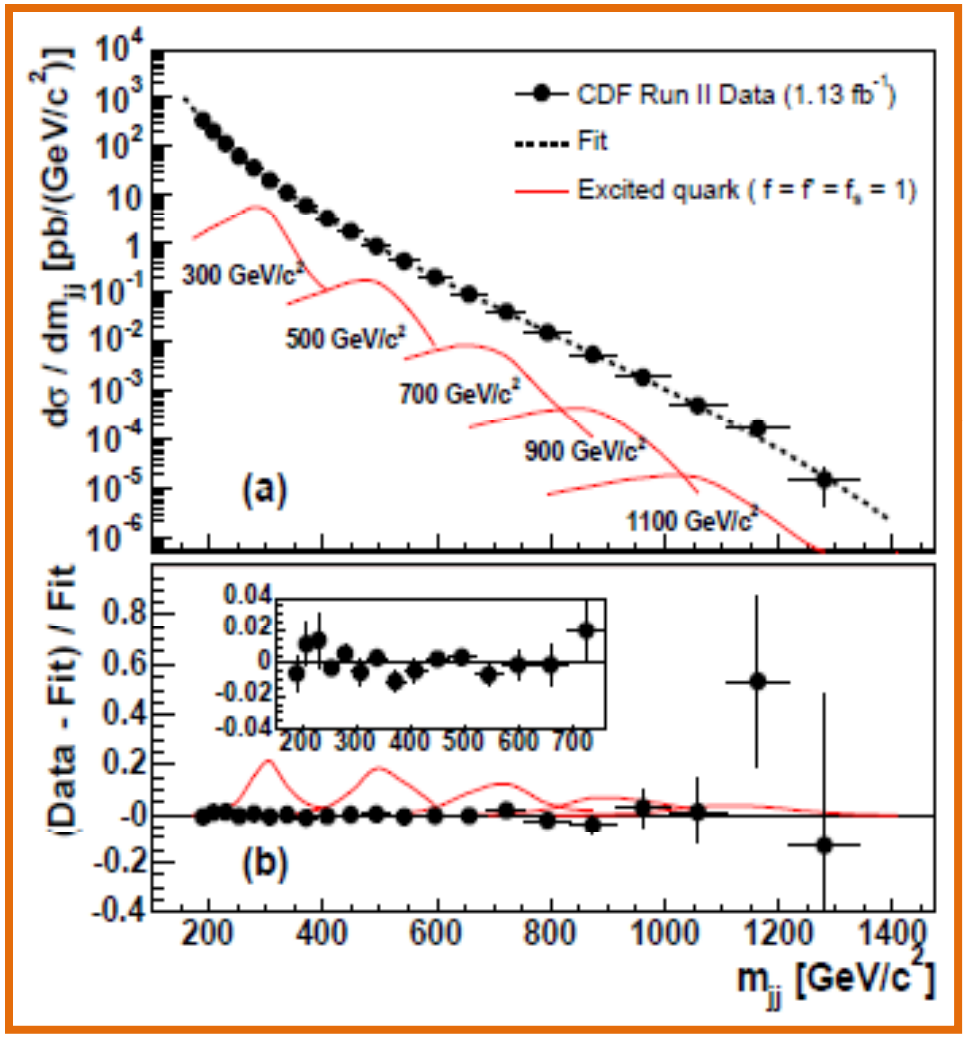
The ultimate discovery range at the LHC for heavy Z' and W' is very large, reaching 5 TeV and even beyond

(Note that the plot shows one channel for one experiment only)

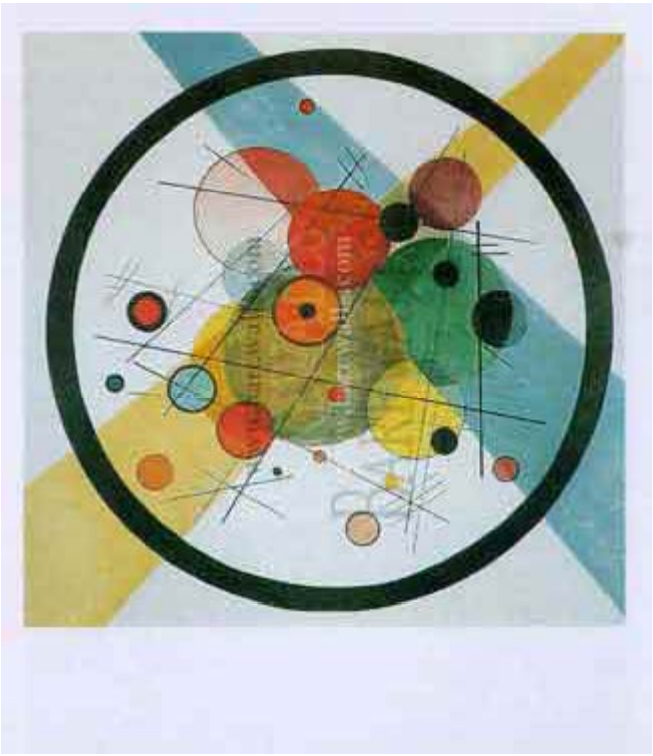


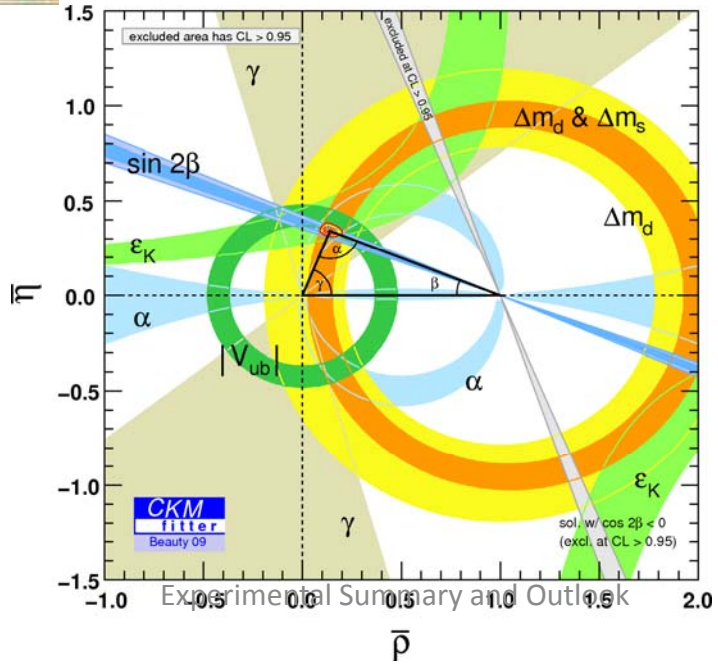
Di-jet mass distributions: QCD, bump-hunts, searches for sub-structure …





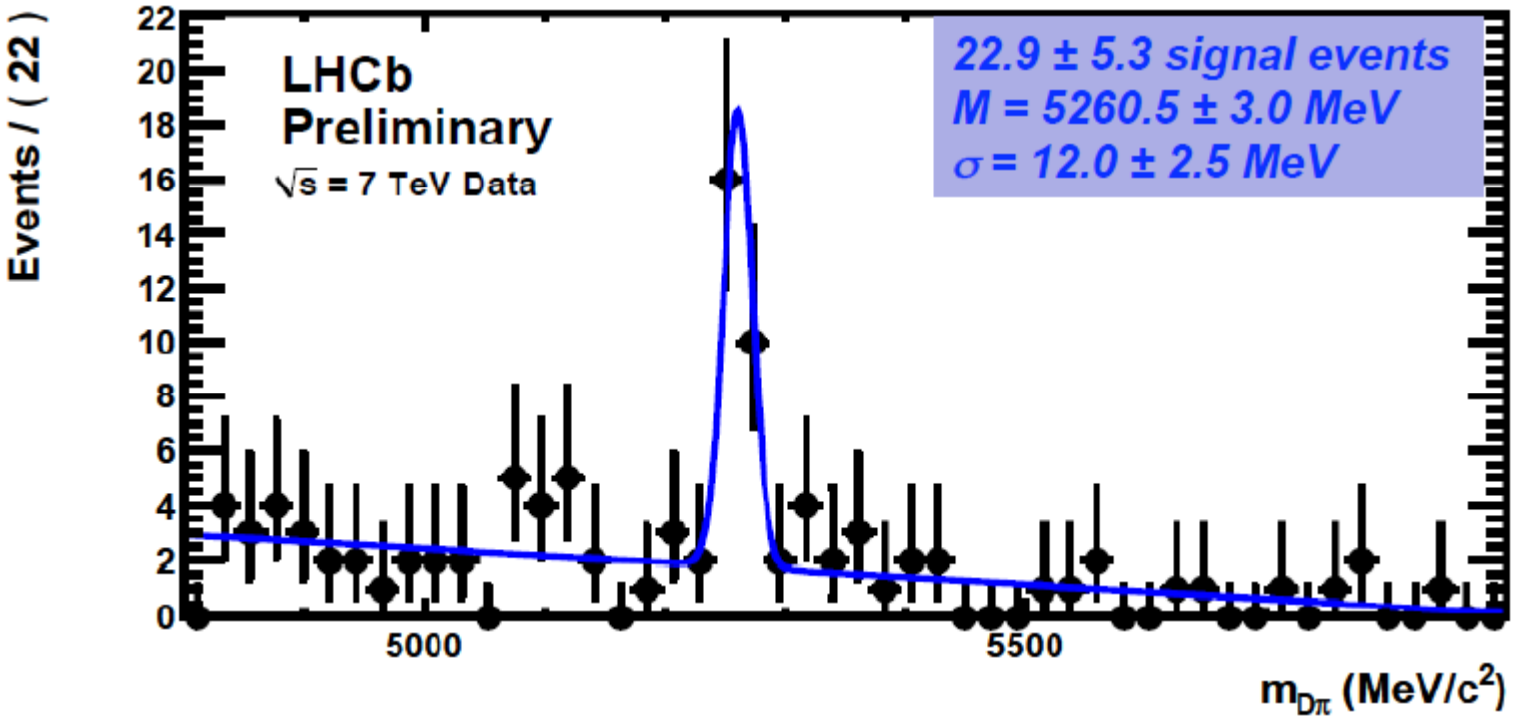
Early hints of news from 'Beyond the Standard Model' may come from 'beautiful' flavour physics...





First fully reconstructed B mesons

$B^0 \rightarrow D^+\pi^-$ + $B^+ \rightarrow D^0\pi^+$



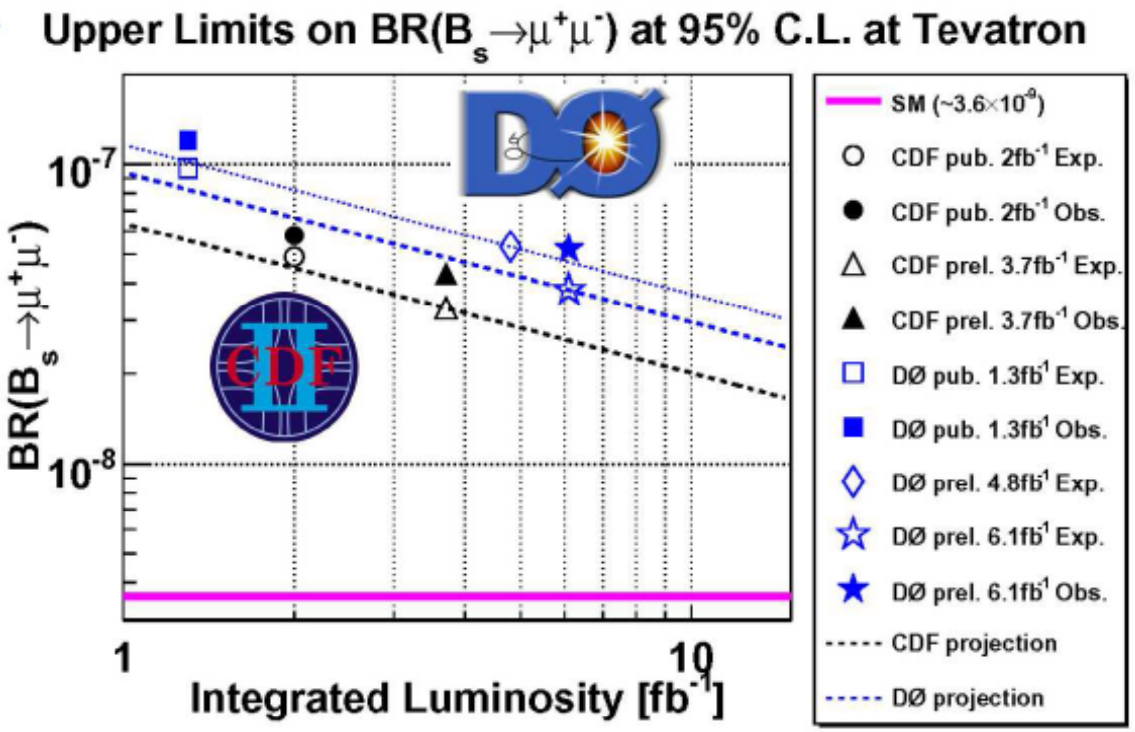
Calibration of the mass scale and B-field is ongoing

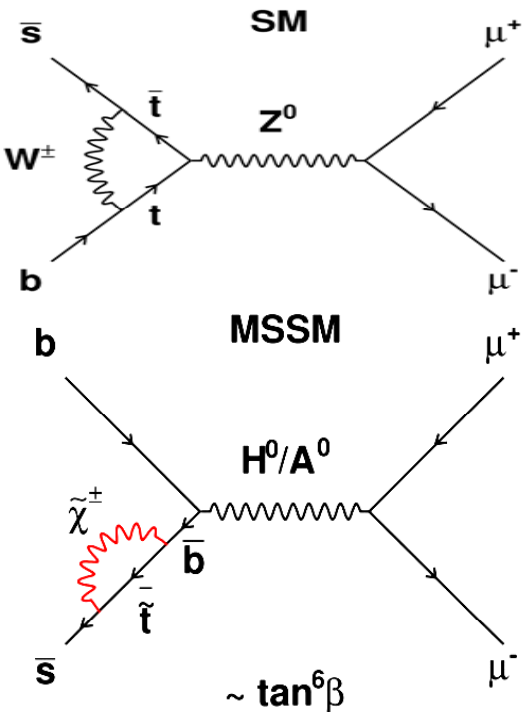
$B_s \rightarrow \mu\mu$

Small BR in SM: $(3.2 \pm 0.2) \times 10^{-9}$

Sensitive to NP

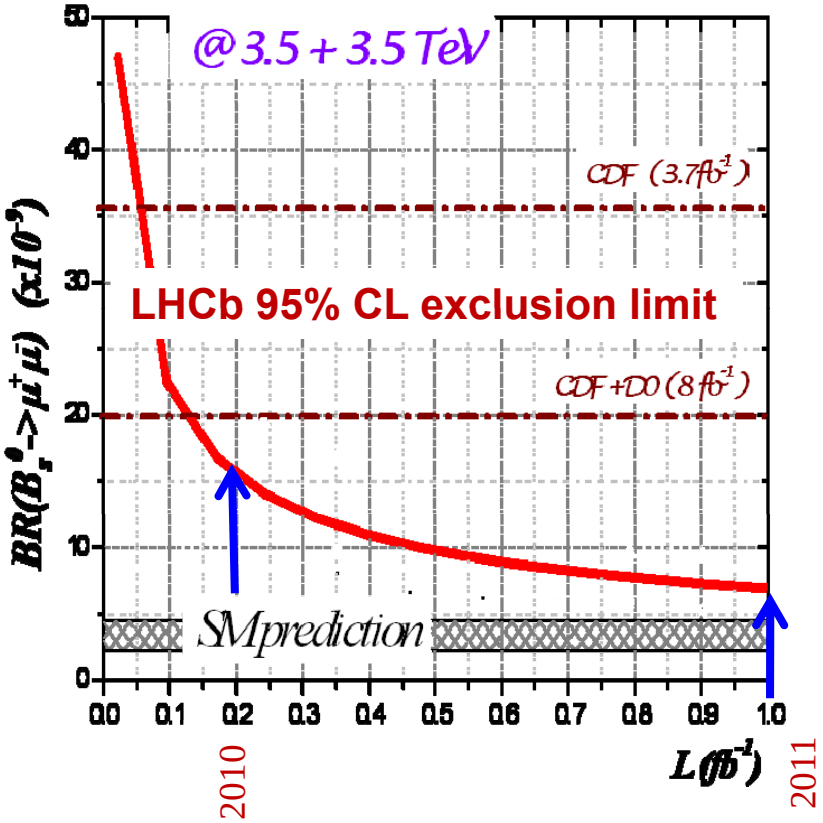
- **could be strongly enhanced in SUSY**
  - **In MSSM scales like ~tan$^6\beta$**



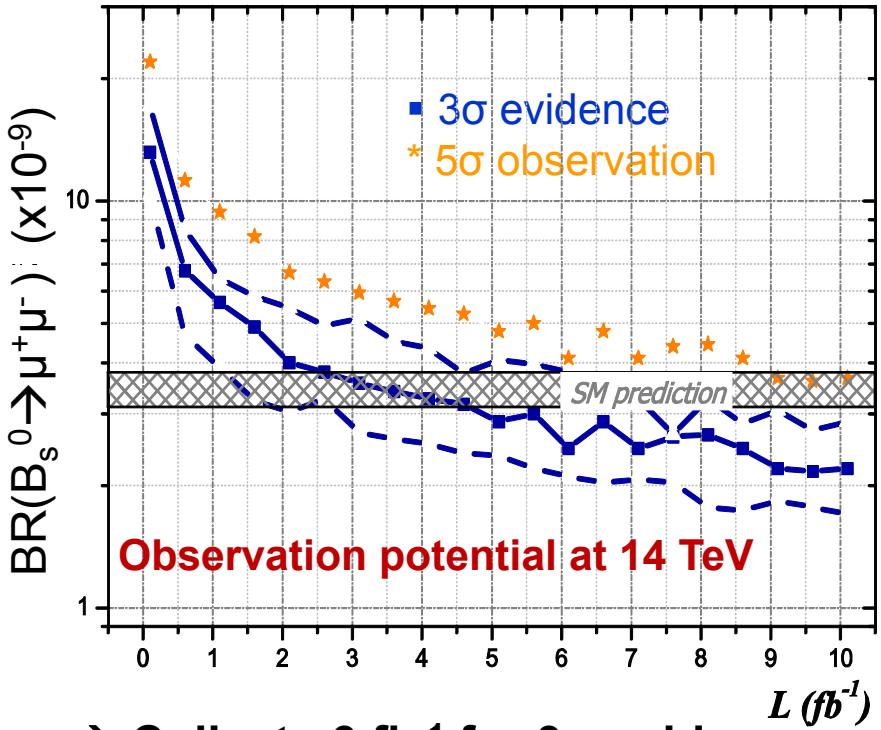


- CDF Preliminary, 3.7 fb^{-1}: $< 4.3 \cdot 10^{-8}$ at 95% C.L.
- DØ Preliminary, 6.1 fb^{-1}: $< 5.2 \cdot 10^{-8}$ at 95% C.L.

Physics reach for BR($B_s^0 \to \mu^+\mu^-$) as function of integrated luminosity (and comparison with Tevatron)



With ~0.2 fb^{-1} LHCb should improve on expected Tevatron limit

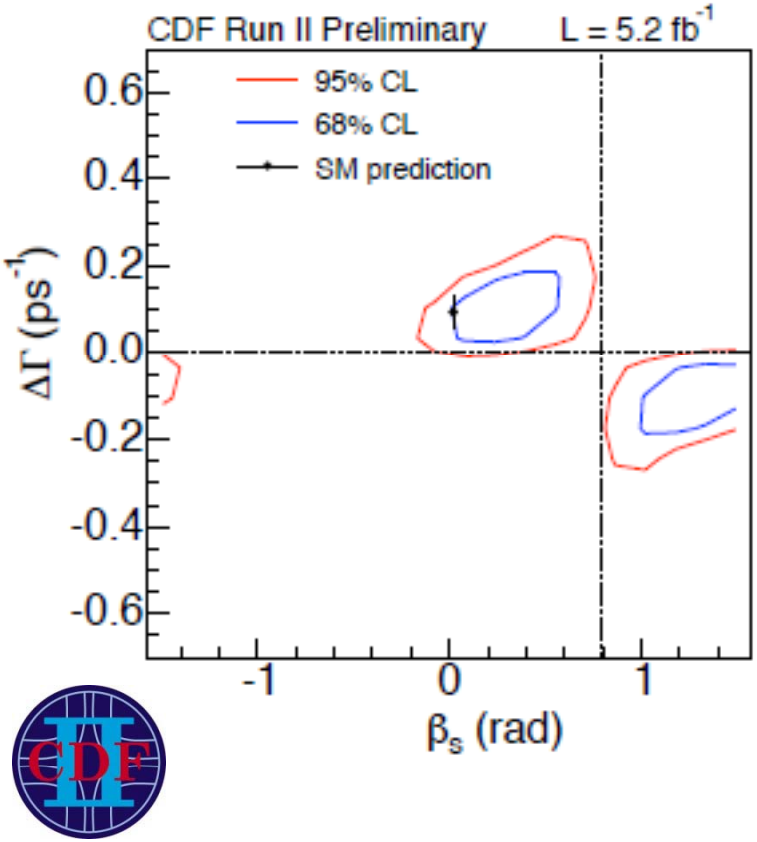


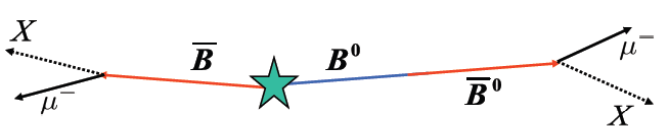
→ **Collect ~3 fb^{-1} for 3σ evidence of SM value and ~10 fb^{-1} for 5σ observation of SM**

(Note: ATLAS/CMS will be competitive)

Two new results which get a lot of attention (rightly so!)

Bs mixing phase (from $B_s \to J/\psi\,\phi$)





- Asymmetry in "same-sign" muons from decays of mixed neutral B mesons:

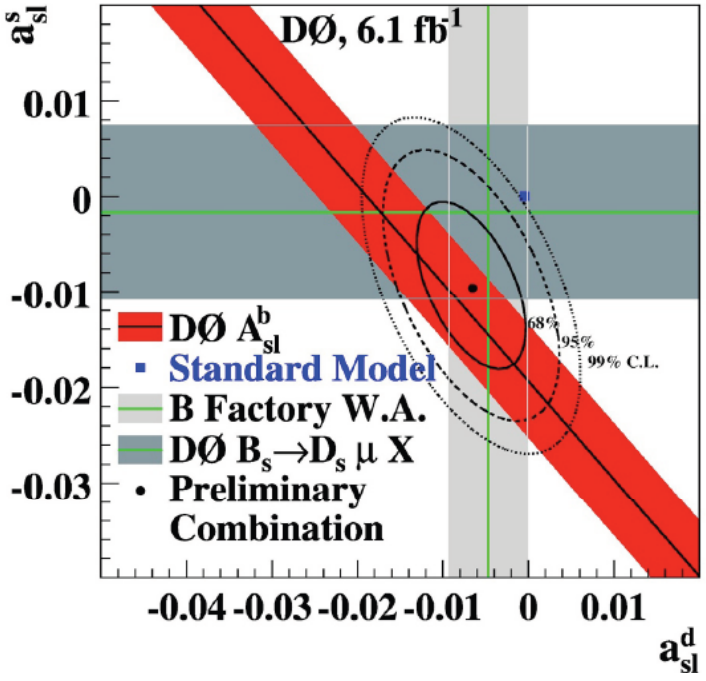
$$a^b_{sl} \equiv \frac{\Gamma\left(\bar{B} \to \mu^+ X\right) - \Gamma\left(B \to \mu^- X\right)}{\Gamma\left(\bar{B} \to \mu^+ X\right) + \Gamma\left(B \to \mu^- X\right)}$$

$$A^b_{sl} \equiv \frac{N^{++} - N^{--}}{N^{++} + N^{--}}$$

Grossman, Nir, Raz, Phys.Rev.Lett.97:151801,2006.

$$A^b_{sl} = (-0.957 \pm 0.251\,(\text{stat}) \pm 0.146\,(\text{syst}))\,\%$$

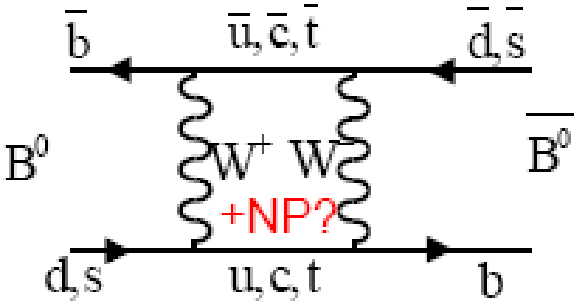
$$A^b_{sl}\,(\text{SM}) = \left(-2.3^{+0.5}_{-0.6}\right) \times 10^{-4}$$

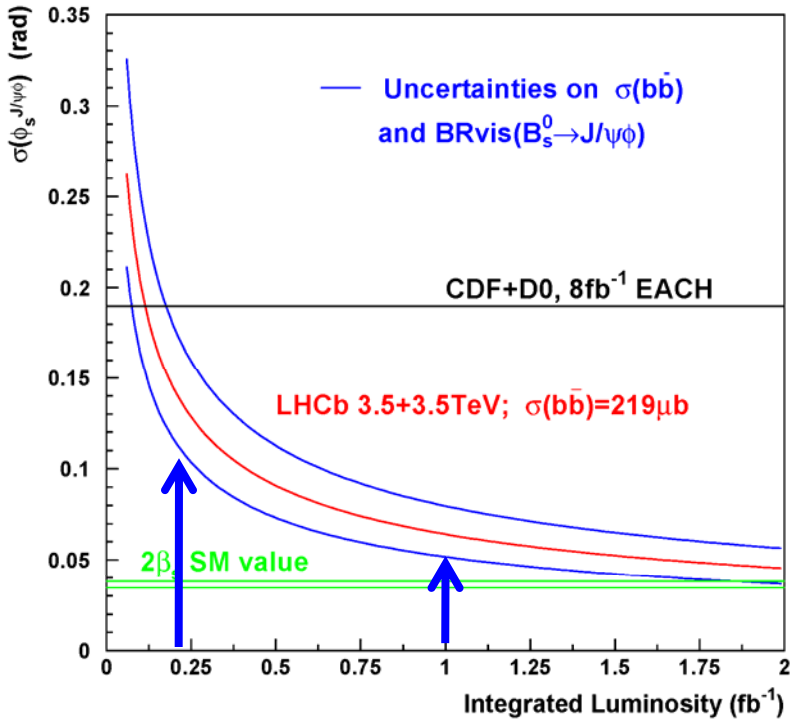


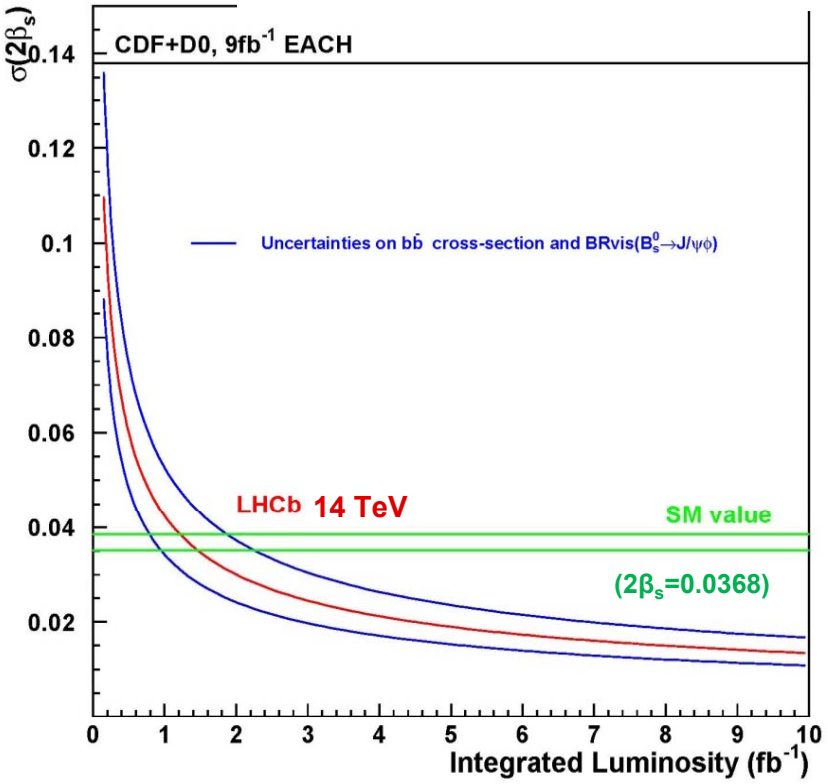
B_s-$\bar{B}_s$ mixing phase ϕ_s (from $B_s \to J/\psi\,\phi$)

Sensitive to New Physics effects in box diagrams

- $\phi_s = \phi_{s(SM)} + \phi_{s\,(NP)}$
- $\phi_{s(SM)} = -2\beta_s = -2\lambda^2\eta \sim -0.04$







→ ***With ~0.2 fb^{-1} LHCb should improve on expected Tevatron limit***

Exciting times are ahead of us!

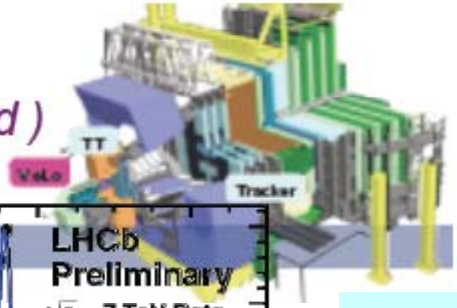
Thank you for your attention

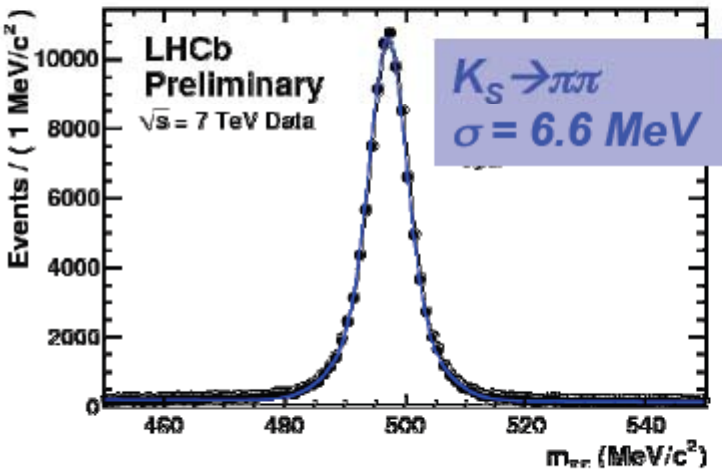
Cordial thanks to the organizers/DESY crew for such an enjoyable PLHC2010!

Spares

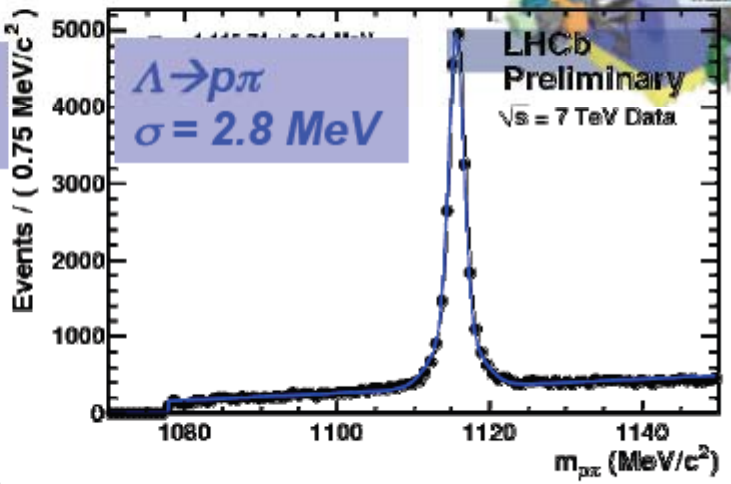
Tracking performance

(mass resolution of reconstructed particles as expected)

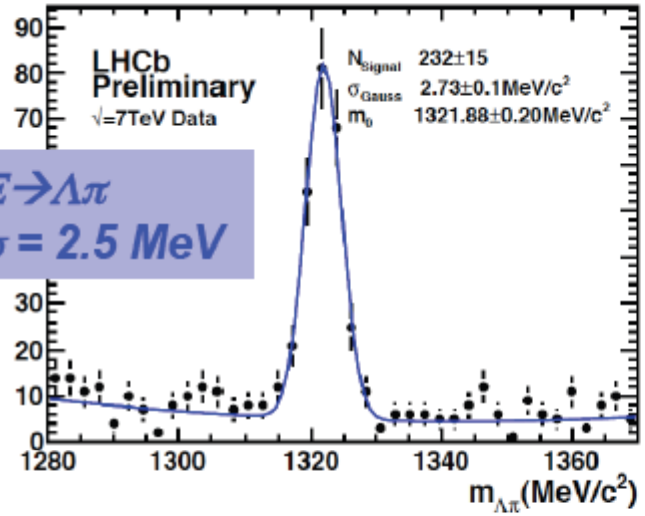




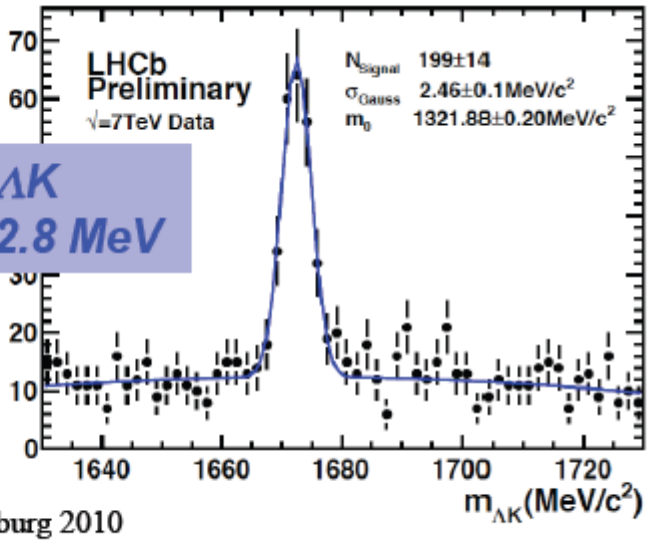
$K_S \rightarrow \pi\pi$
$\sigma = 6.6$ MeV



$\Lambda \rightarrow p\pi$
$\sigma = 2.8$ MeV



$\Xi \rightarrow \Lambda\pi$
$\sigma = 2.5$ MeV



$\Omega \rightarrow \Lambda K$
$\sigma = 2.8$ MeV

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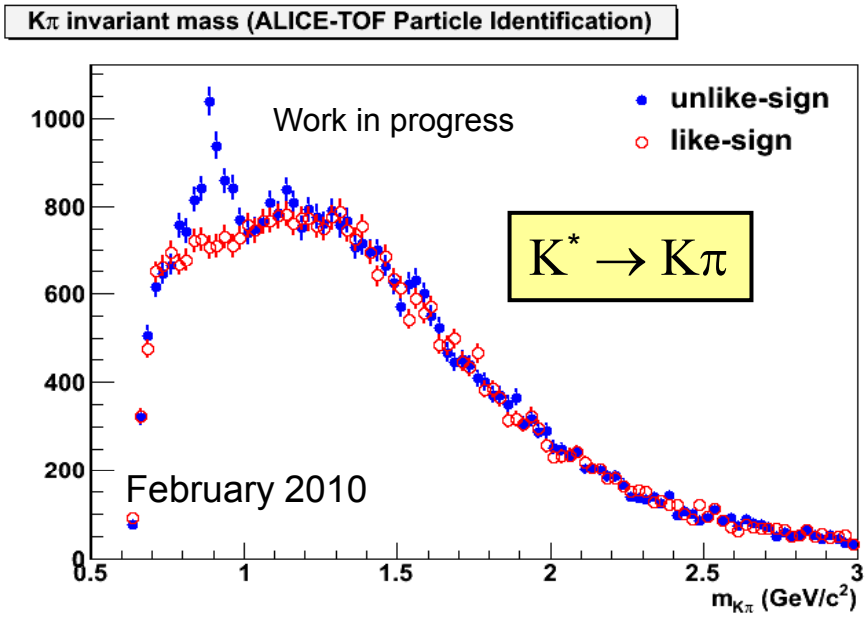
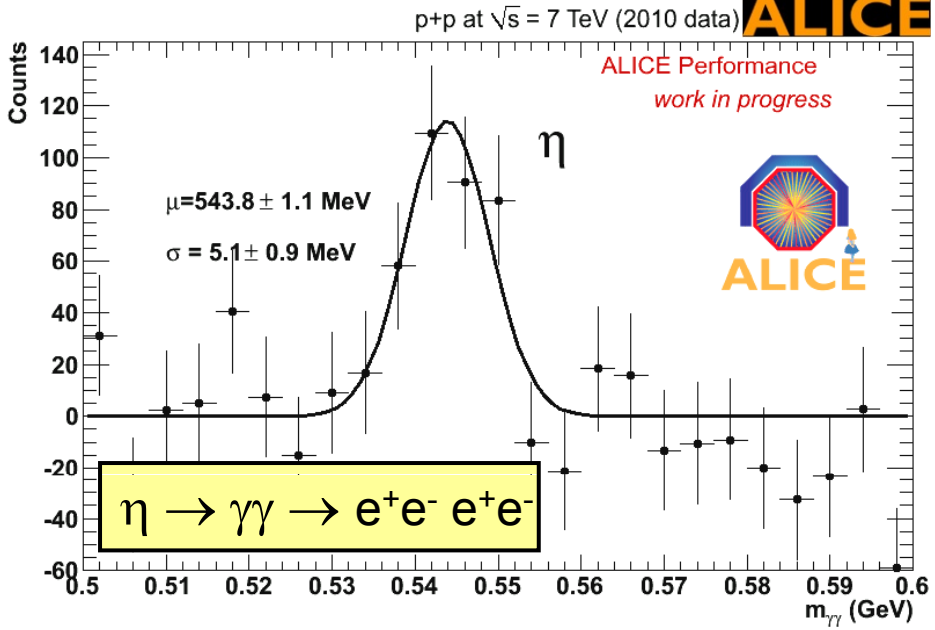
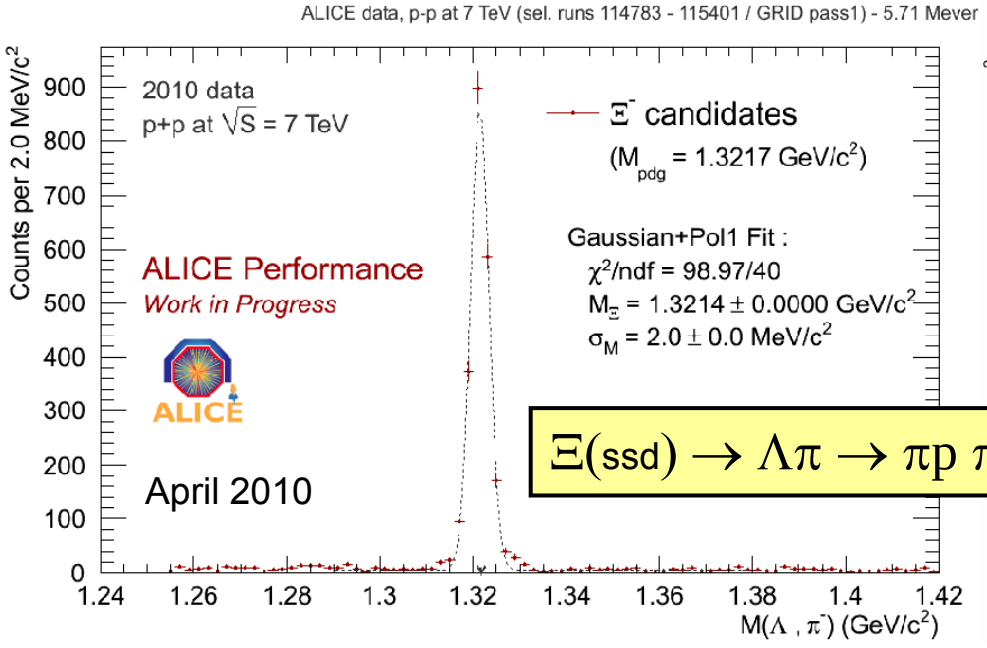
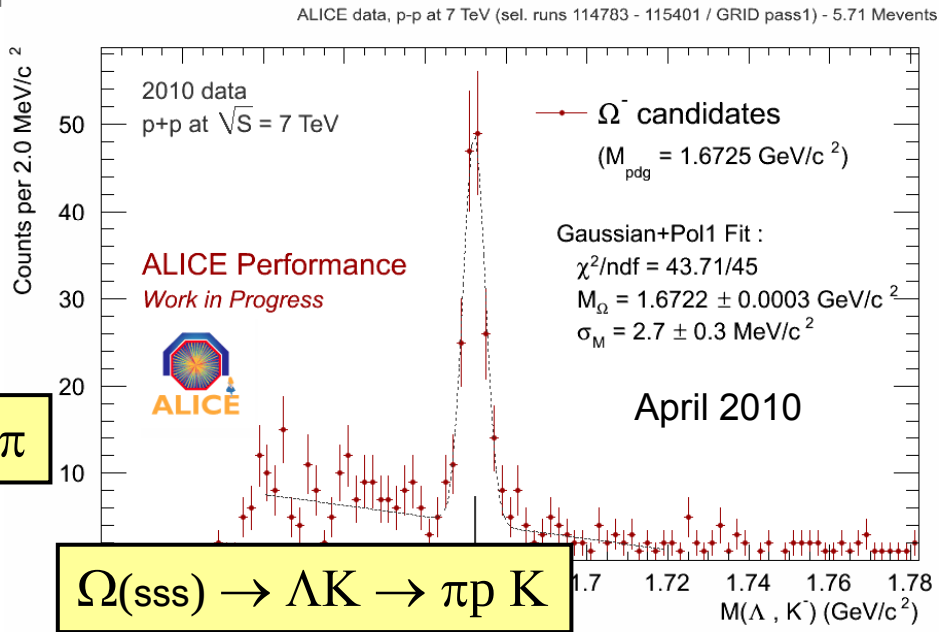
Physics at LHC, Hamburg 2010

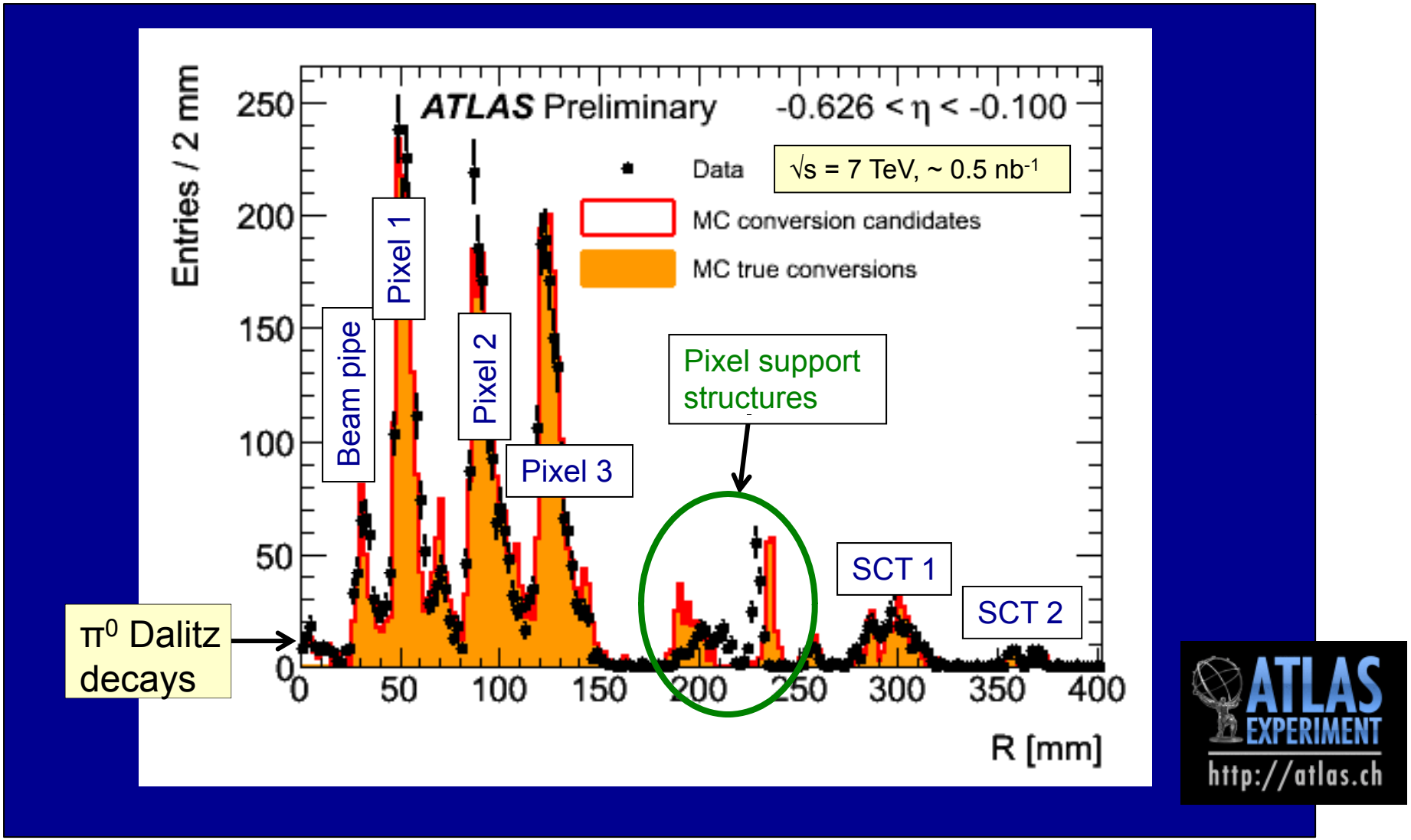
ALICE particle reconstruction





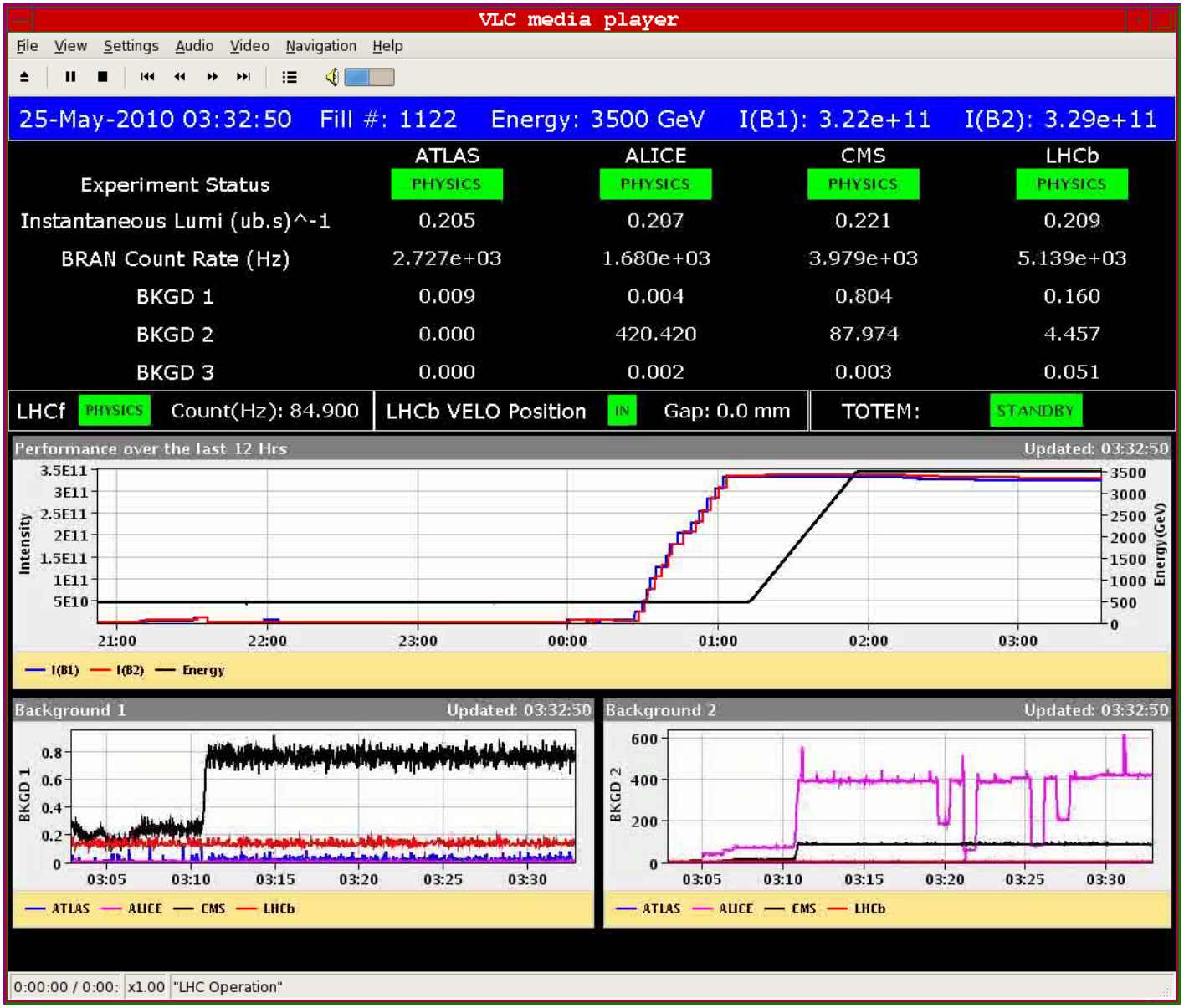


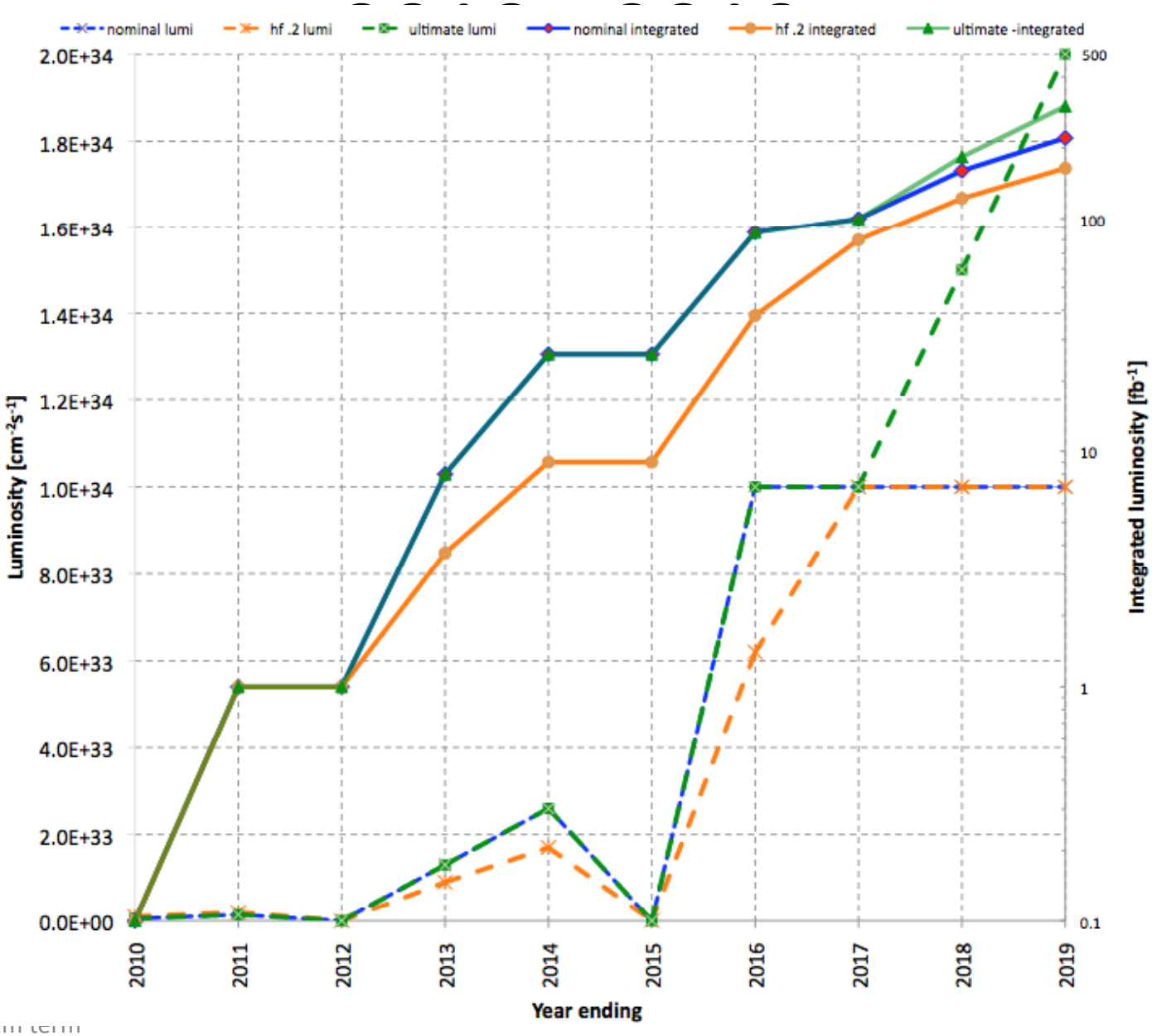




- **Goal is to map ID material to better than 5% (using several methods)**
- **Reconstruction efficiency for Dalitz decays used to constrain beam-pipe thickness (in turn used as reference to estimate material in other layers)**

13 bunches: ~3x10^{29}

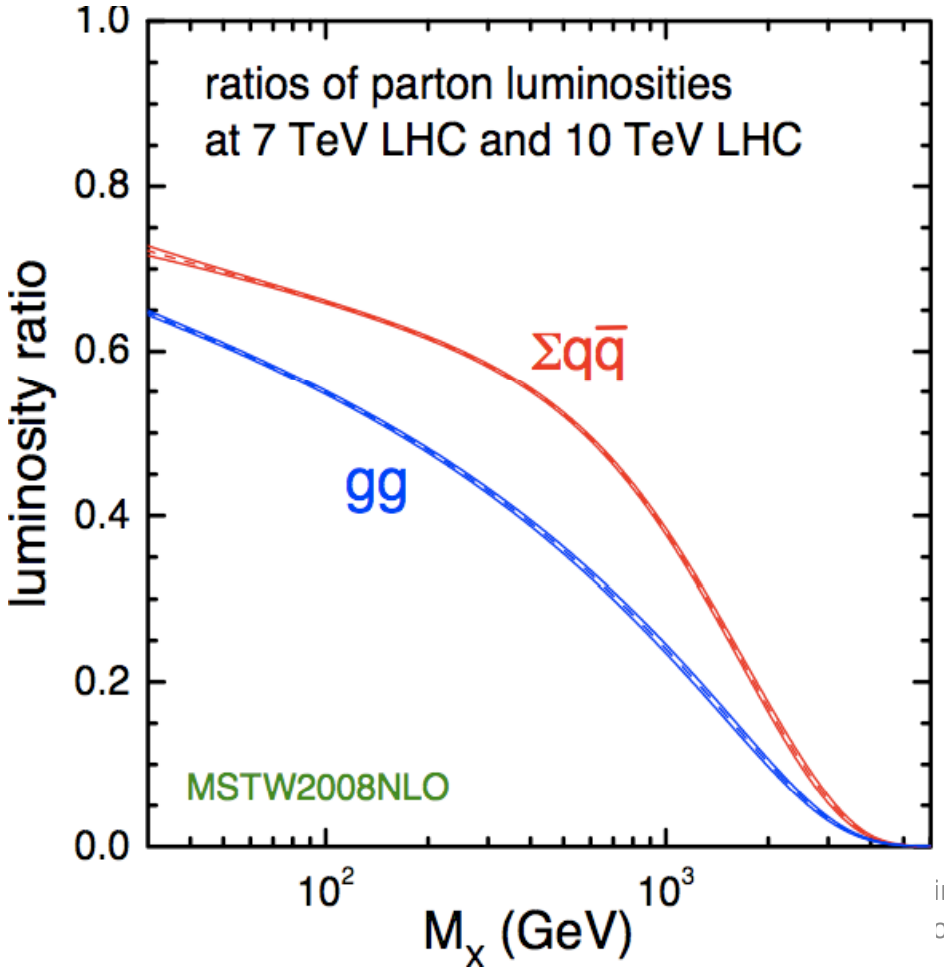


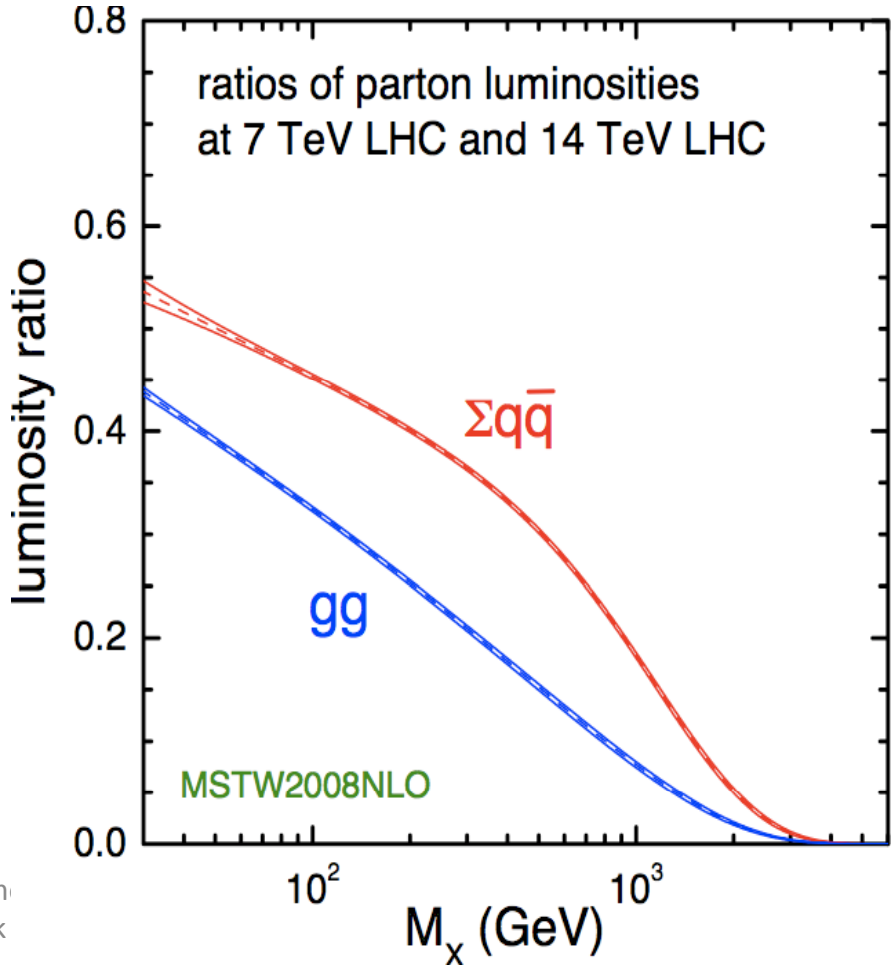

nominal lumi
hf .2 lumi
ultimate lumi
nominal integrated
hf .2 integrated
ultimate -integrated
Luminosity [cm-2s-1]
2.0E+34
1.8E+34
1.6E+34
1.4E+34
1.2E+34
1.0E+34
8.0E+33
6.0E+33
4.0E+33
2.0E+33
0.0E+00
Integrated luminosity [fb-1]
500
100
10
1
0.1
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year ending

Comparing 7 TeV to 10 TeV to 14 TeV...

Ratios of cross-sections at 7/10/14 TeV for processes induced by gg and qq (from James Stirling)

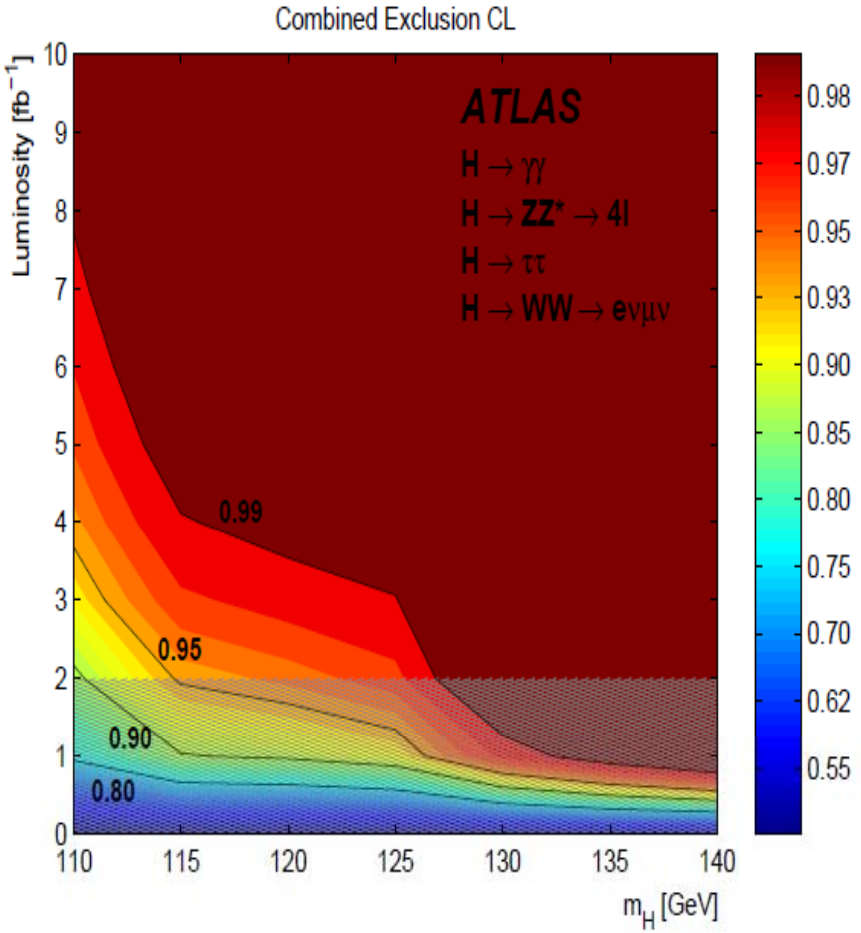
At lower energy it is of course more difficult to produce high mass objects...



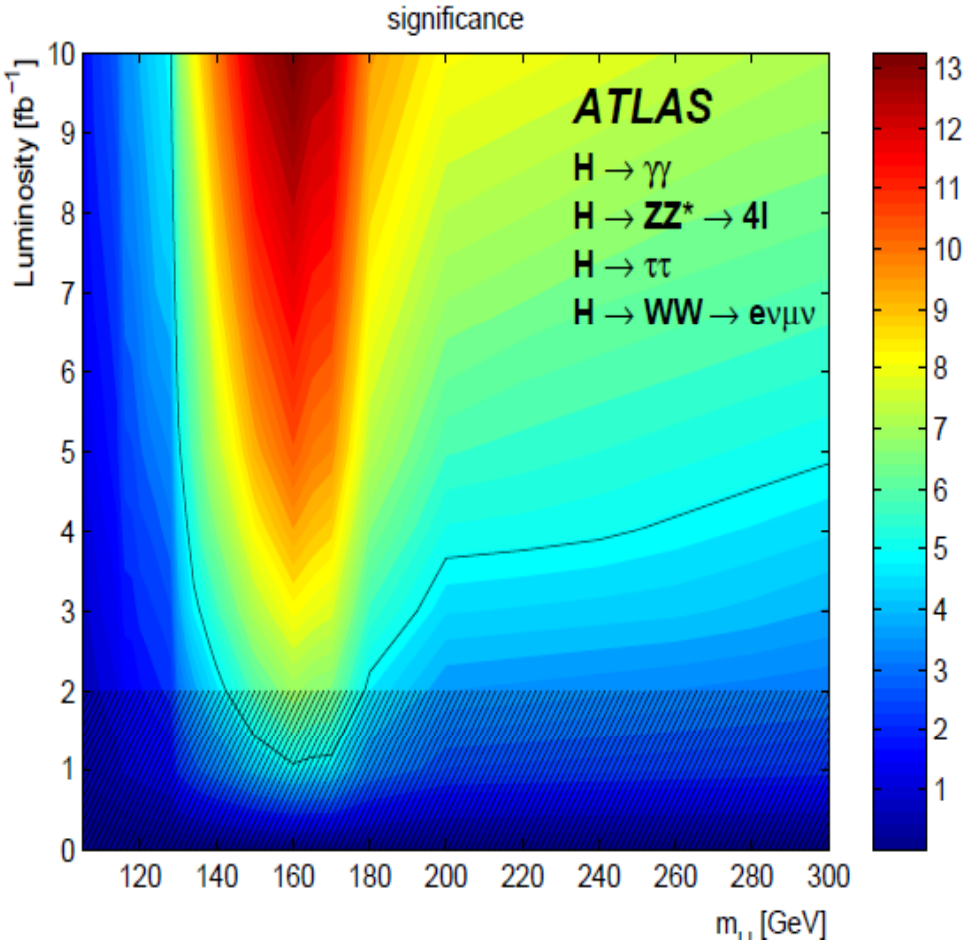


Combining several channels in a single experiment (ATLAS as example, of course CMS very similar)

14 TeV



Exclusion confidence levels

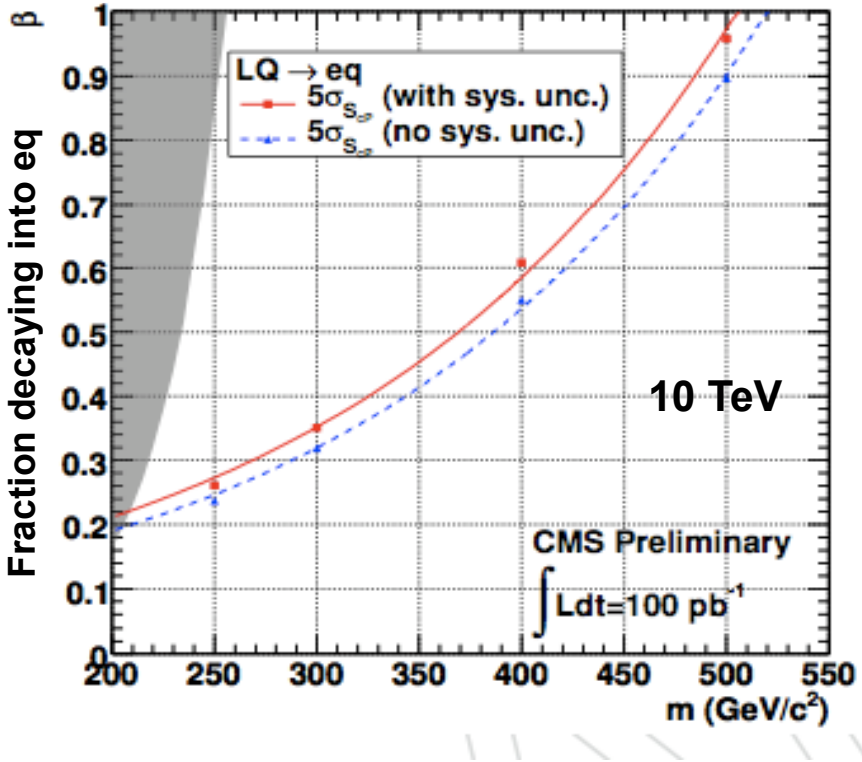


Discovery significance levels in σ

Examples of other searches for new (exotic) physics

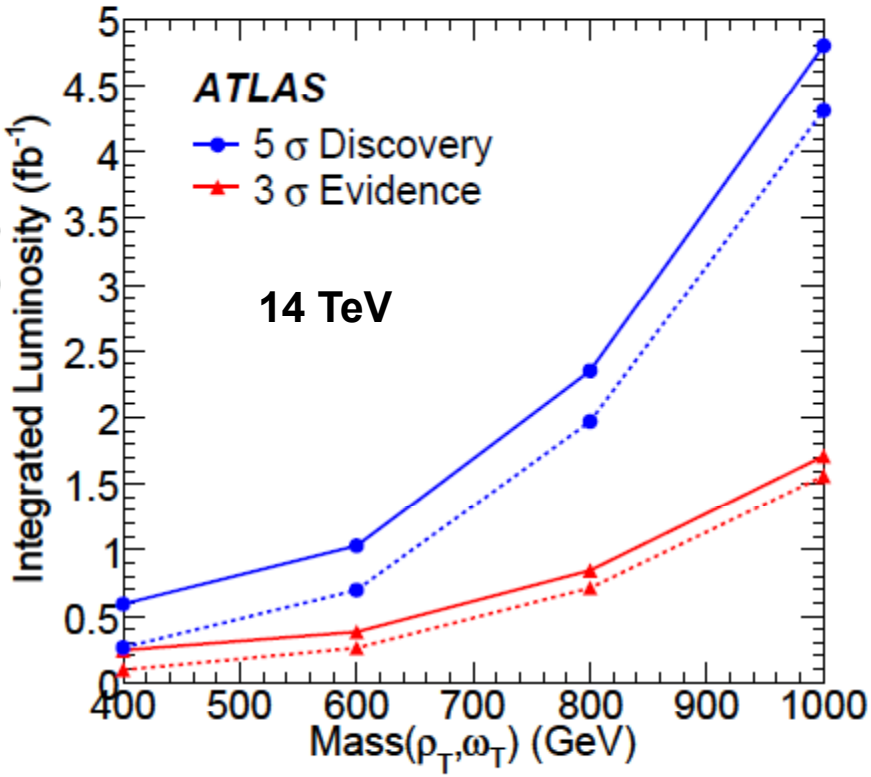
(and there would be many more not mentioned now!)

Lepto-quarks



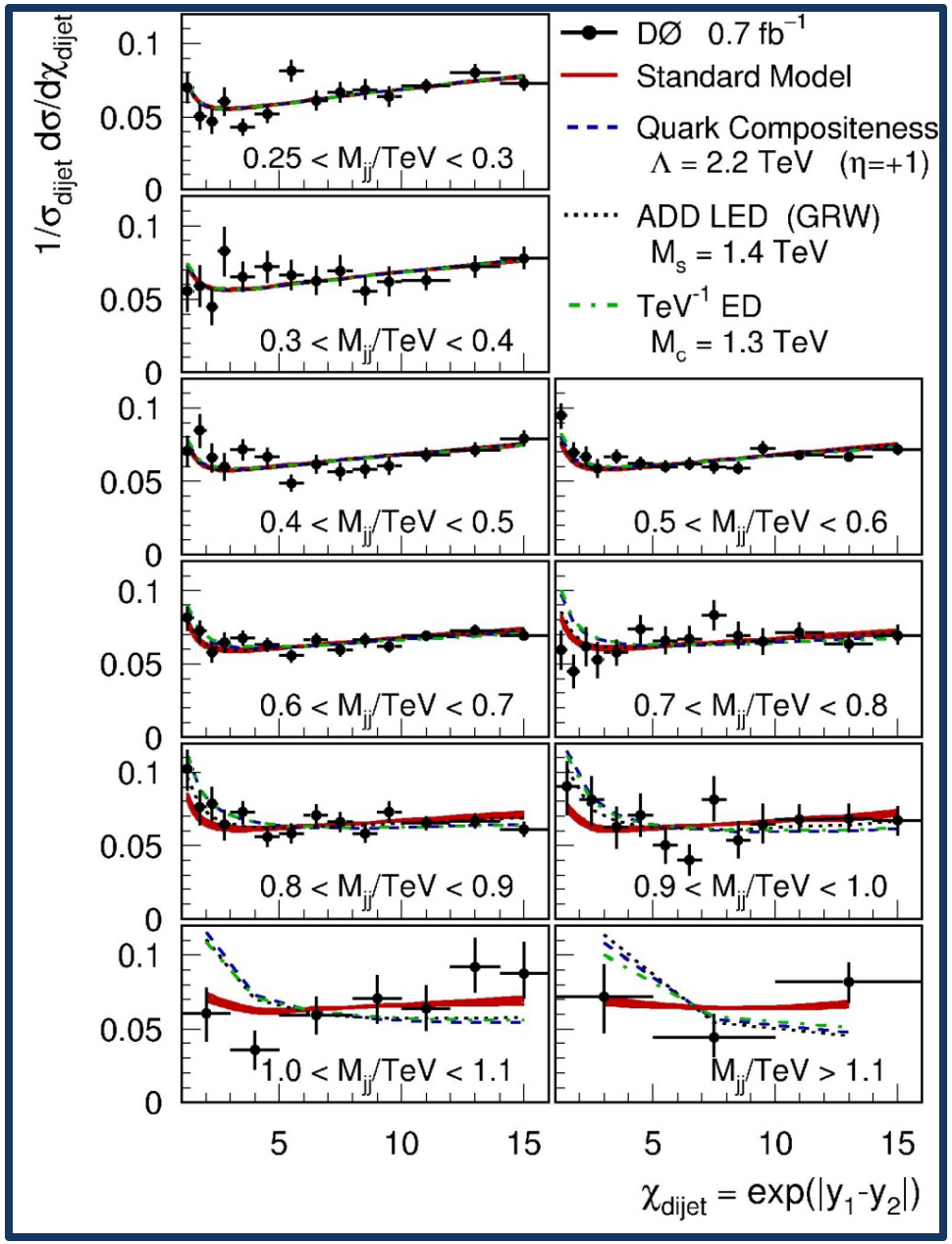
Technicolour resonances

(Models with no Higgs but a new type of force…)



Tevatron limits typically 300 GeV

$\rho_T \to \mu^+\mu^-$ and $\omega_T \to \mu^+\mu^-$


DØ 0.7 fb^{-1}
Standard Model
Quark Compositeness
Λ = 2.2 TeV (η=+1)
ADD LED (GRW)
M$_s$ = 1.4 TeV
TeV^{-1} ED
M$_c$ = 1.3 TeV
1/σ$_{dijet}$ dσ/dχ$_{dijet}$
0.25 < M$_{jj}$/TeV < 0.3
0.3 < M$_{jj}$/TeV < 0.4
0.4 < M$_{jj}$/TeV < 0.5
0.5 < M$_{jj}$/TeV < 0.6
0.6 < M$_{jj}$/TeV < 0.7
0.7 < M$_{jj}$/TeV < 0.8
0.8 < M$_{jj}$/TeV < 0.9
0.9 < M$_{jj}$/TeV < 1.0
1.0 < M$_{jj}$/TeV < 1.1
M$_{jj}$/TeV > 1.1
χ$_{dijet}$ = exp(|y$_1$-y$_2$|)