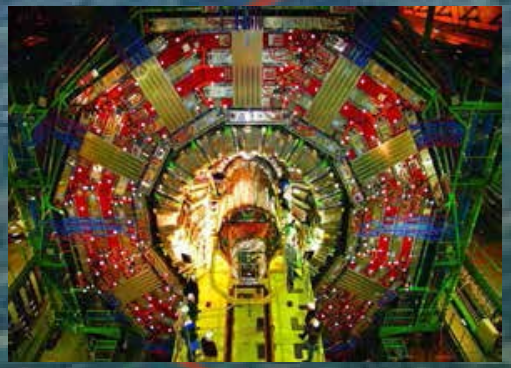
LHC: Datataking and Results at 13 TeV

KET Komitee für Elementarteilchenphysik

KET Jahrestagung, Bad Honnef, 21.11.2015

Thomas Müller, KIT

LHCb



CMS

ALICE

ATLAS

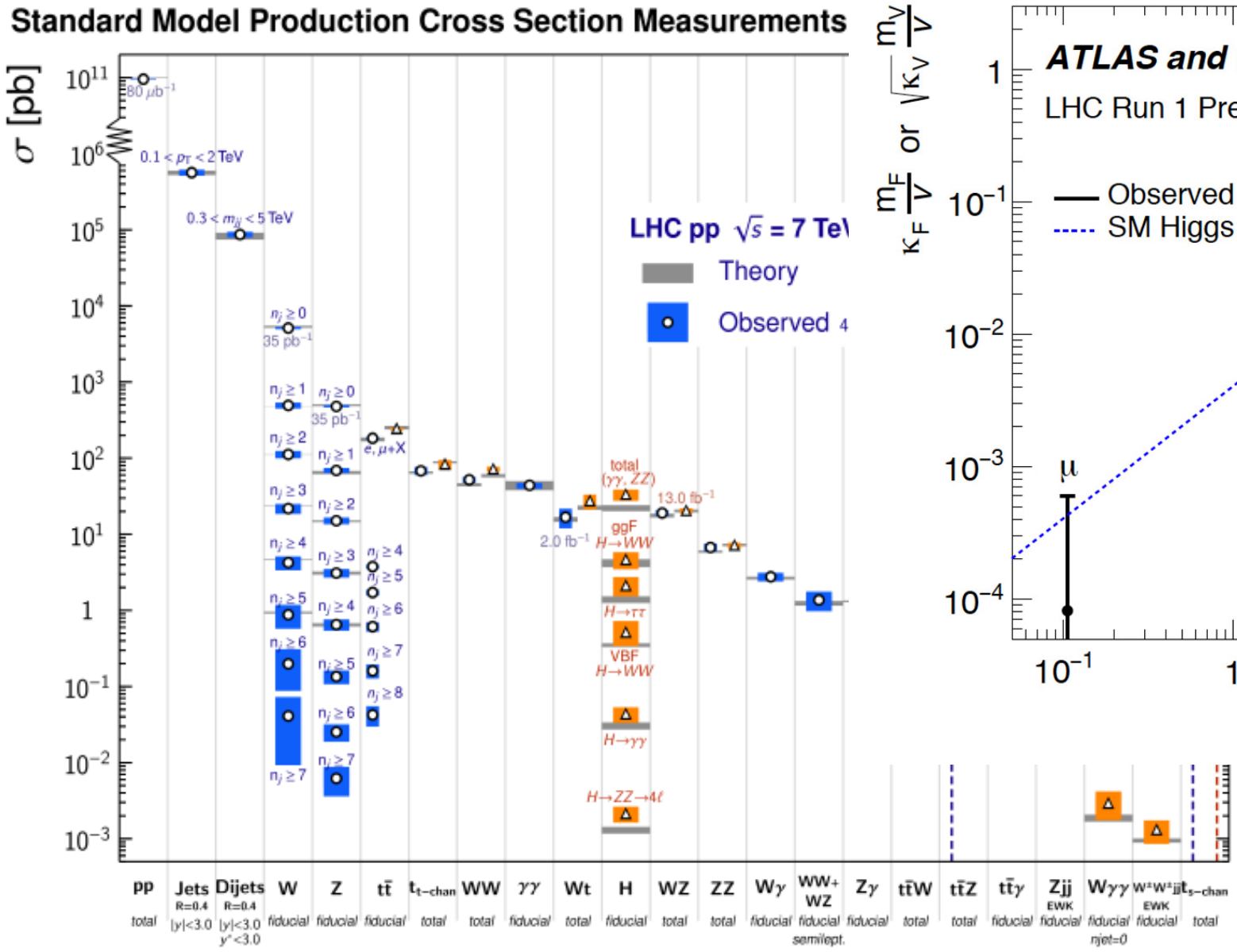
References

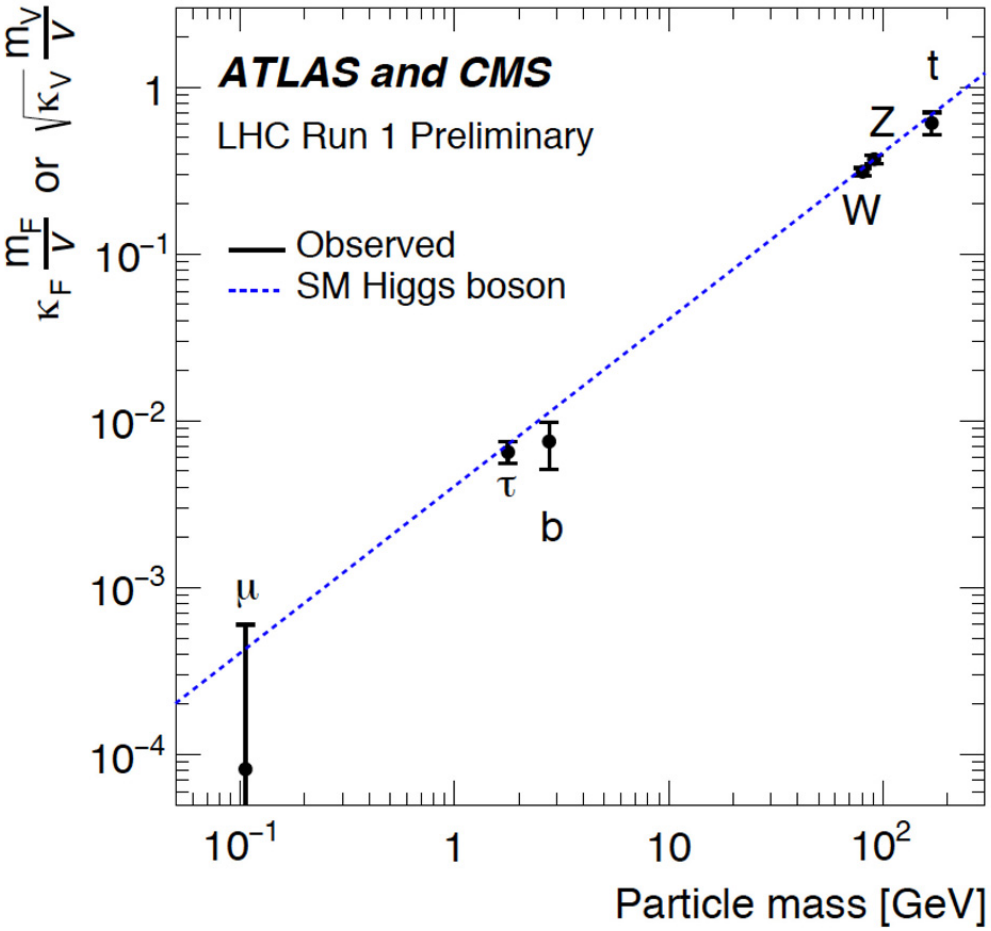
Transparencies were extracted from the presentations at the

- XXXV Physics in Collisions Warwick, Sep. 2015
  https://indico.cern.ch/event/374792/
- RRB meeting CERN, Oct. 2015
  https://indico.cern.ch/event/407749/
- 9th Annual Meeting of the Helmholtz Alliance „Physics at the Terascale“
  DESY, Nov. 2015
  https://indico.desy.de/conferenceDisplay.py?confId=12812

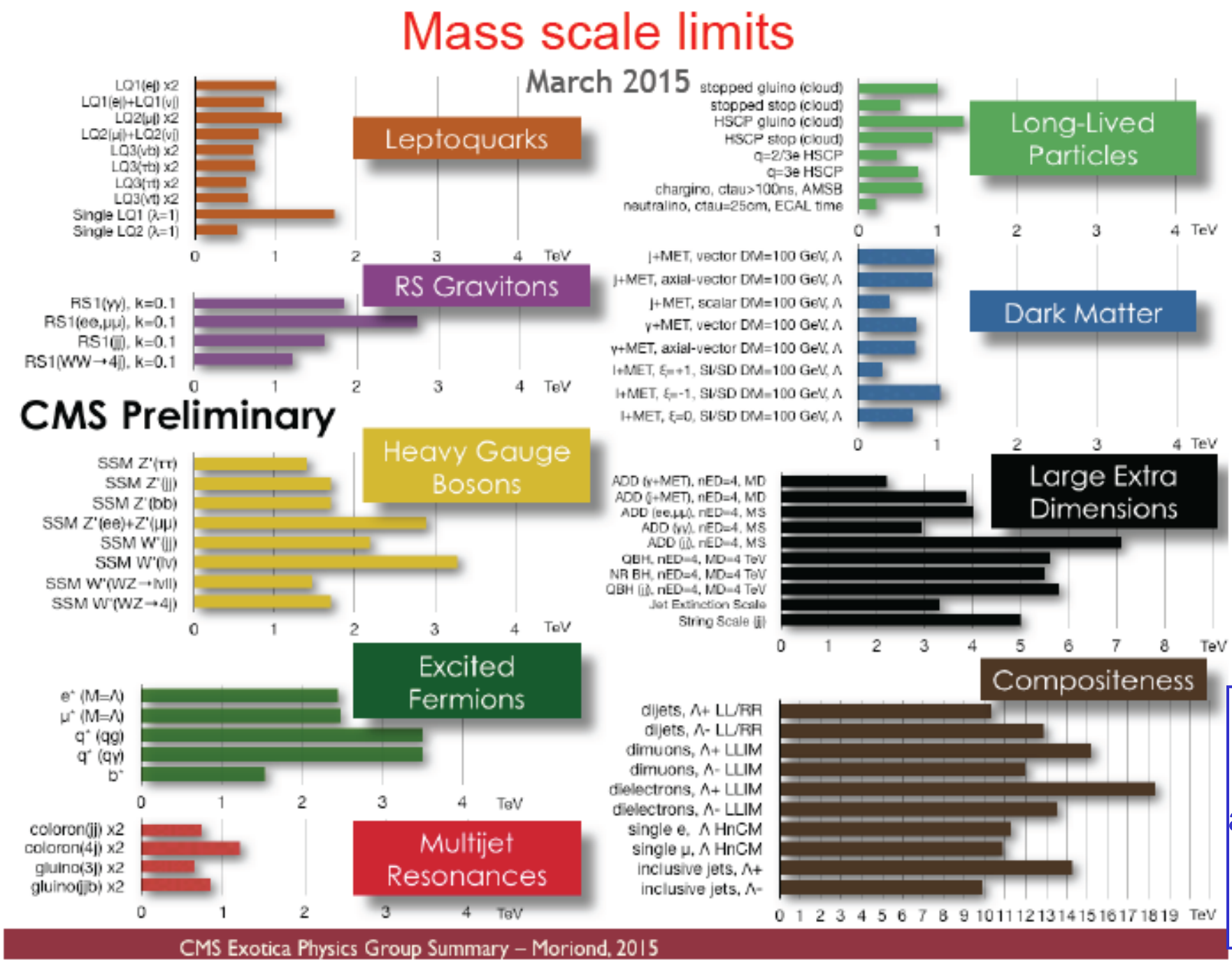
1. Legacy from Run I

Confirmation of the Standard Model



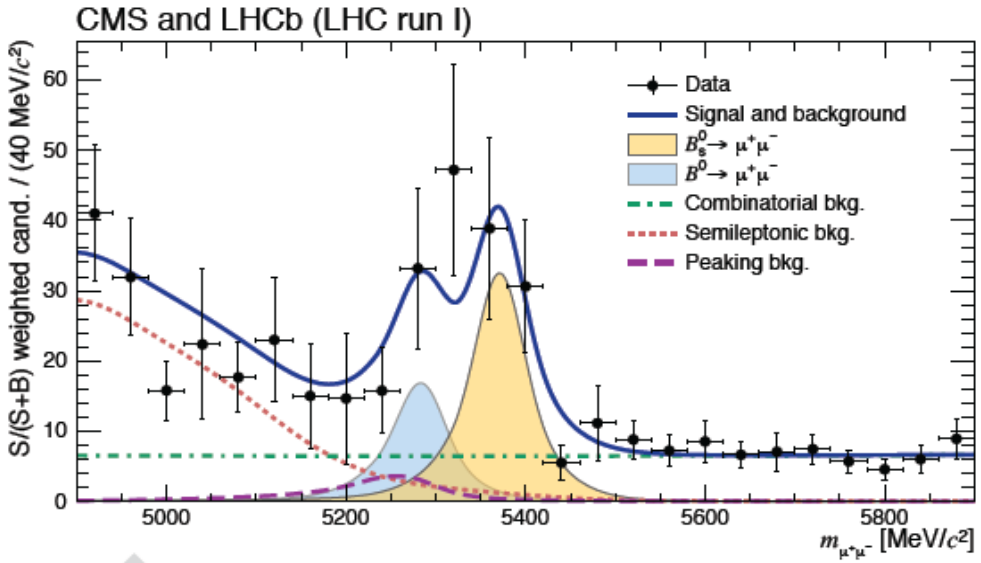


Direct searches yield only limits so far..



We have crossed the TeV scale almost everywhere. But: only in strong processes !

Precision measurements in the flavor sector…

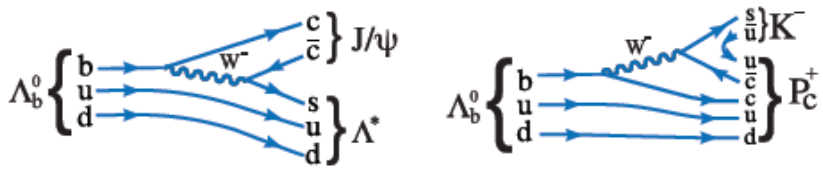


CMS & LHCb: observation of $B_s \to \mu\mu$

[Nat. 522 (2015) 68]

Observation of new states consistent with pentaquarks

[PRL 115, 072001 (2015)]

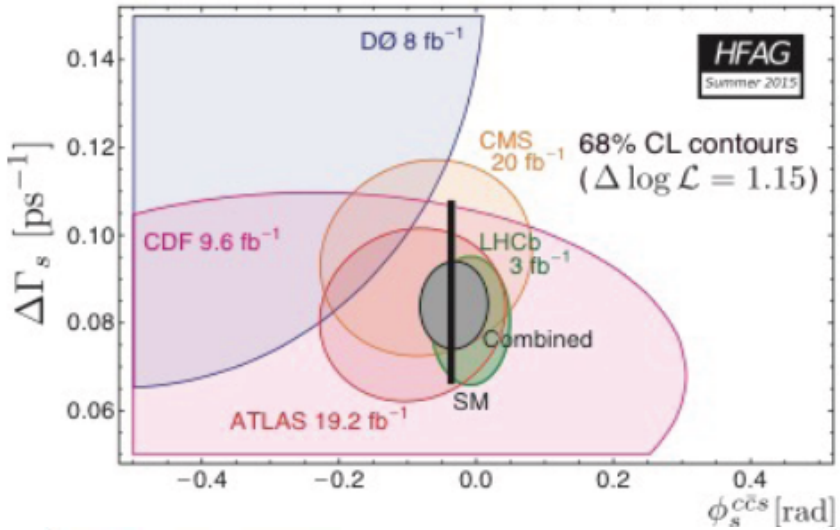



or

or … ?

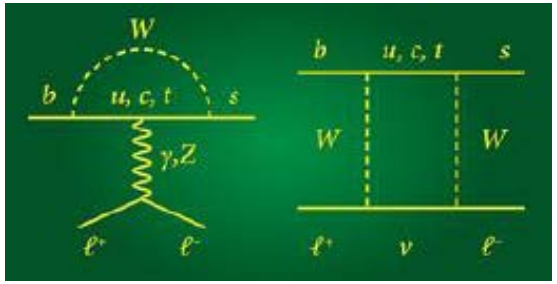
Precision measurement of ϕ_s

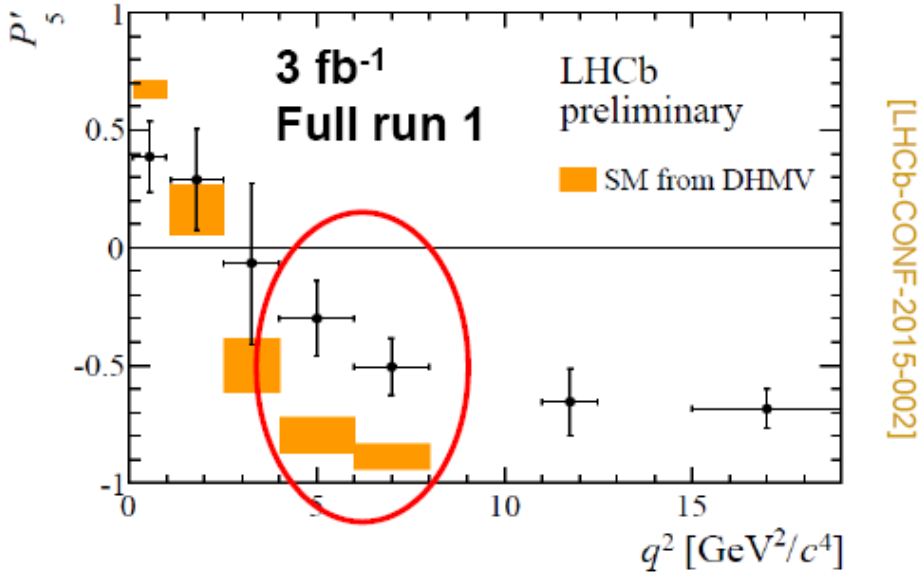
[PRL 114, 041801 (2015)]



… and some tensions

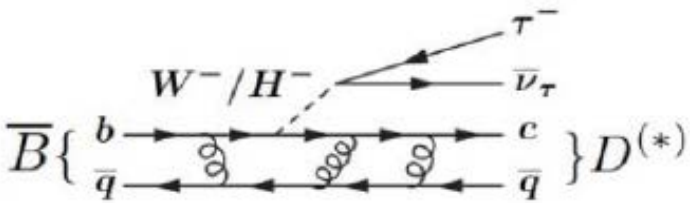
Intriguing hints from $b \to s l^+ l^-$



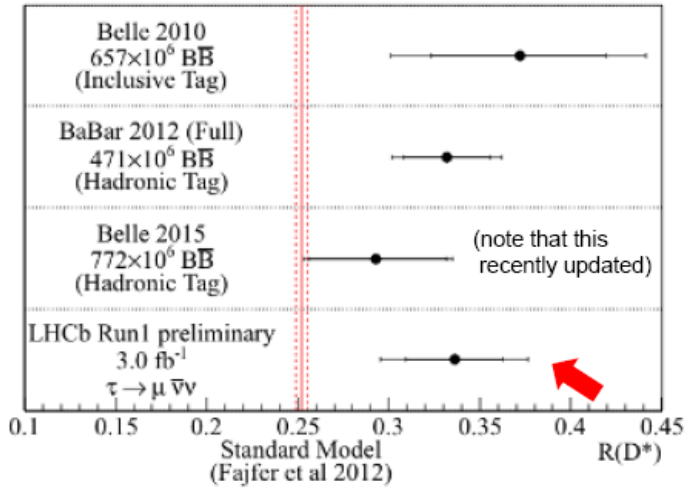


Testing lepton universality in $R(D^*) \equiv \mathrm{BR}(B \to D^* \tau \nu)/\mathrm{BR}(B \to D^* \mu \nu)$

$B \to D^* \tau \nu$ is an important channel to study as it has sensitivity to *e.g.* charged Higgs sector. For normalisation purposes measure branching fraction relative to $B \to D^* \mu \nu$.



LHCb confirms trend of *B*-factory measurements:



R(D)* & *R(D)* results together have 3.9σ tension w.r.t SM.

2. Searching for new Answers at 13 TeV !

Superconducting Magnets and Circuits Consolidation (SMACC)

Monumental effort

- Over 350 persons involved
- Including preparation: ~1,000,000 working hours
- No serious accidents!

Jean-Philippe Tock

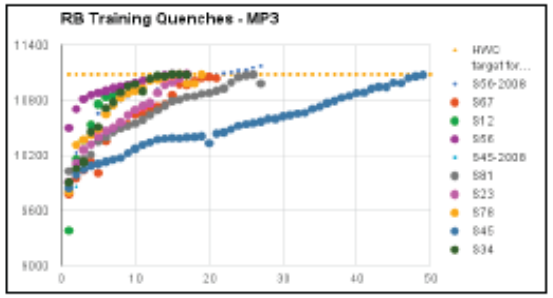
Collaborations with NTUA (Athens), WUT (Wroclaw) and support of DUBNA

SMACC project : Closure of the last interconnection – 18.06.2014
Activity led by A Musso (TE-MSC)

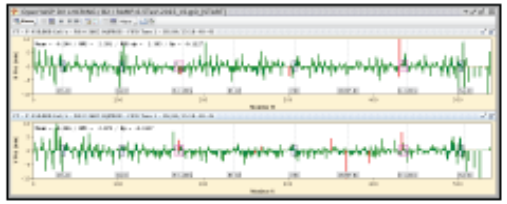
2015 LHC operation at a glance

From: Matteo Solfaroli, LHCC open session, Sep 23, 2015

3rd Apr Completion of PT campaign



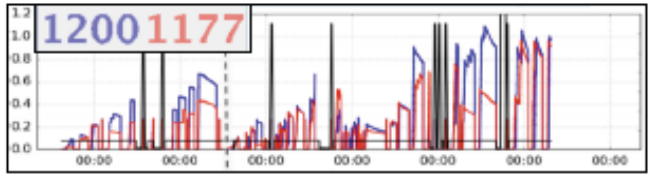
5th Apr First circulating beam



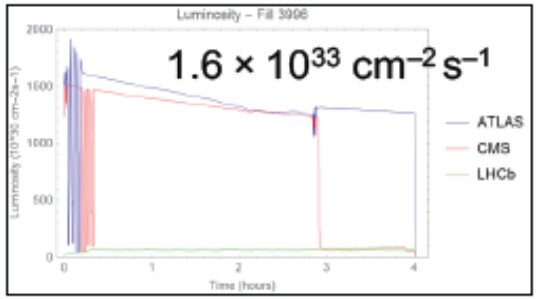
10th Apr 6.5 TeV for the first time (ever!)

3rd June First STABLE BEAMS!

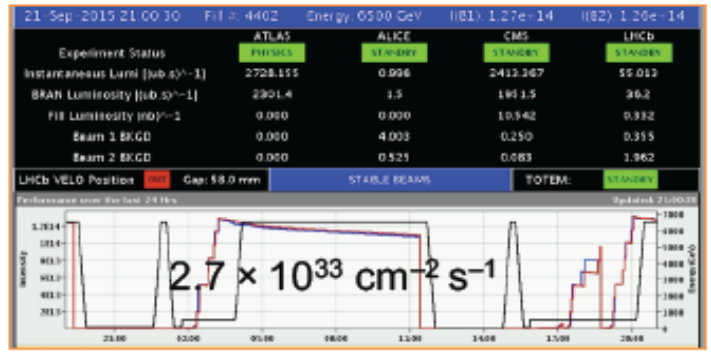
30th June end of scrubbing for 50 ns



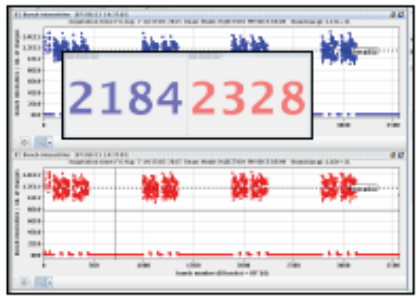
14th July 476b (50 ns)



21st Sep 25 ns STABLE BEAMS with 1177 bunches/beam



7th Aug end scrubbing for 25 ns



TS-1 | MD-1 | MD-2 + TS-2

April | June | July | August | September

Intense beam commissioning phase

Since then, Oct/Nov:

- 2232 colliding bunches in ATLAS/CMS
- L_{max} of 5.2 · 10^{33}
- Nov 4: MD/TS-3
- Nov 20: Ions

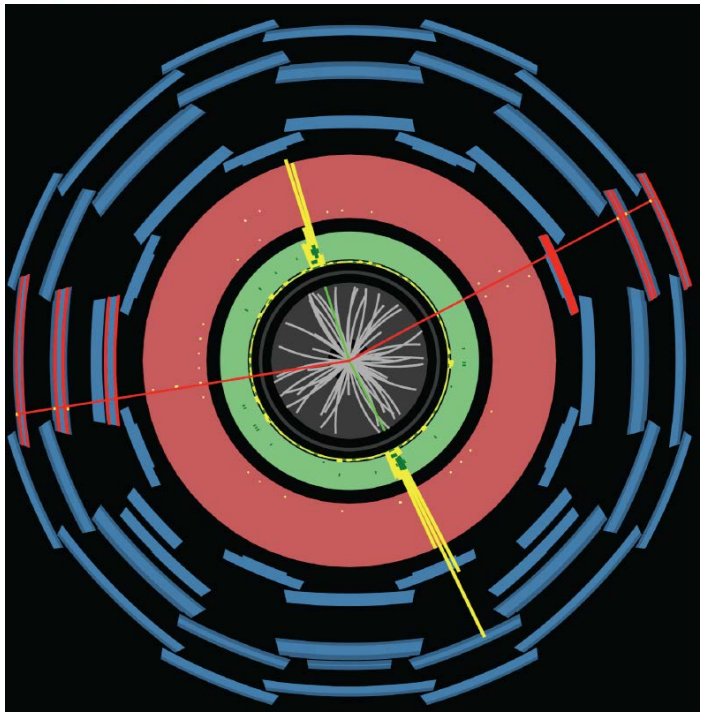
Start 2016 in production mode

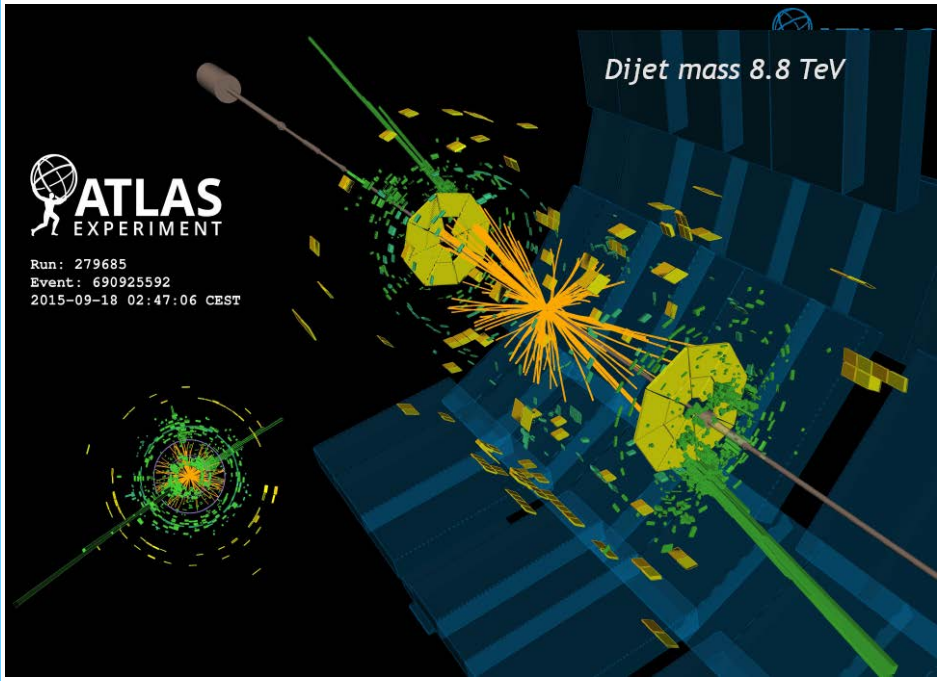
- 6.5 TeV, machine scrubbed for 25 ns operation (doublet beam)
- β^* = 40 cm in ATLAS and CMS
- Rapid intensity ramp up should be possible
- With the beam of today (1825) will reach $1x10^{+34}$ cm^{-2} s^{-1}
- Hope to push this further in 2016 to ~$1.2x10^{+34}$.
- Later, with a full machine and higher I_b, can reach >$1.5x10^{+34}$
- Reasonable availability assumed – usual caveats apply

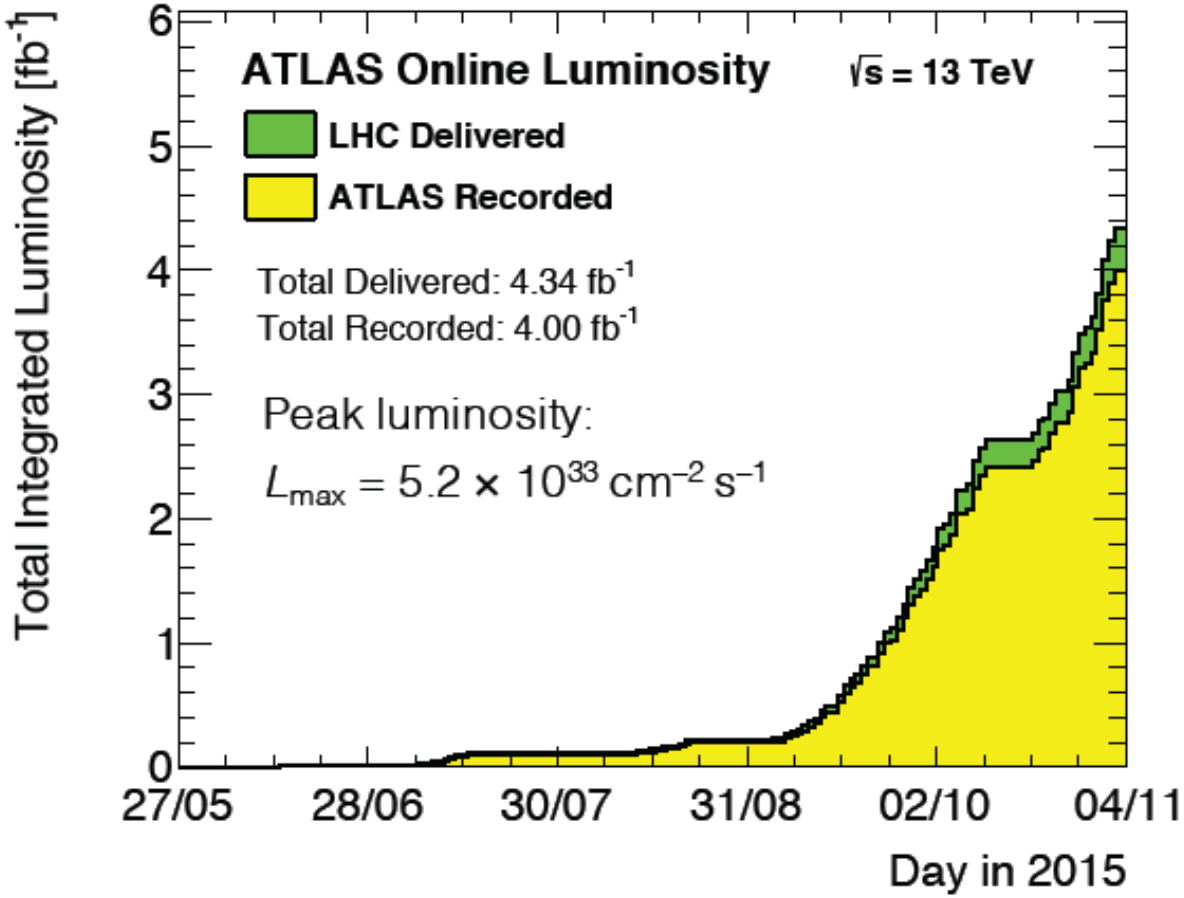
	Peak lumi $x10^{34}$ $cm^{-2}s^{-1}$	Days proton physics	Approx. int lumi [fb^{-1}]
2015	~0.5	65	4
2016	1.2	160	30
2017	1.5	160	36
2018	1.5	160	36

3. First 13 TeV Results

3.1 New results from ATLAS



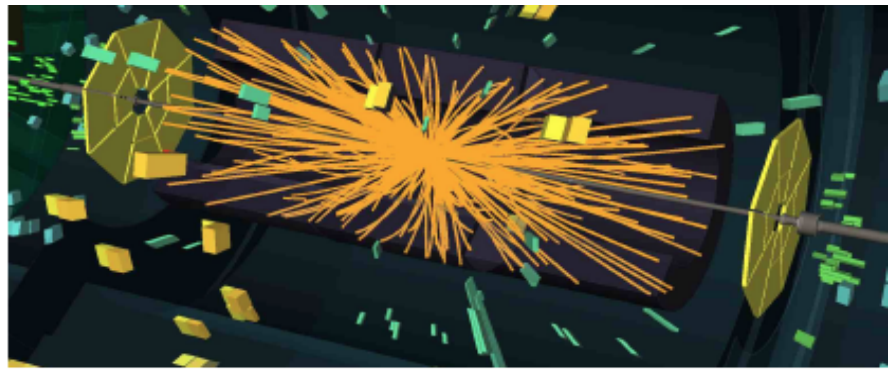




ATLAS restart in 2015, so far

- high data-taking efficiency (92%)
- good data-quality efficiency (85-95%, analysis dependent)
- efficient software & computing (few days from detector to analysis data sample)

Inelastic Cross-Section

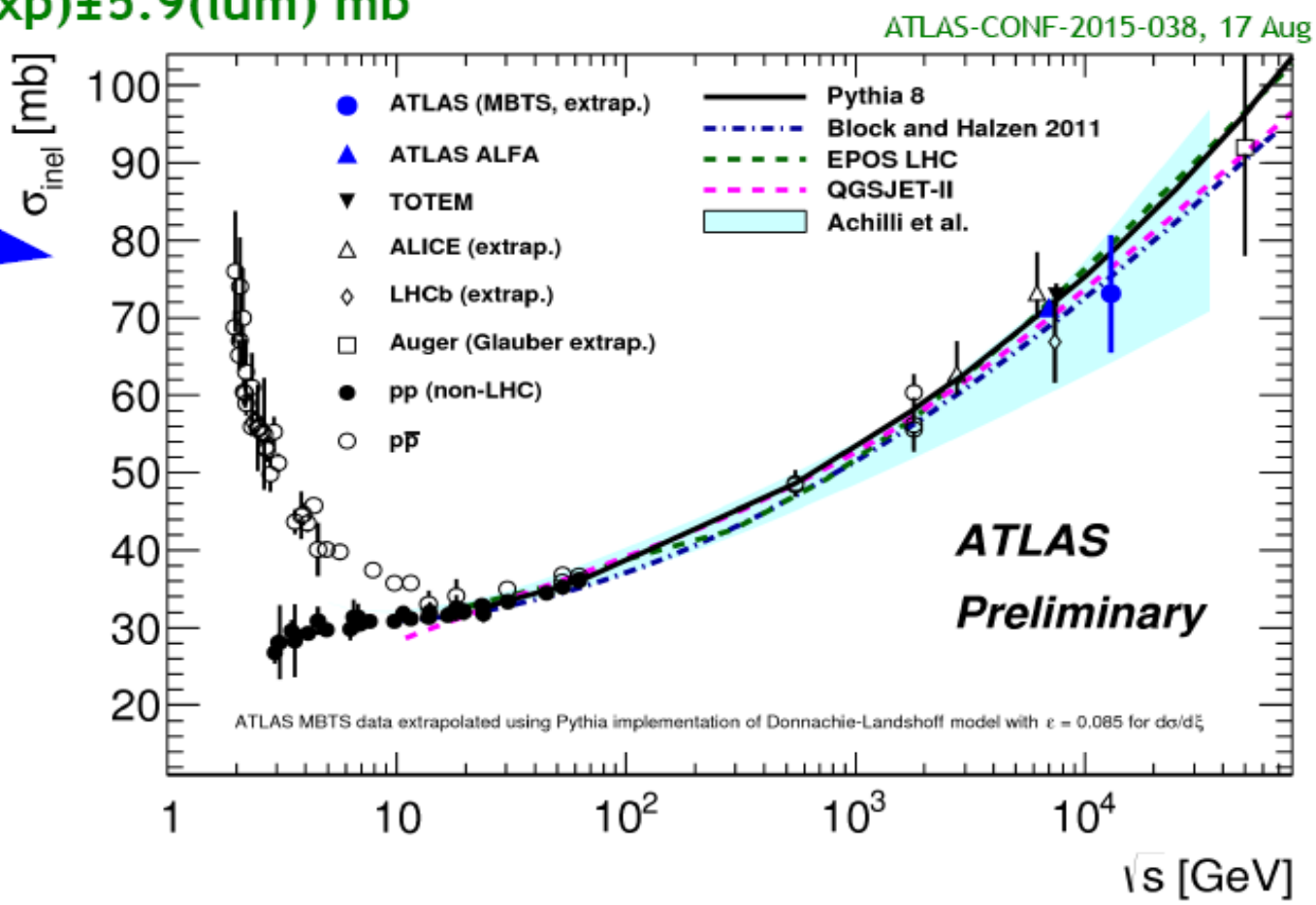


- June low-pileup data
- MBTS (2.1<|η|<3.9): new scintillators
- Error dominated by luminosity

Fiducial cross-section

σ_{inel}(fid)=65.2±0.8(exp)±5.9(lum) mb

Extrapolate to full acceptance

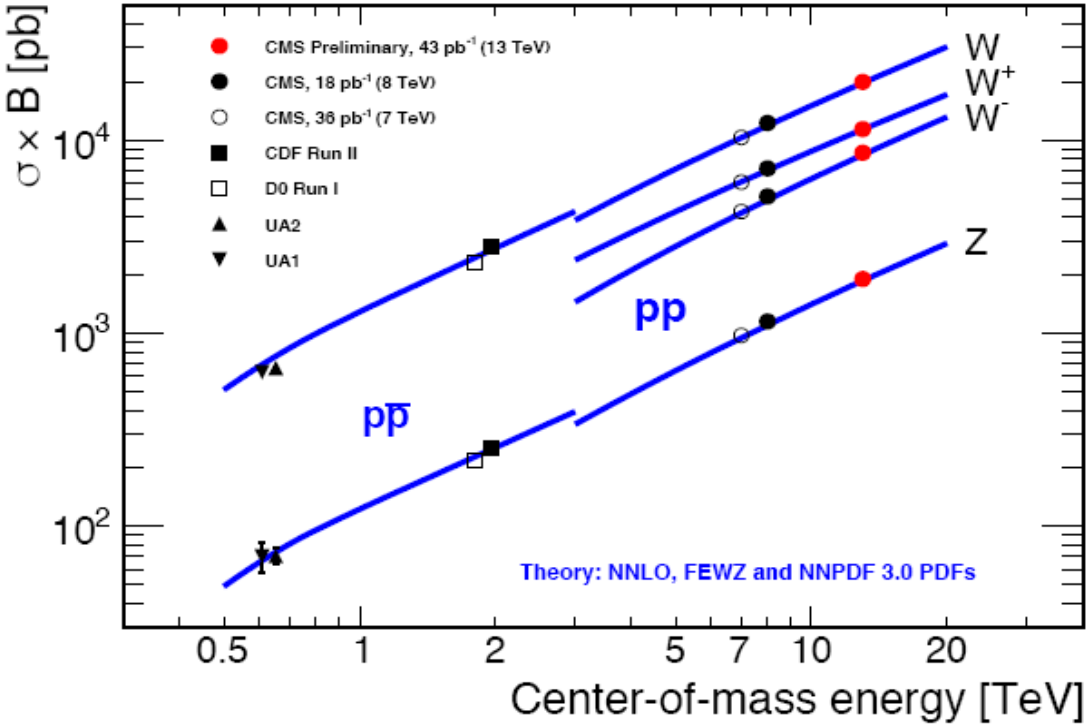


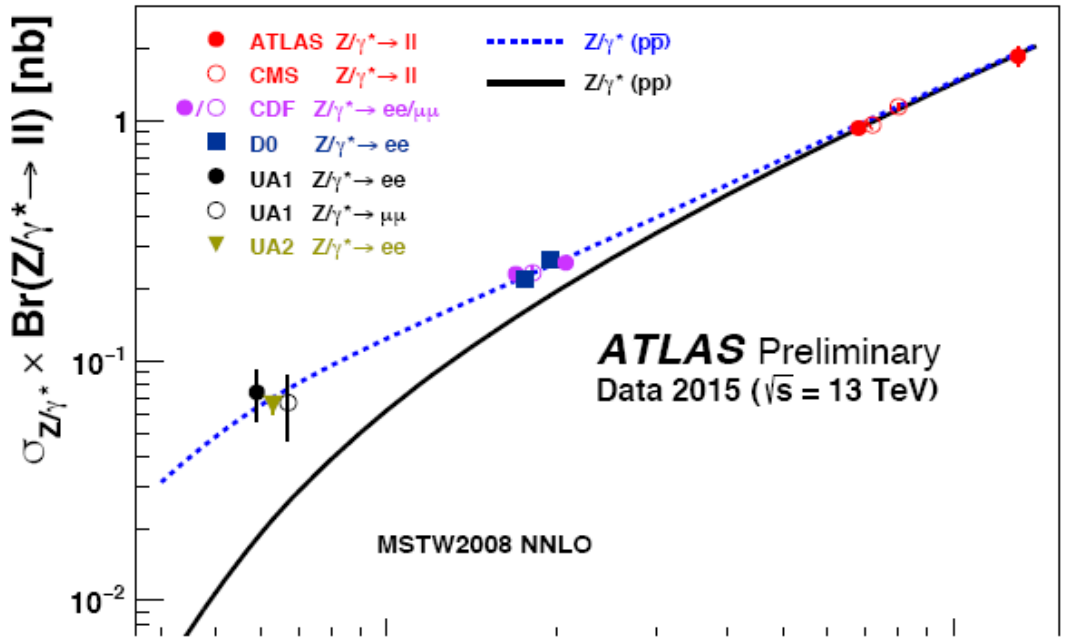
W/Z Boson Cross-Sections

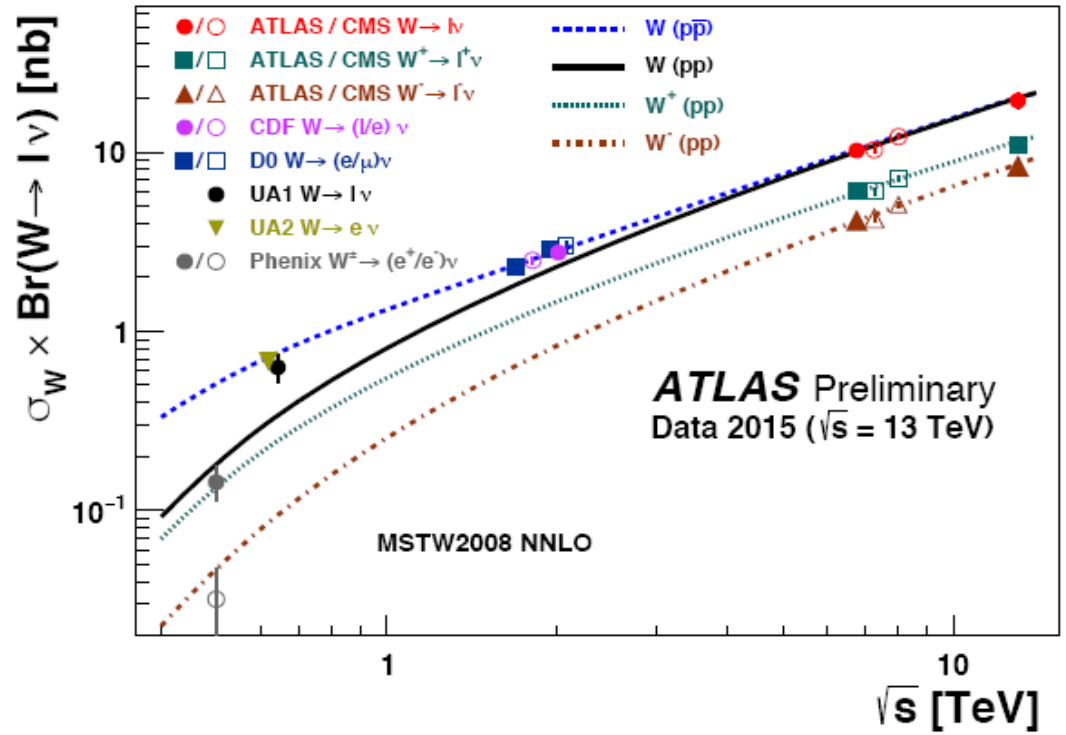
Cross-section measurements

Comparison of measured cross-sections with NNLO QCD & NLO EW predictions (FEWZ 3.1)

Good agreement found within uncertainties, also with lepton universality

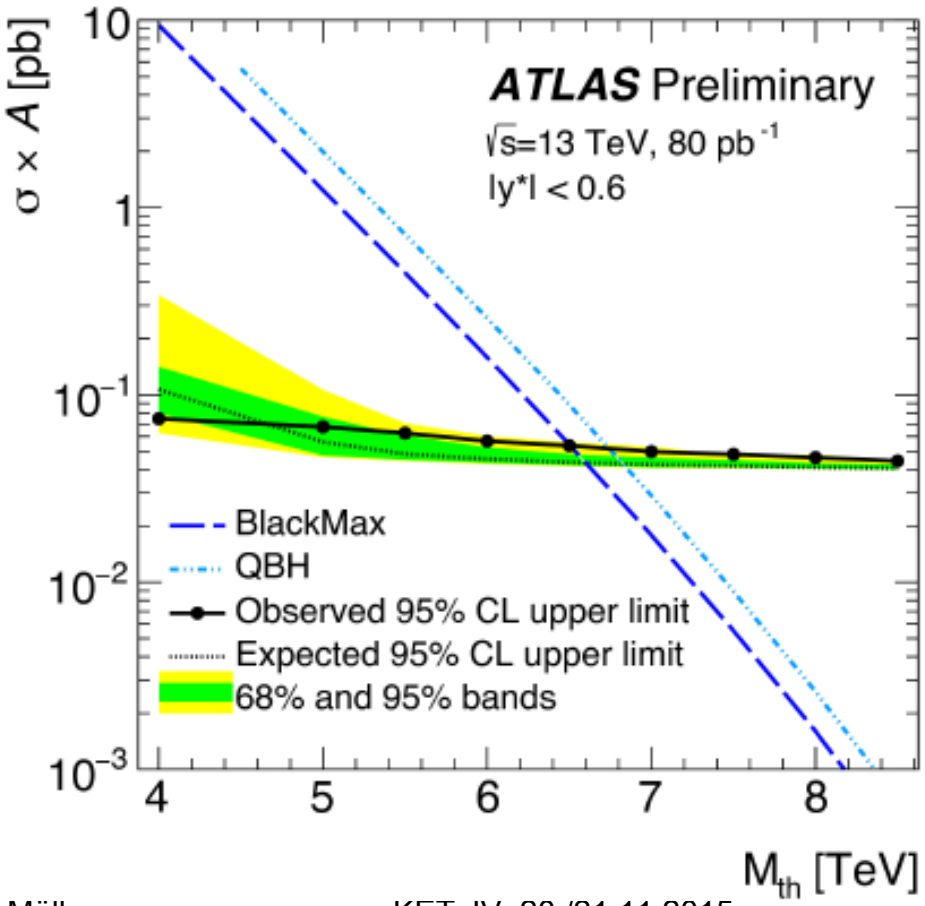


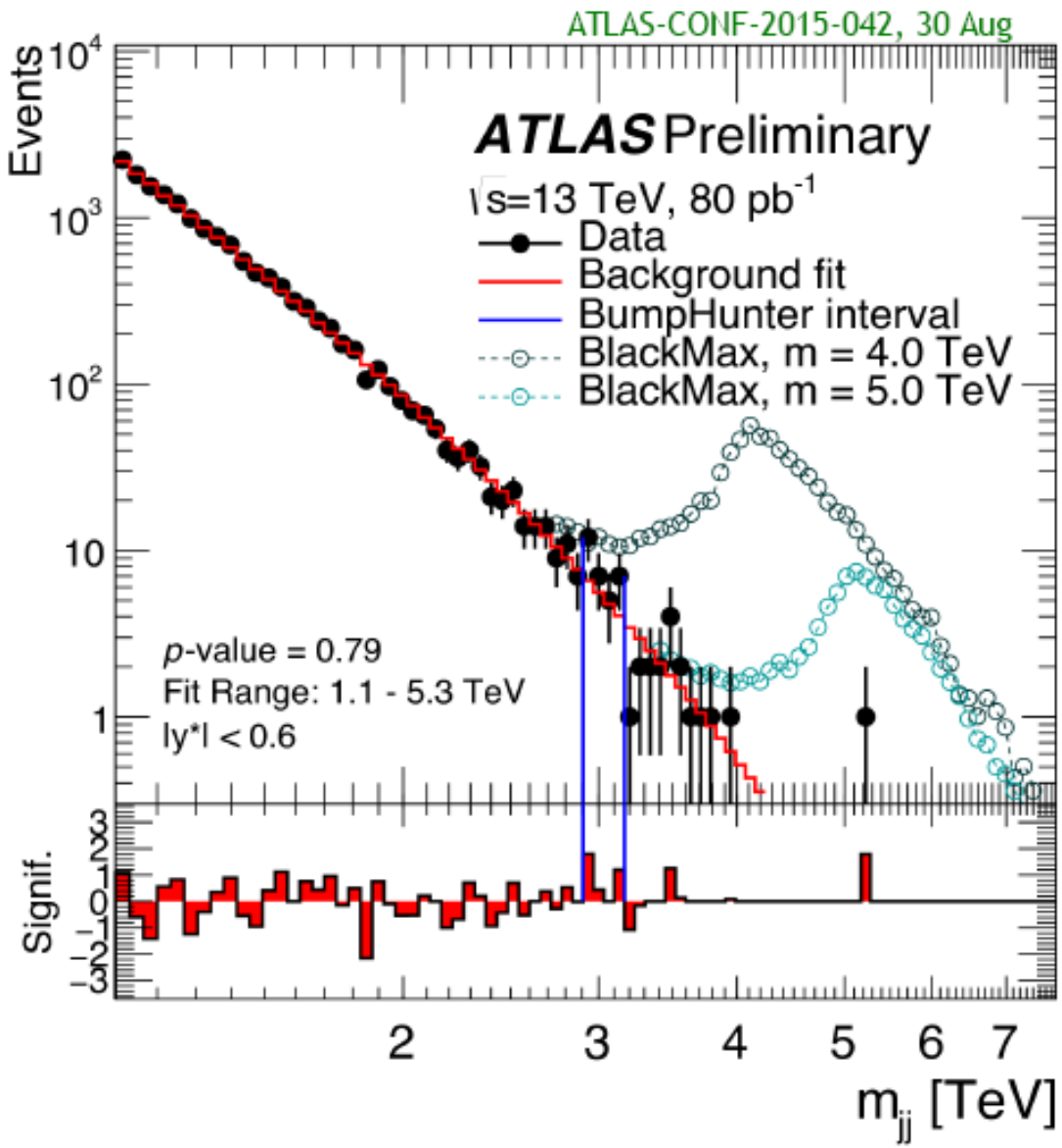




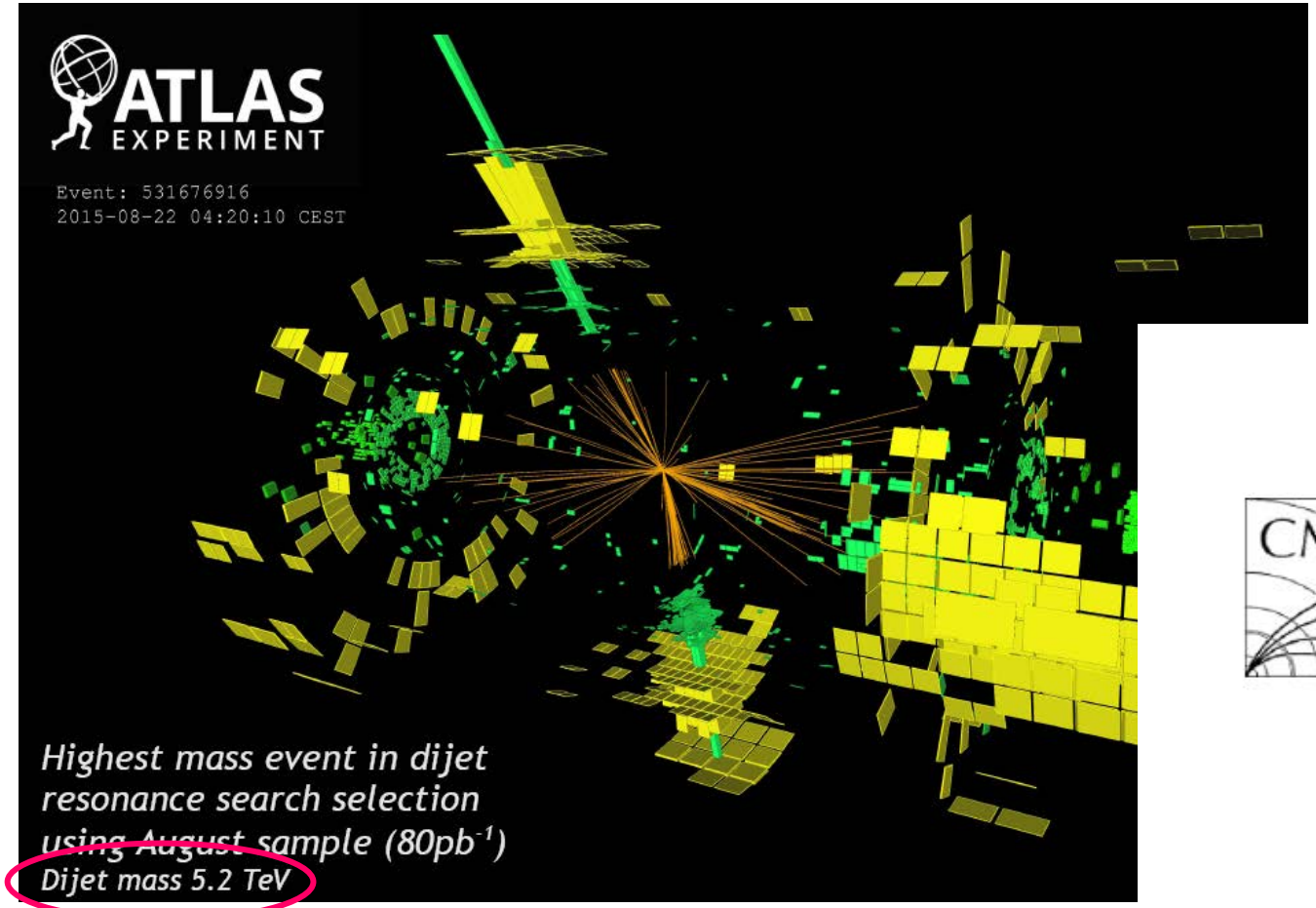
Going for multi-TeV

Di-jet **resonance** search in m(jj) (August data)

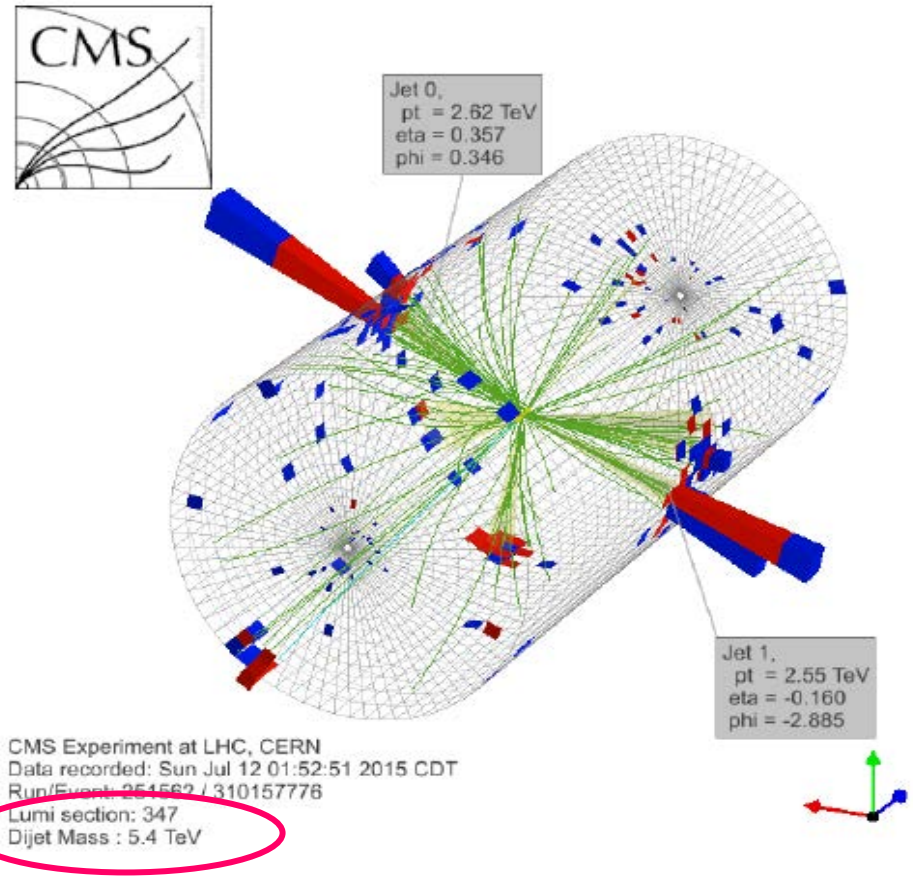




Sensitivity *beyond Run-1* in strong gravity models (very high $\hat{\sigma}$)

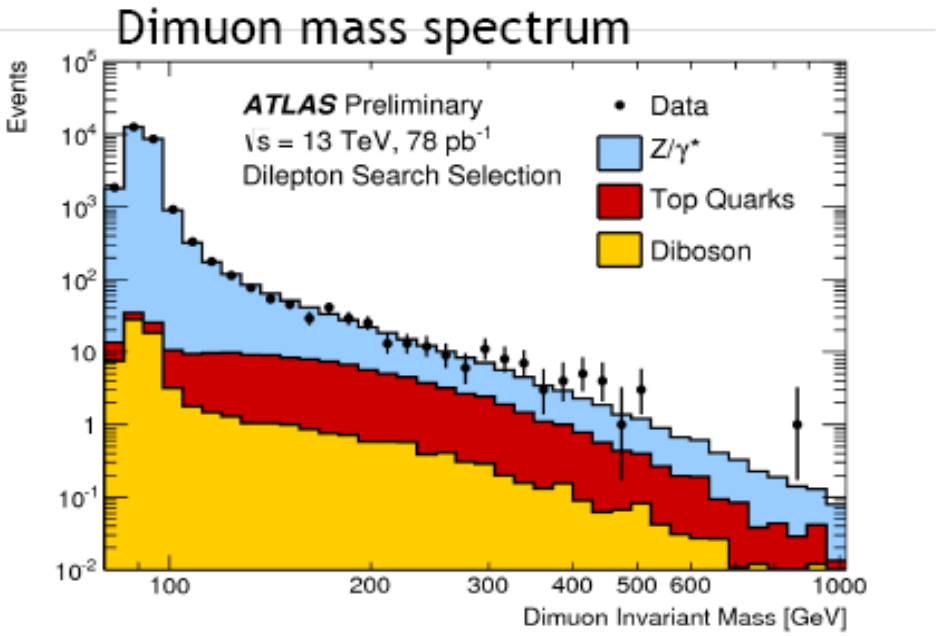


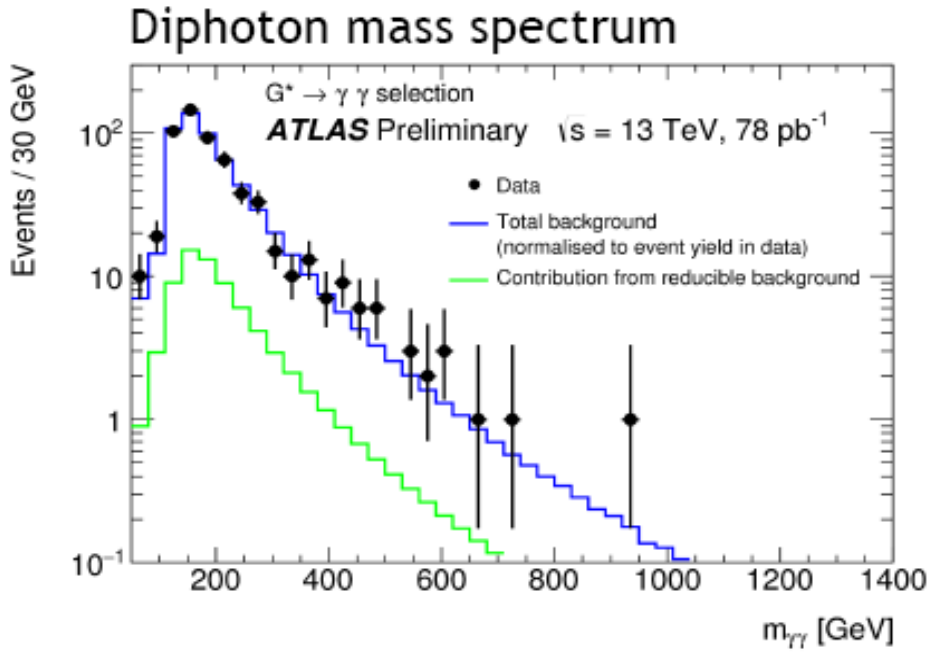
CMS PAS EXO-15-001

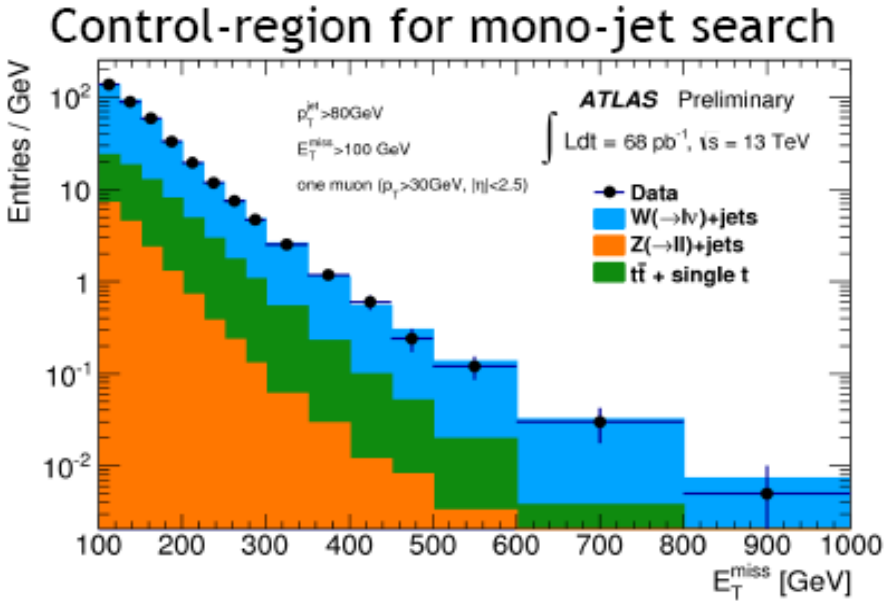


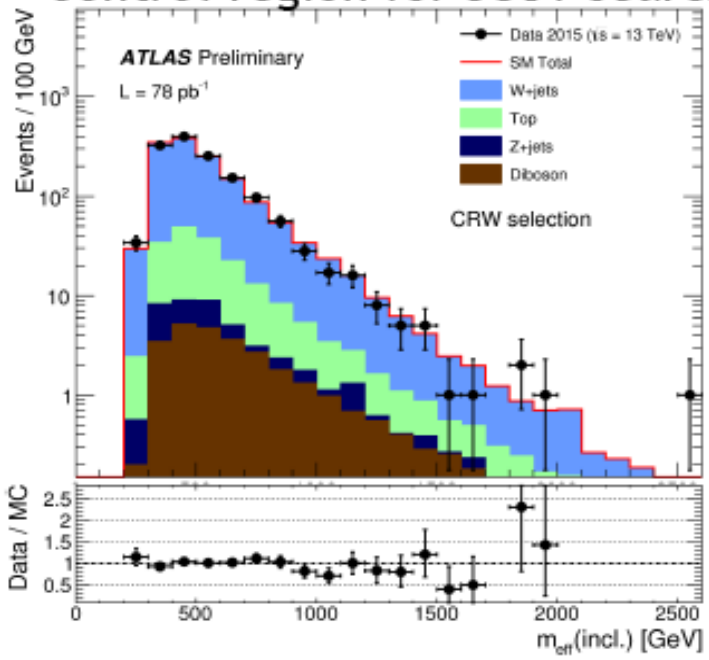
What a coincidence

Preparing for other searches

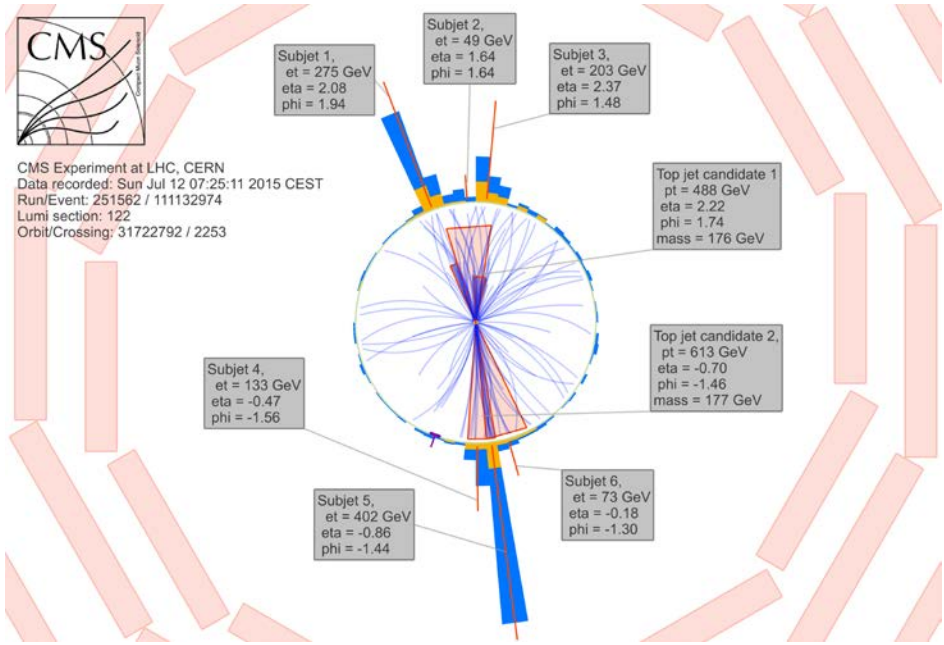


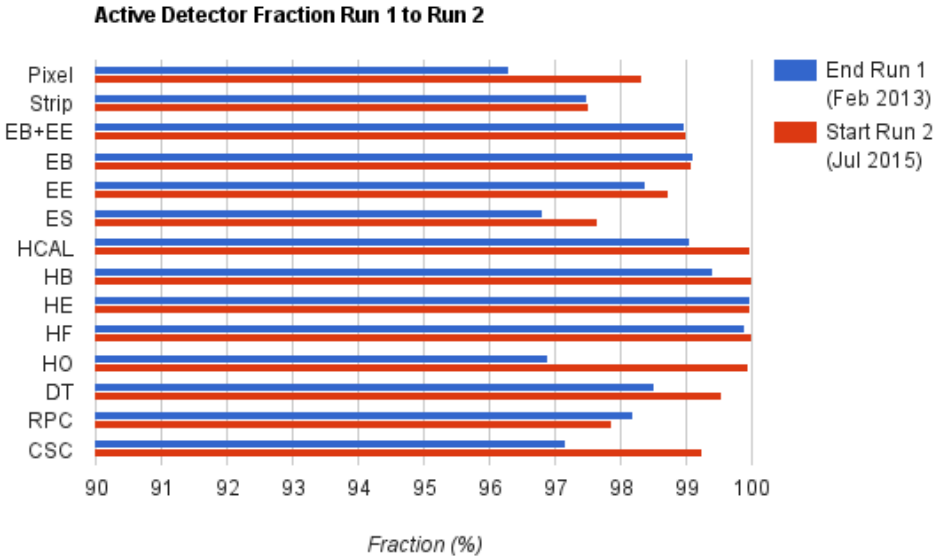


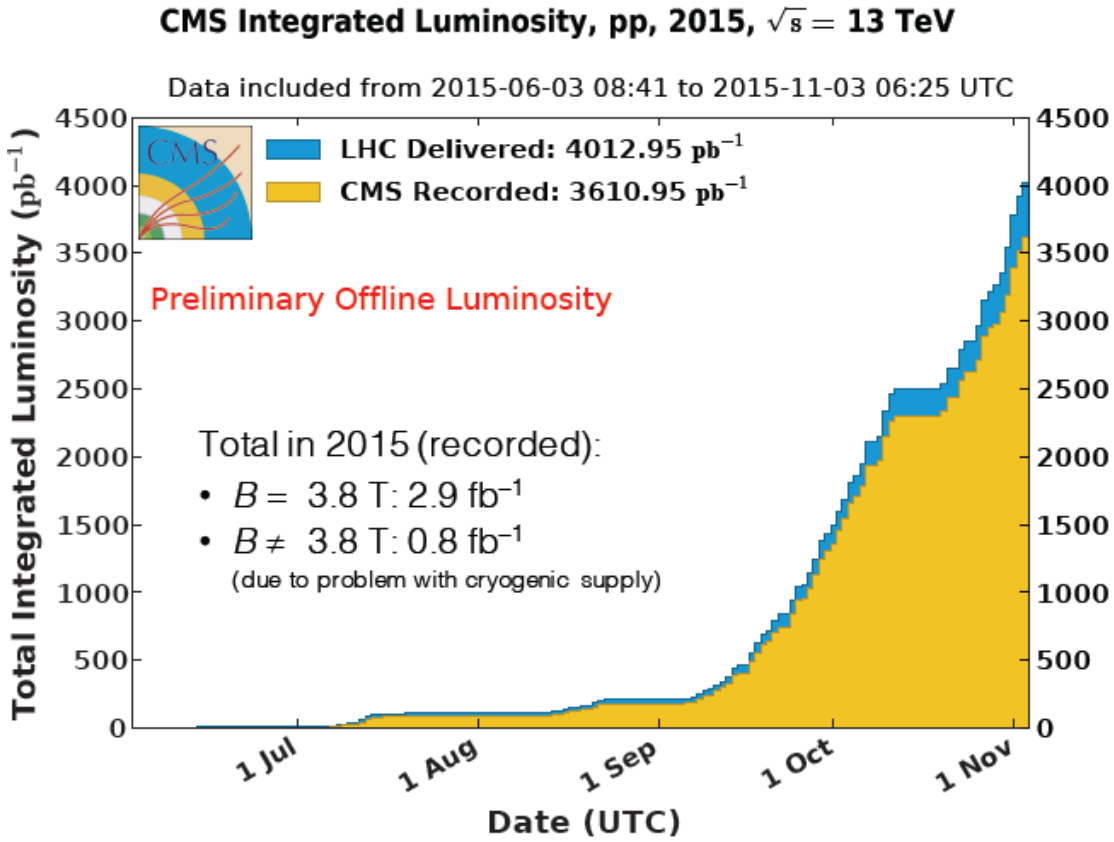




3.2 New results from CMS







Solutions for problem with LHe Cryo Plant

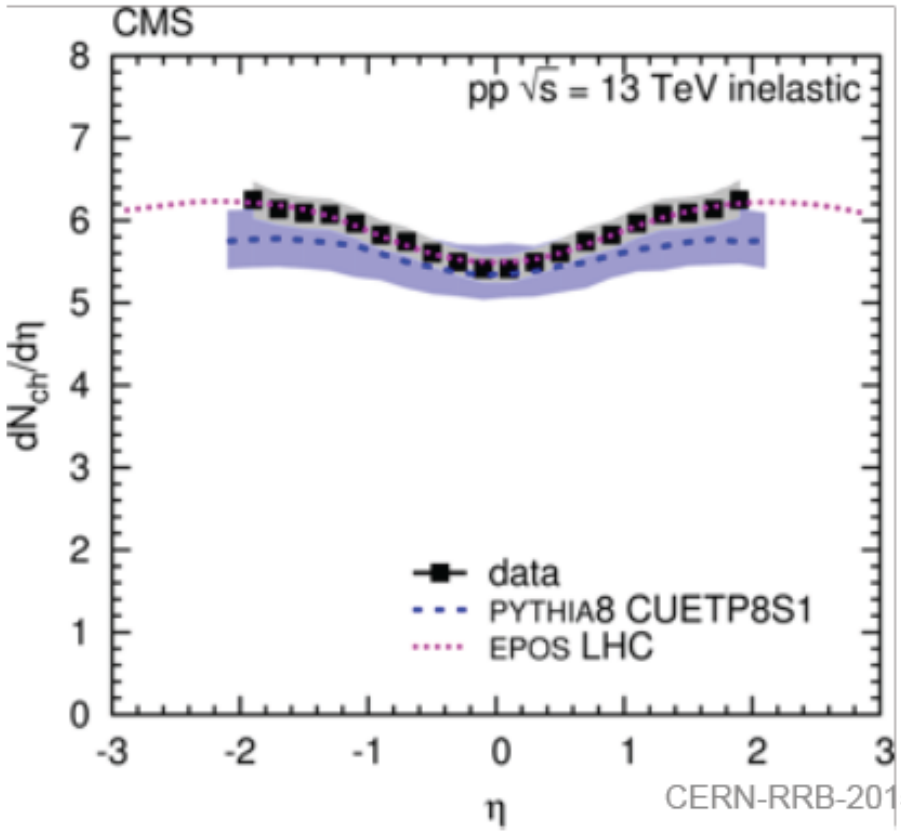
Overall data taking efficiency >92%

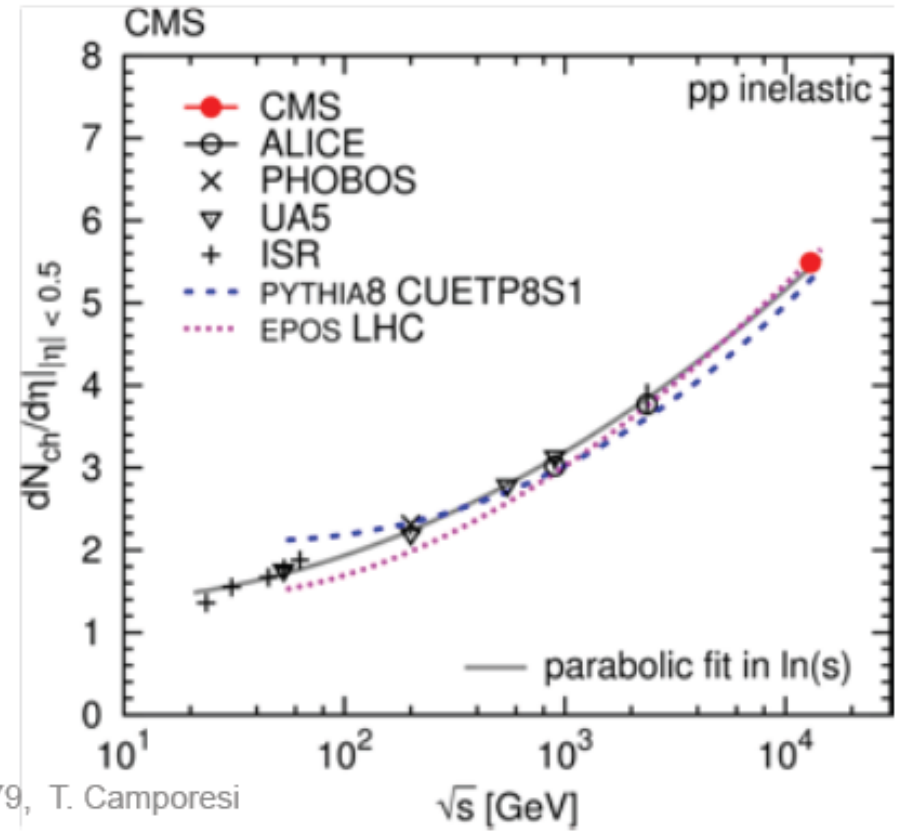
First LHC Publication: Rapidity Densities

Lack of B field has not prevented us from exploiting the first runs taken at low luminosity

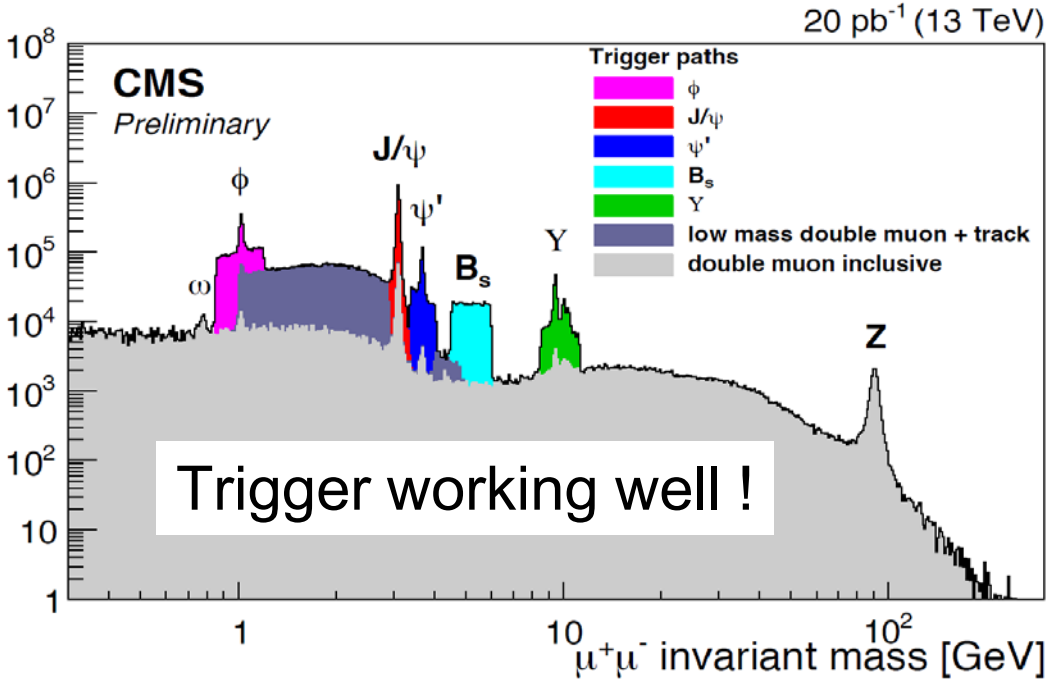
Submitted to PLB
http://arxiv.org/abs/1507.05915

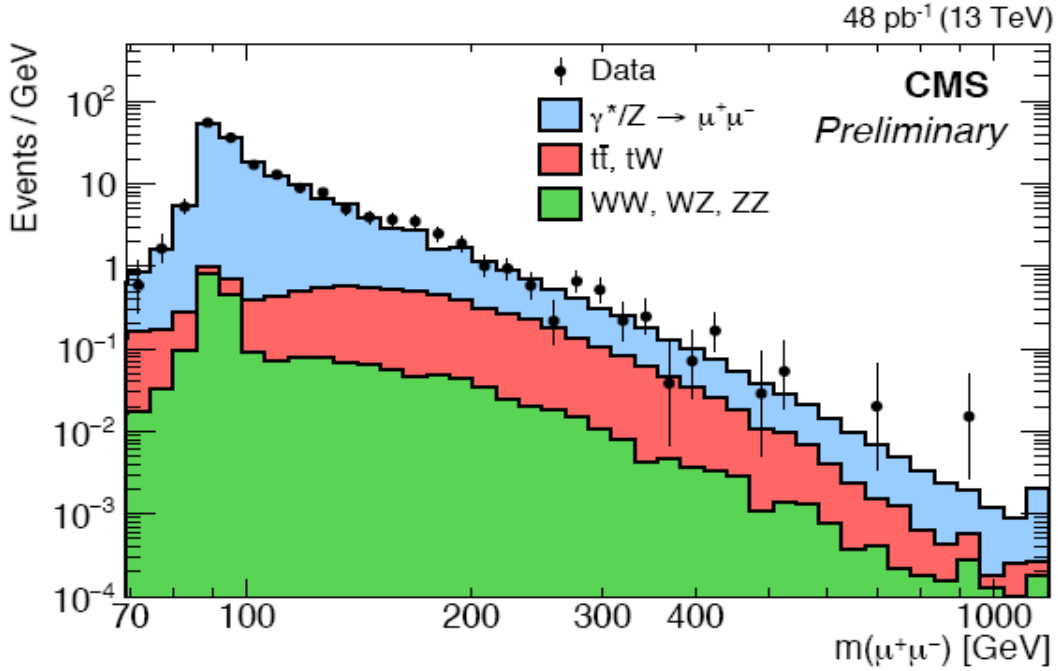
$dN_{ch}/d\eta||\eta|<0.5 = 5.49 \pm 0.01\ (stat) \pm 0.17\ (syst)$

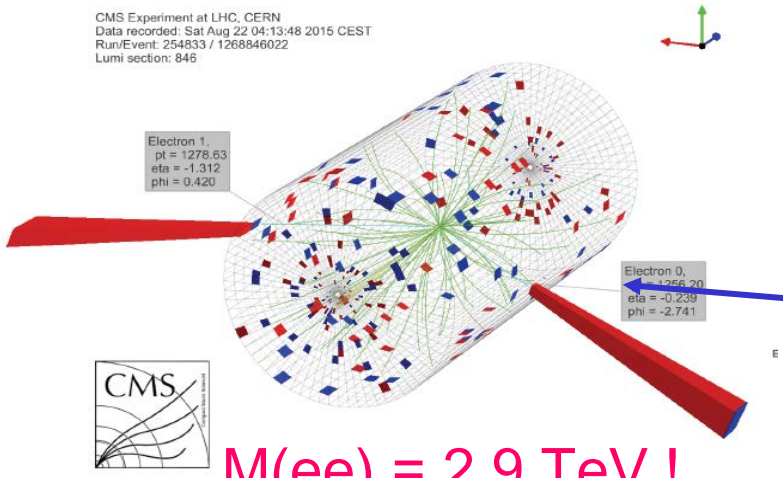




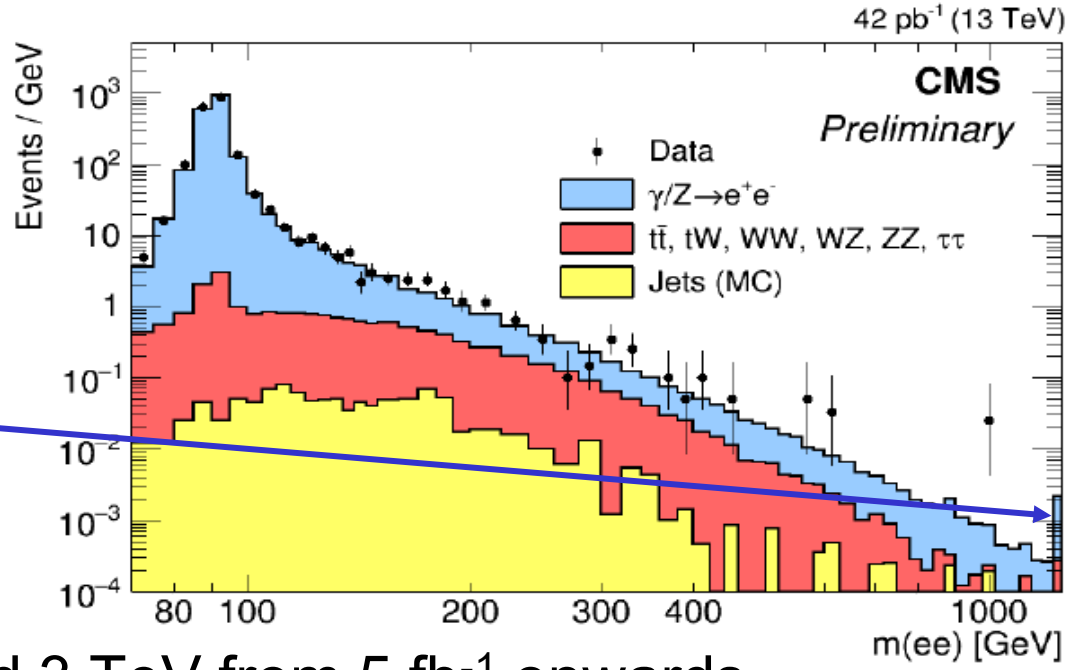
Drell-Yan





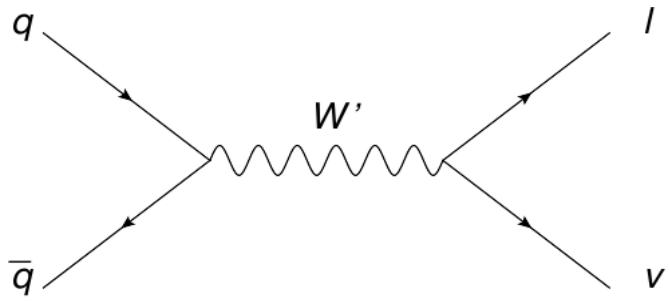


M(ee) = 2.9 TeV !

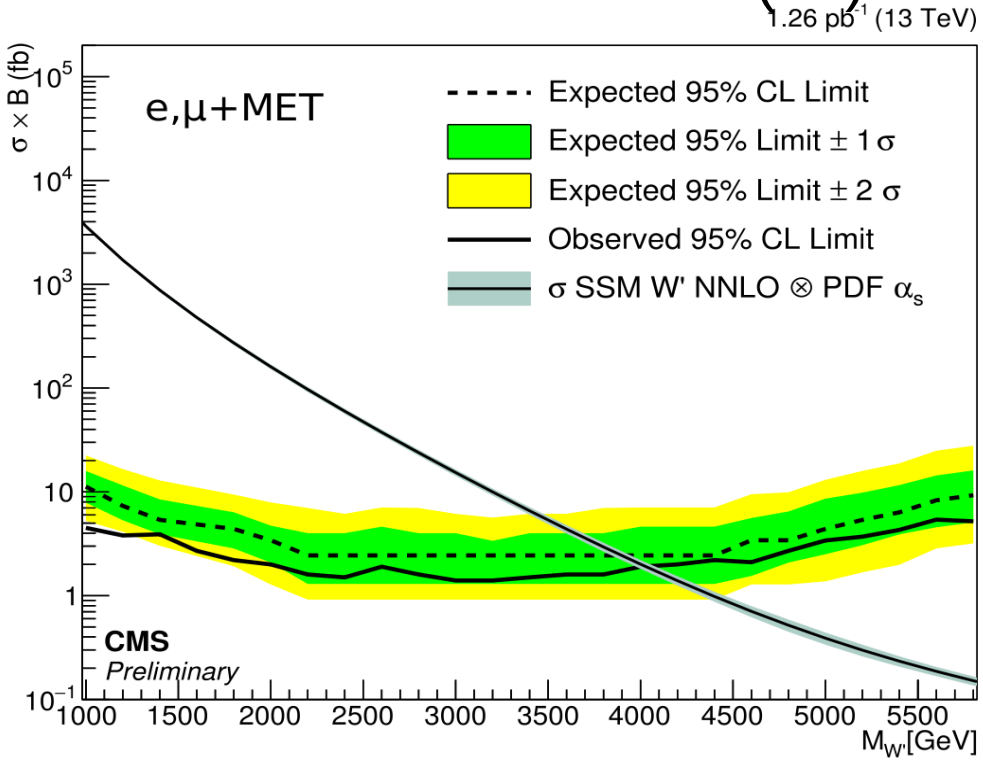


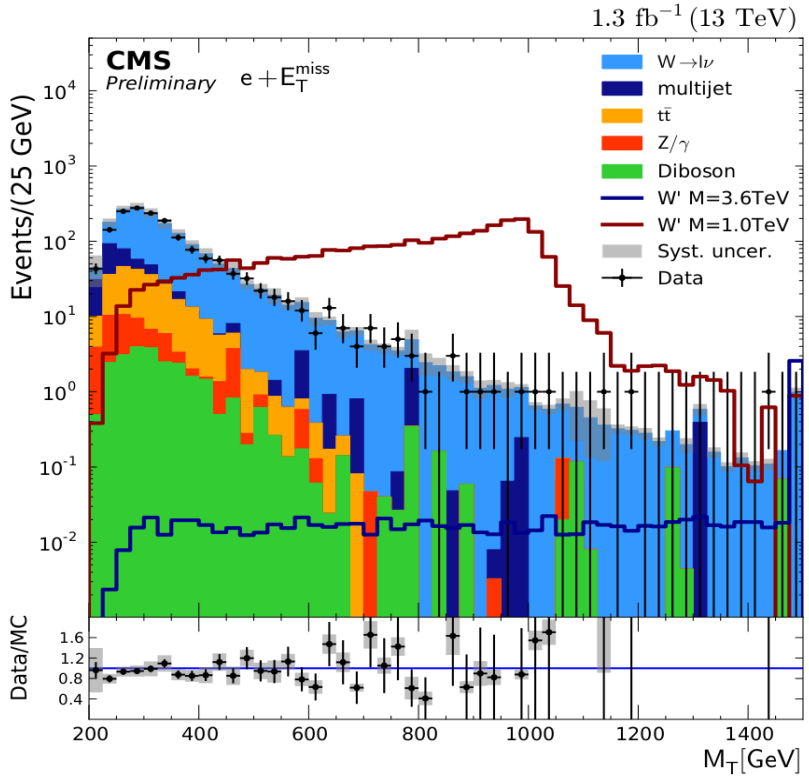
Sensitivities for scales beyond 3 TeV from 5 fb^{-1} onwards

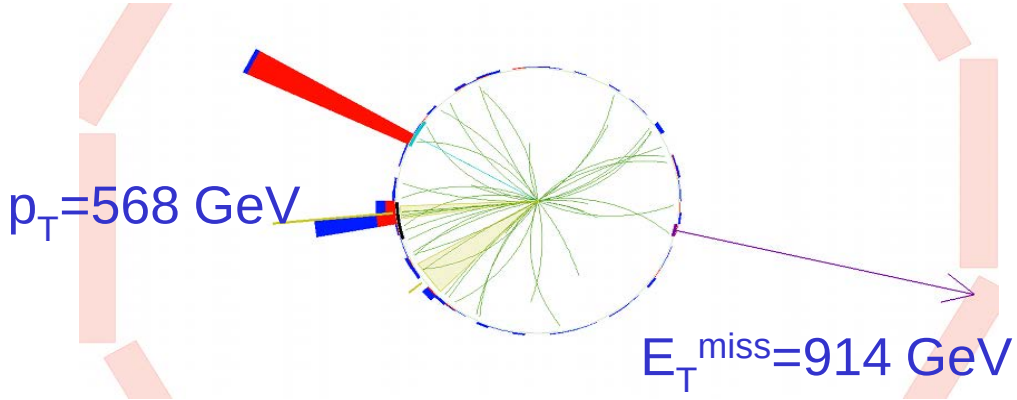
Search for W' → lν with √s=13 TeV data



Preliminary combined electron and muon channel exclusion limit on M(W'):



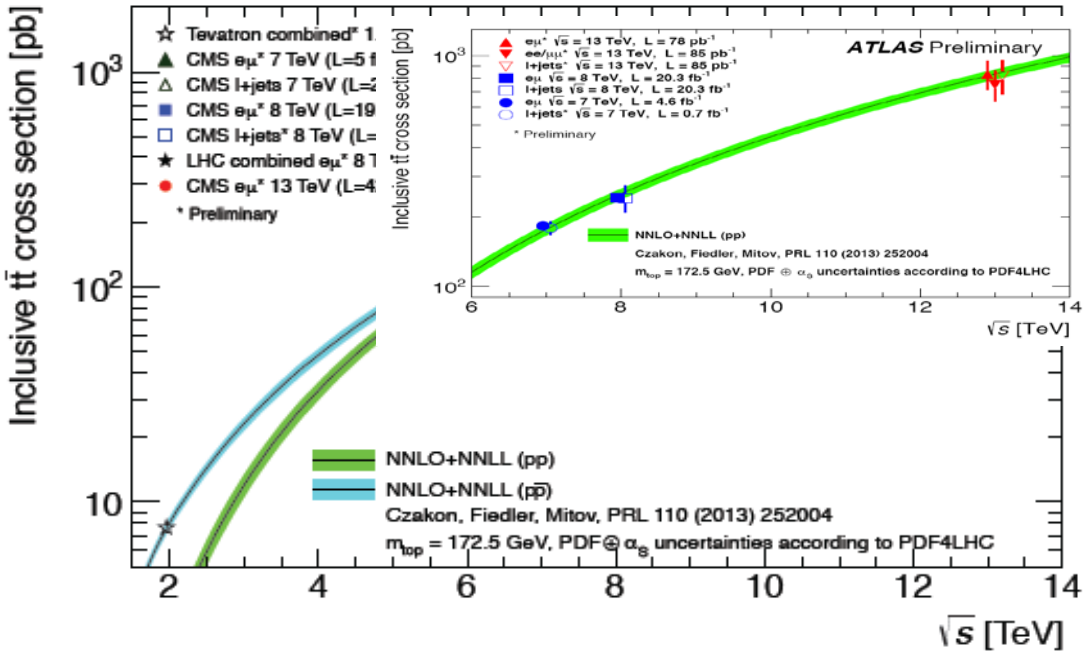




Run-2 limit of 4 TeV exceeds 3.28 TeV from run 1

Highest M_T event with M_T=1426 GeV

Top Quarks



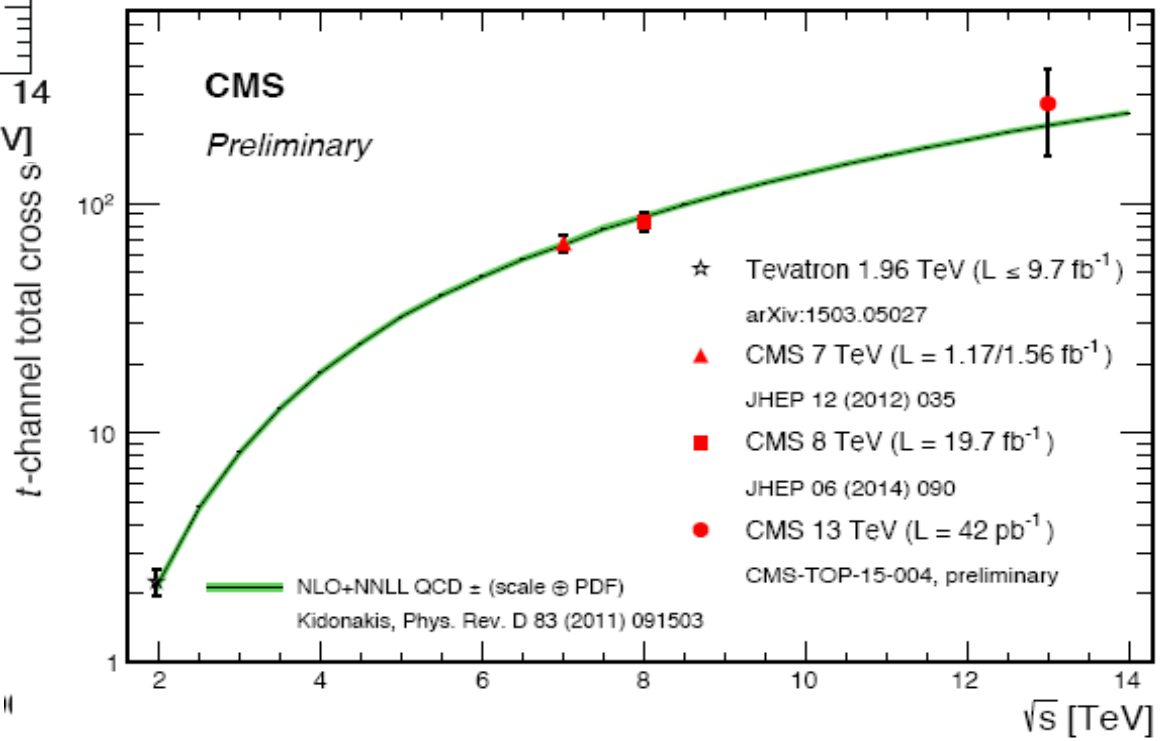
Inclusive ttbar cross section @13 TeV measured:

- eμ and semi-leptonic channels

Allow to extract the pole mass from NNPDF30 PDF to be $m_{t,pole} = 173.6^{+1.7}_{-1.8}$ GeV

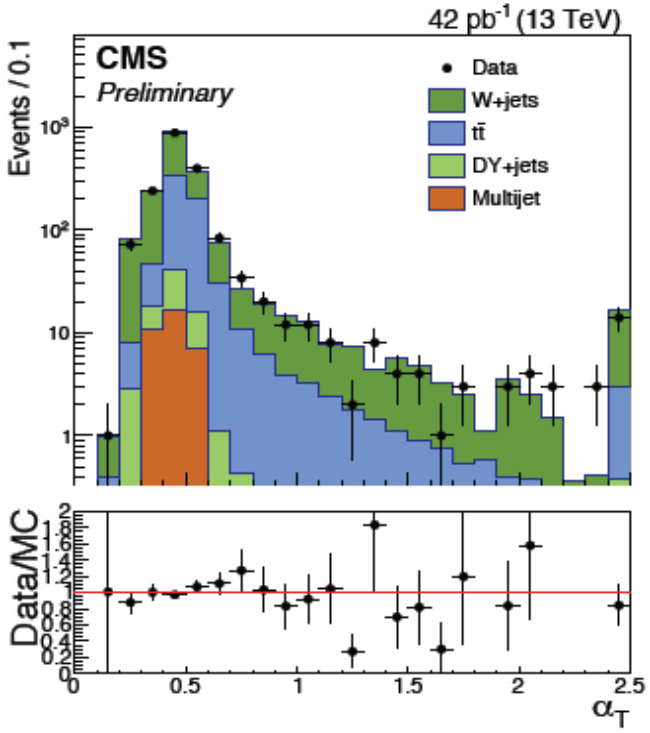
t-channel single top cross section @13 TeV measured:

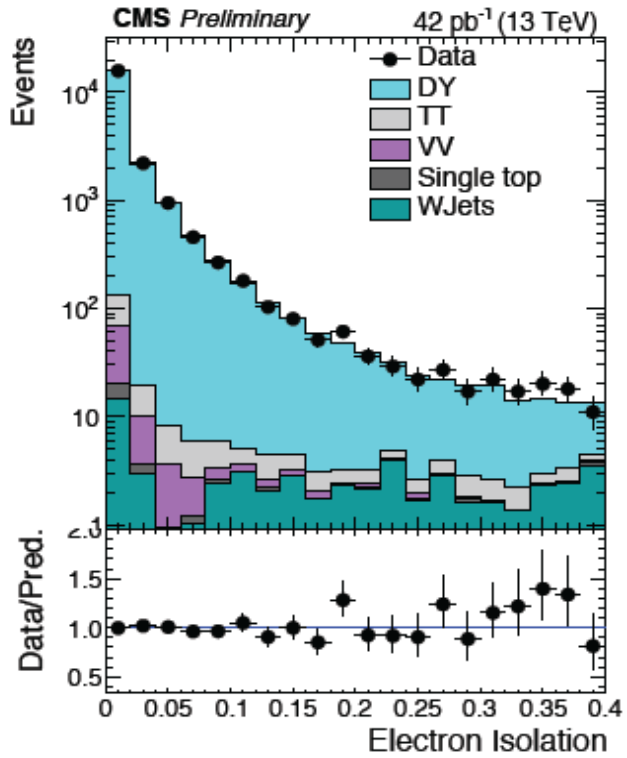
- μ + jet channel

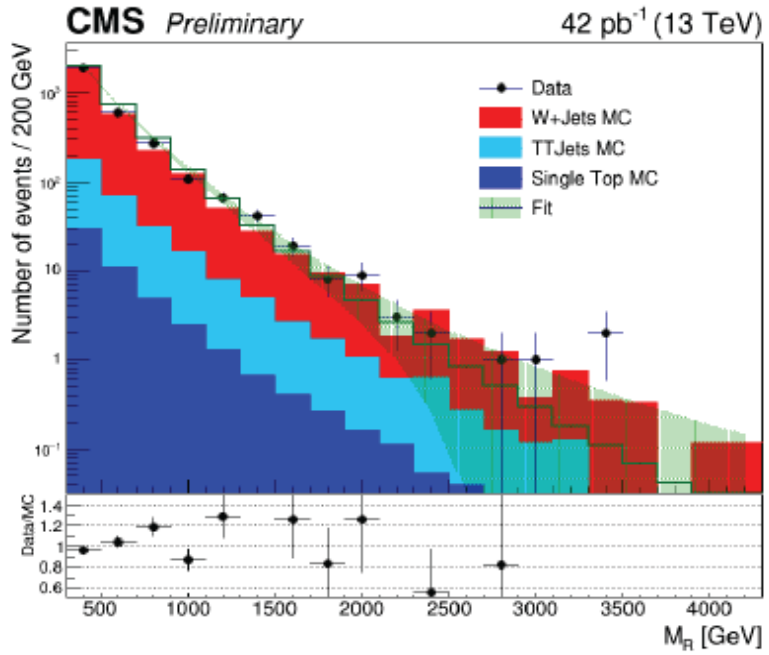


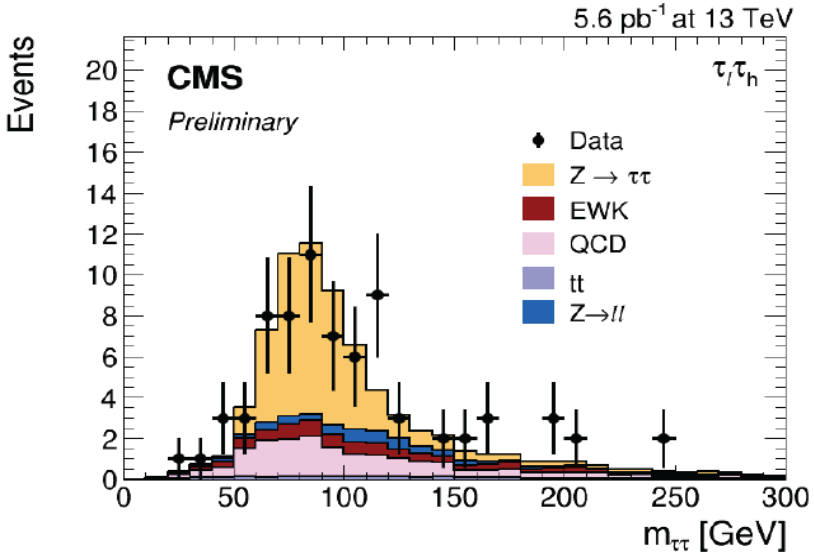
$$|V_{tb}| = 1.12 \pm 0.24\,(\text{exp.}) \pm 0.02\,(\text{theo.})$$

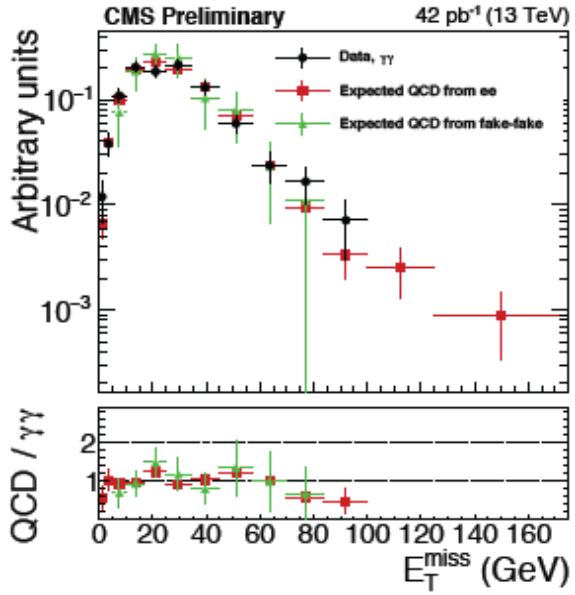
Preparing for SUSY and Higgs searches



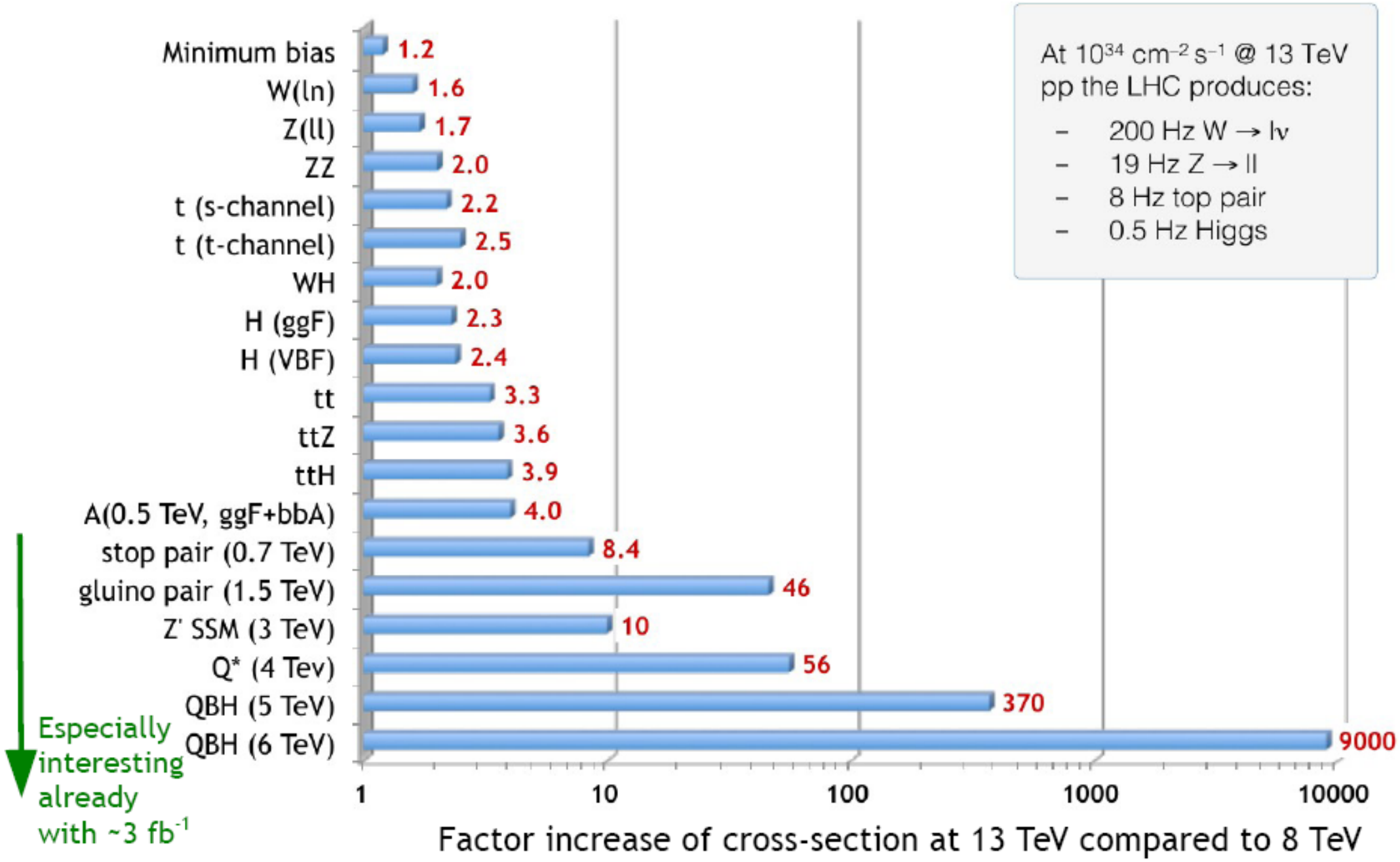




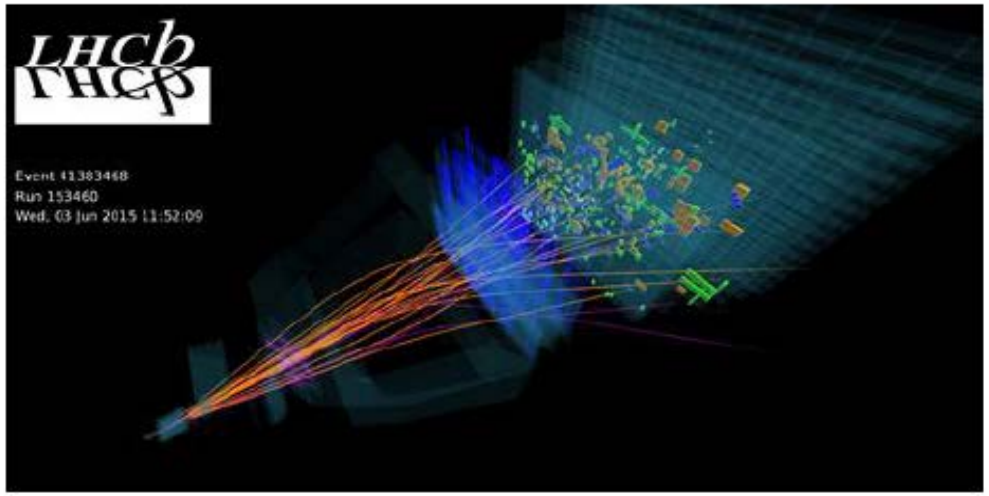




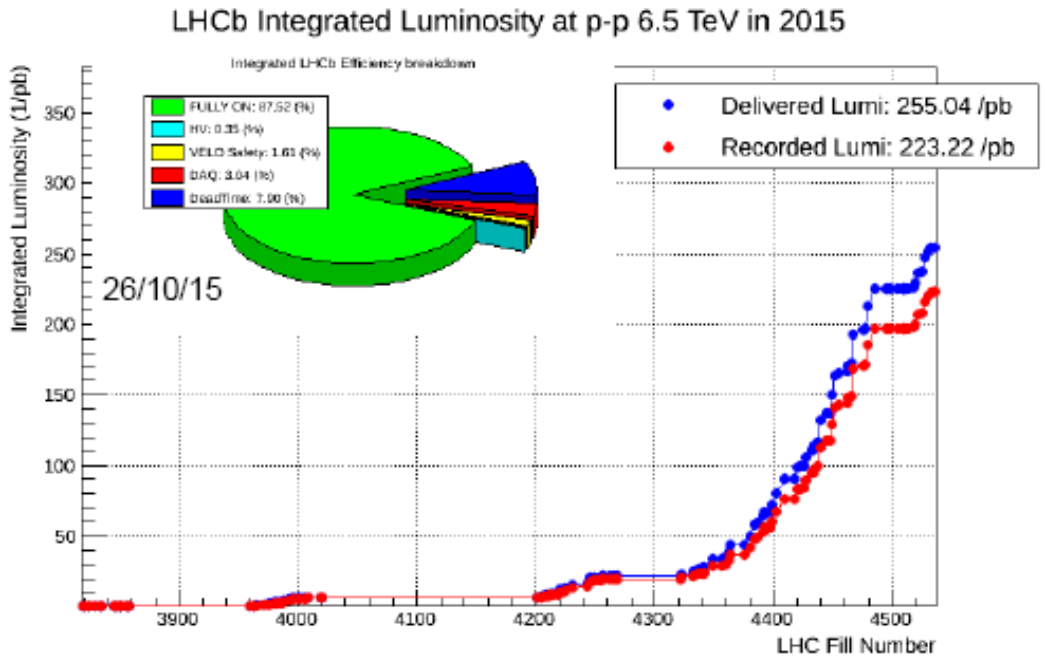
Cross-section increase 8 TeV → 13 TeV



3.3 New results from LHCb

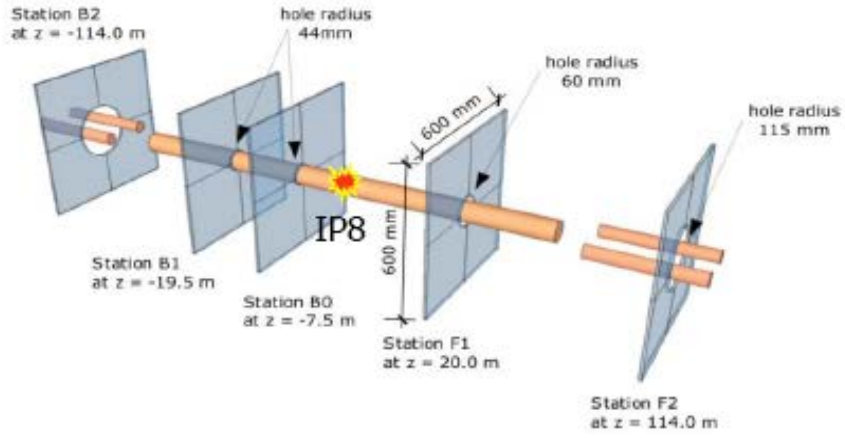


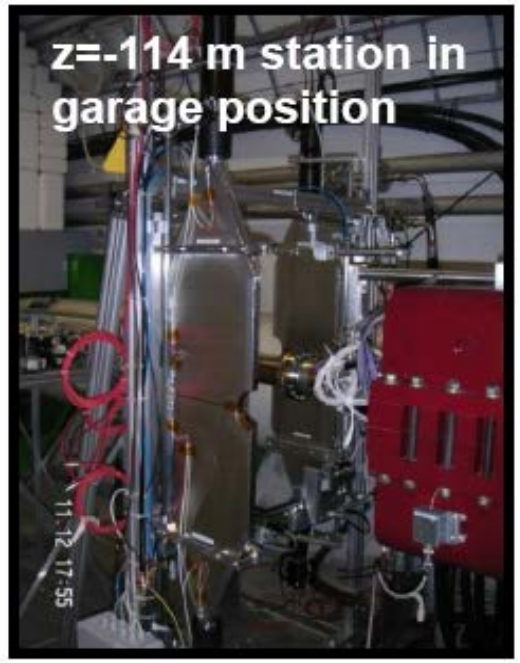
All
wo



…including new
High Rapidity
Shower Counters
for LHCb (HeRSChel)

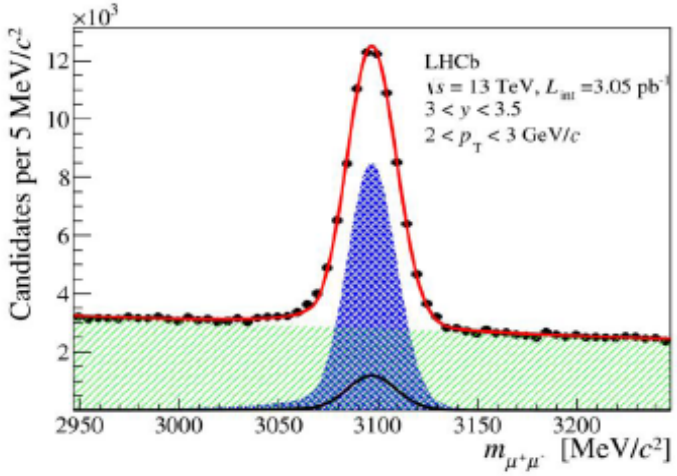
Installed for diffractive
physics to improve
rapidity gap definition.

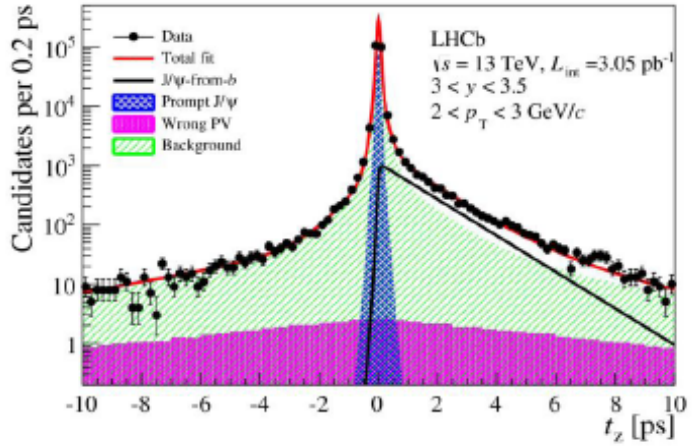




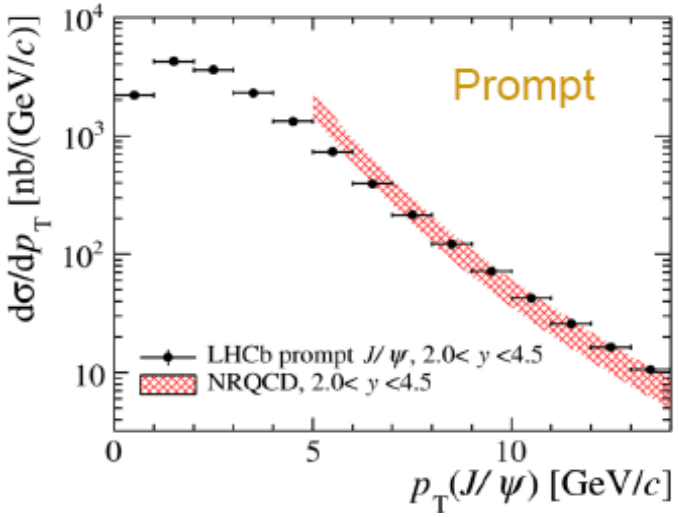
J/Ψ production at $\sqrt{s} = 13$ TeV

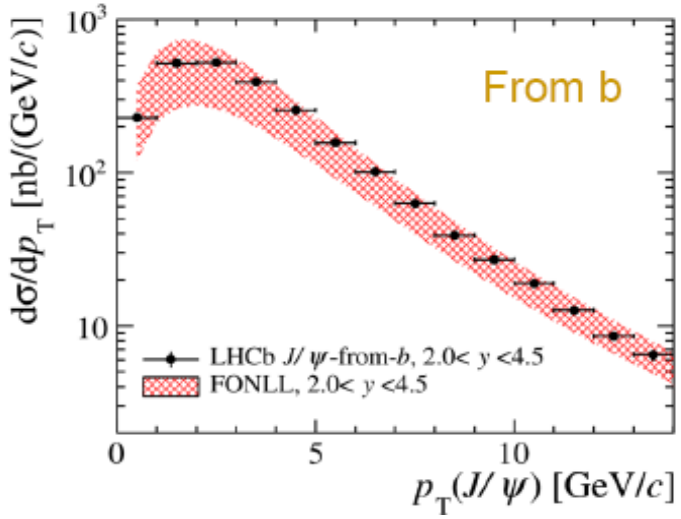
13 TeV J/Ψ signal split into prompt & b-hadron components by pseudo decay time



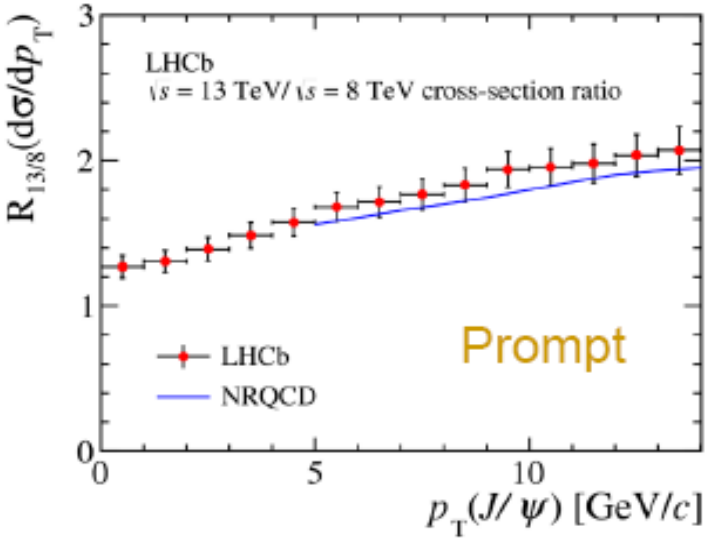


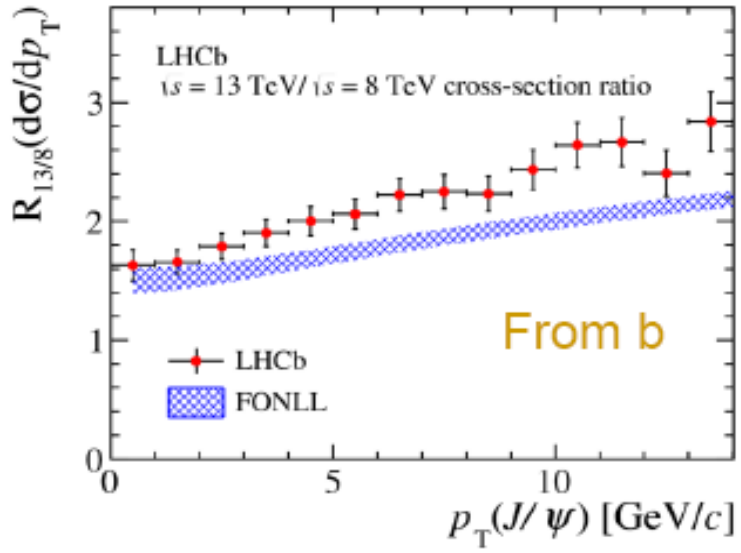
Double-differential cross-sections measured (vs p_T,y), here integrated over y



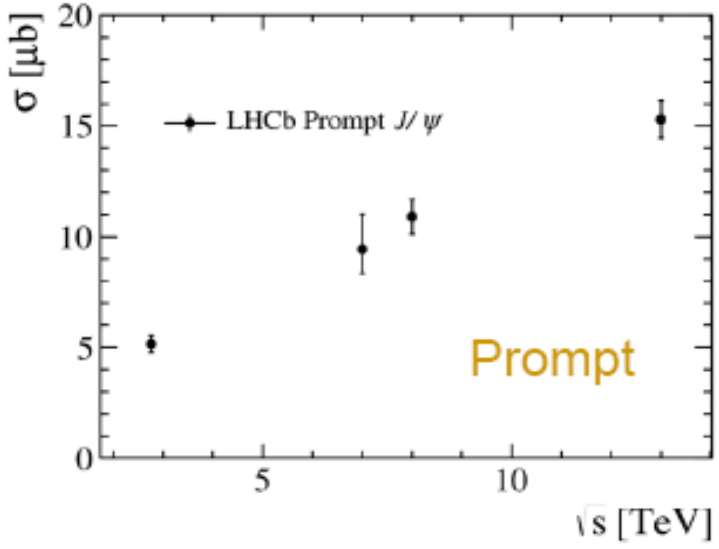


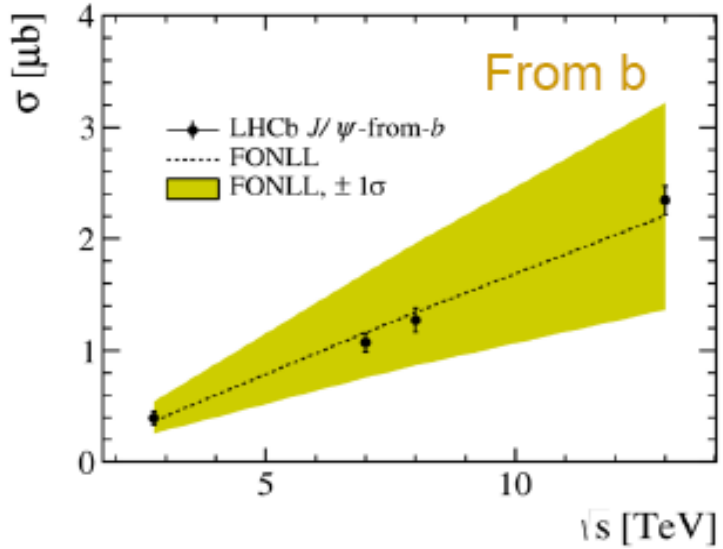
Ratios of x-sections at 13 TeV to 8 TeV, within *y* acceptance, vs p_T





Total cross-sections within acceptance vs. collision energy

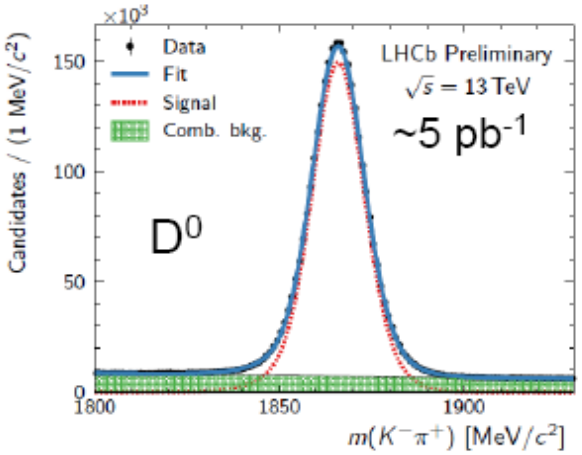


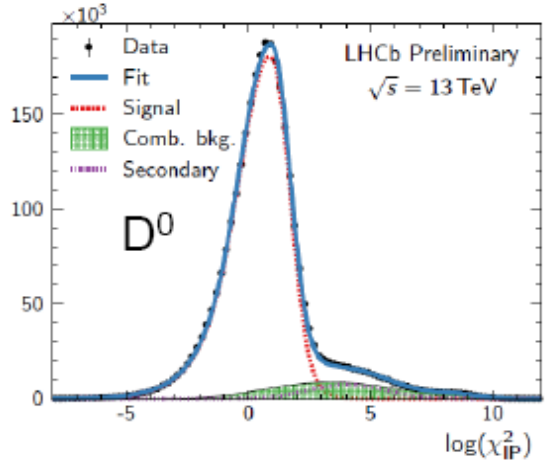


Prompt charm production at √s = 13 TeV

[arXiv:1510.01707]

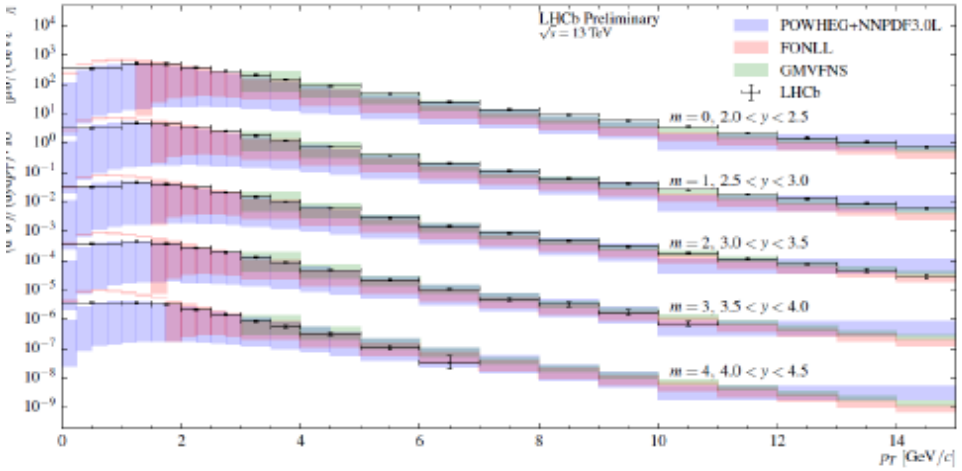
Charm meson candidates returned in TURBO stream used to determine differential cross-sections for prompt charm mesons: D^0, D^+, D_s^+, D^{*+}



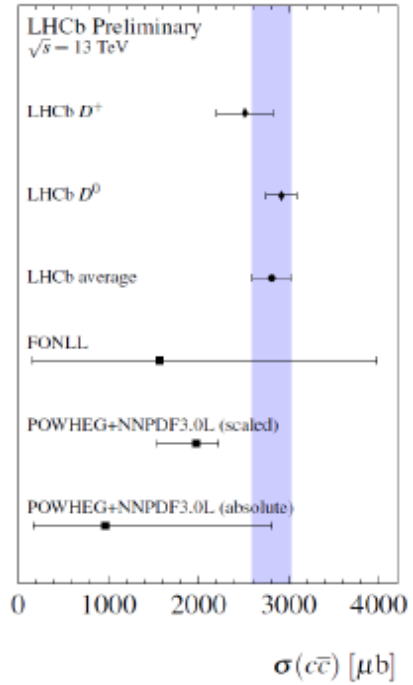


Separate prompt & secondary components using impact parameter (χ_{IP}^2) distribution

D^0 differential cross-sections



Integrate out, & use fragmentation fractions to obtain full *b*bar x-section within acceptance (p_T<8, 2<*y*<4.5)



4. LHC: German Participation

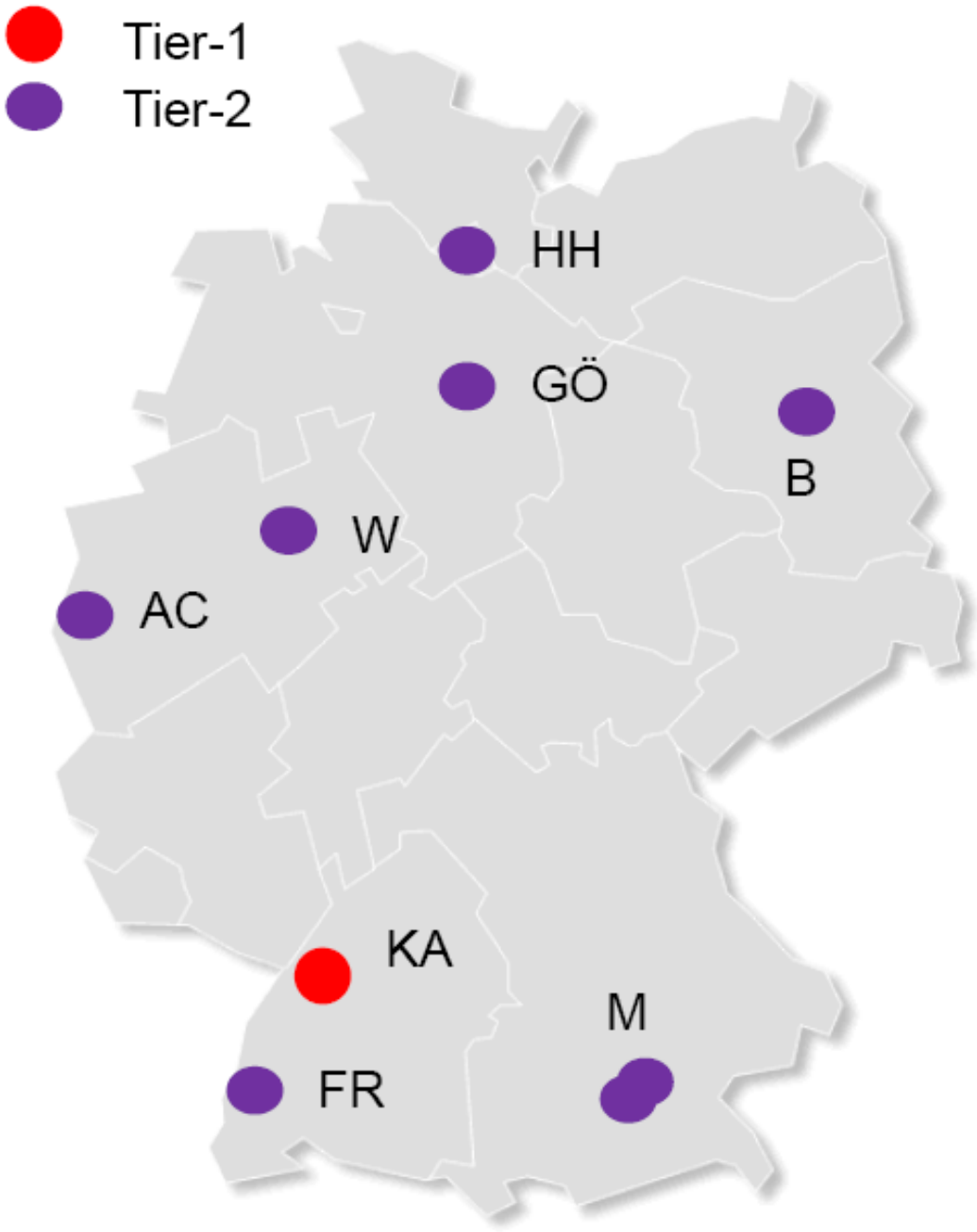
ATLAS: FSP-103
13 Universities + DESY + MPP
~420 Scientists
~200 Graduate Students

CMS: FSP-104
3 Universities + DESY + KIT
~200 Scientists
~ 90 Graduate Students

LHCb: FSP-105
4 Universities + MPK Heidelberg
~100 Scientists
~ 40 Graduate Students

ALICE: FSP-201
9 Universities + GSI Darmstadt
~125 Scientists
~ 40 Graduate Students

LHC Computing in Germany



German share on WLCG Tier1 & Tier 2

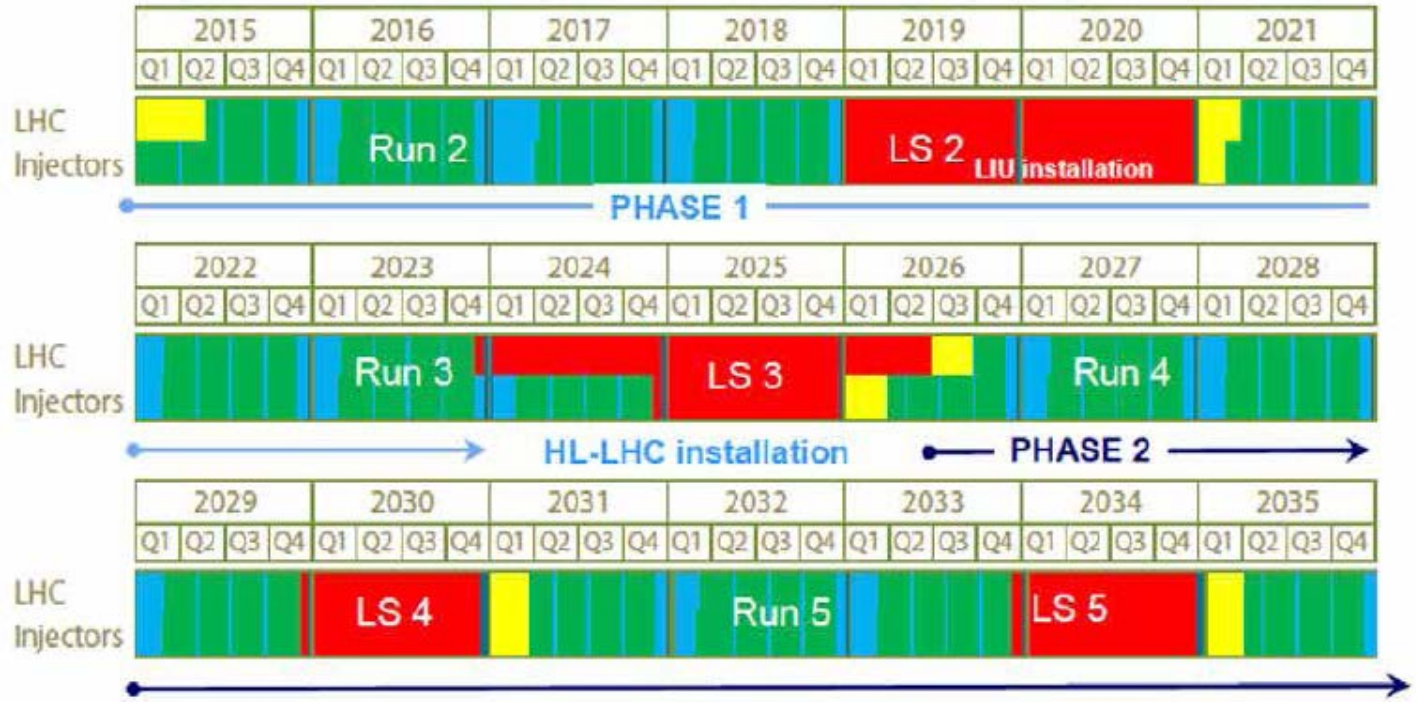
- BMBF-Sondermittel 2014 for University Tier2 and for HGF- & MPG- contributions guarantee German Tier2 for 2015/16
  Financing unclear from 2017 onwards
- So far no firm commitment for an increment in Tier 1 sector for 2016, but positive rumors!!!
  (German T1-Contribution reduced by ca. 20%)

Tier1 (D)	ATLAS	CMS	LHCb	Alice
2015	12%	10%	20%	23%
2016	10%	8%	16%	19%

Tier2 (D)	ALTAS	CMS	LHCb	Alice
2015	12%	8%	-	4%
2016	12%	8%	-	7%

Source: WLCG Rebus Data Bank, Nov. 2015

Longterm perspectives



Der Detektorausbau ist in zwei Stufen geplant:

Phase-I: ALICE, ATLAS, CMS und LHCb, Bau von 2014 – 2018,
Installation im *long shutdown* 2 (LS2)

Phase-II: ATLAS und CMS, Bau von 2017-2023, Installation im *long shutdown* 3 (LS3)

BMBF: Starke Unterstützung! RRB 2015: Gute Fortschritte!

5. Summary, Acknowledgements

- LHC had a very good start into the 13 TeV Running operation
- A few snags are getting under controle (UFOs, ULO)
- Detectors well calibrated, operate perfectly
- A few concerns (CMS LHe Refridgerator)
- Already 4 fB^{-1} of accumulated collision events
- New preliminary results almost outclass in some aspects Run 1

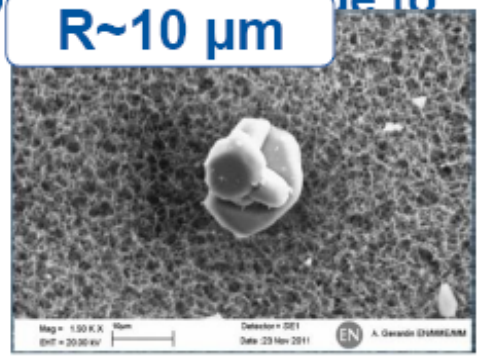
We physicists at the LHC Detectors are very grateful for the incredible work of the accelerator teams and the detector support

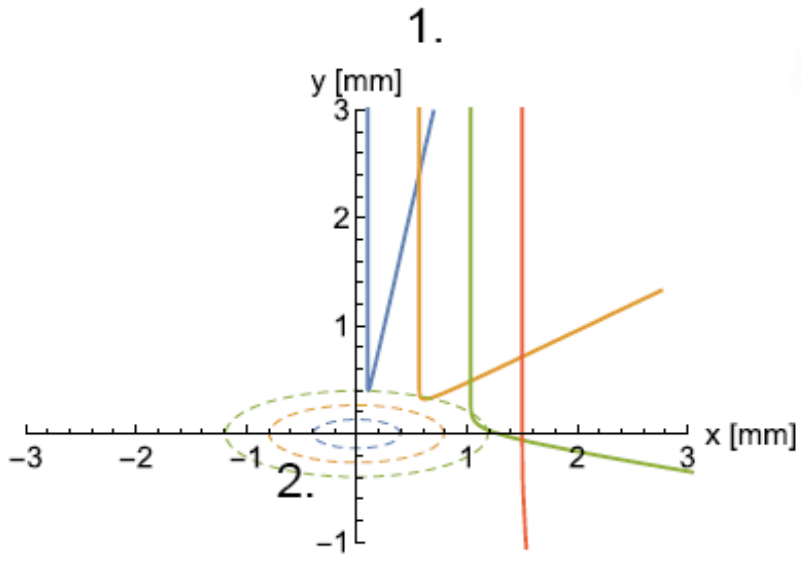
In Germany, we are extremely grateful for the relentless, faithful and uncomplicated support by our Funding Agencies: Länder, DFG, HGF, MPG, EU, and

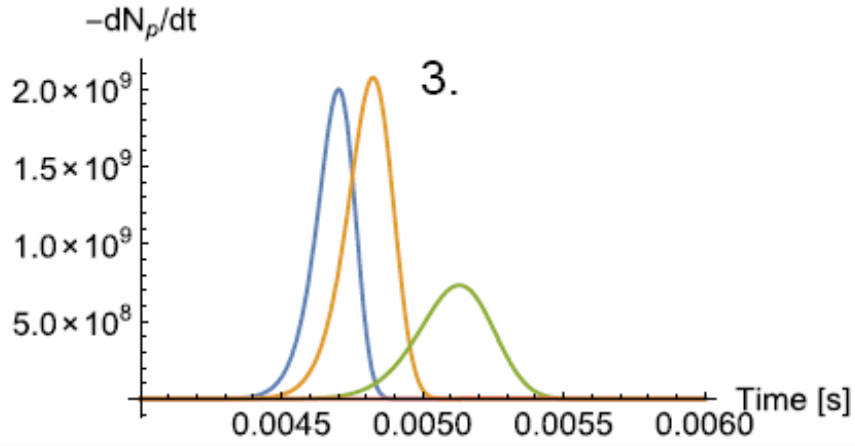
BMBF

What are UFOs ?

1. A macroparticle falls from the top of the beam screen. The mechanism for the release of the particle is not well understood.
2. The macroparticle is ionized by the primary protons in the beam.
3. At the same time, inelastic collisions result in particle showers that heat the SC coils and are registered in the BLMs.
4. The positively ionized macroparticle is subsequently repelled from the beam due to the beam electric field.



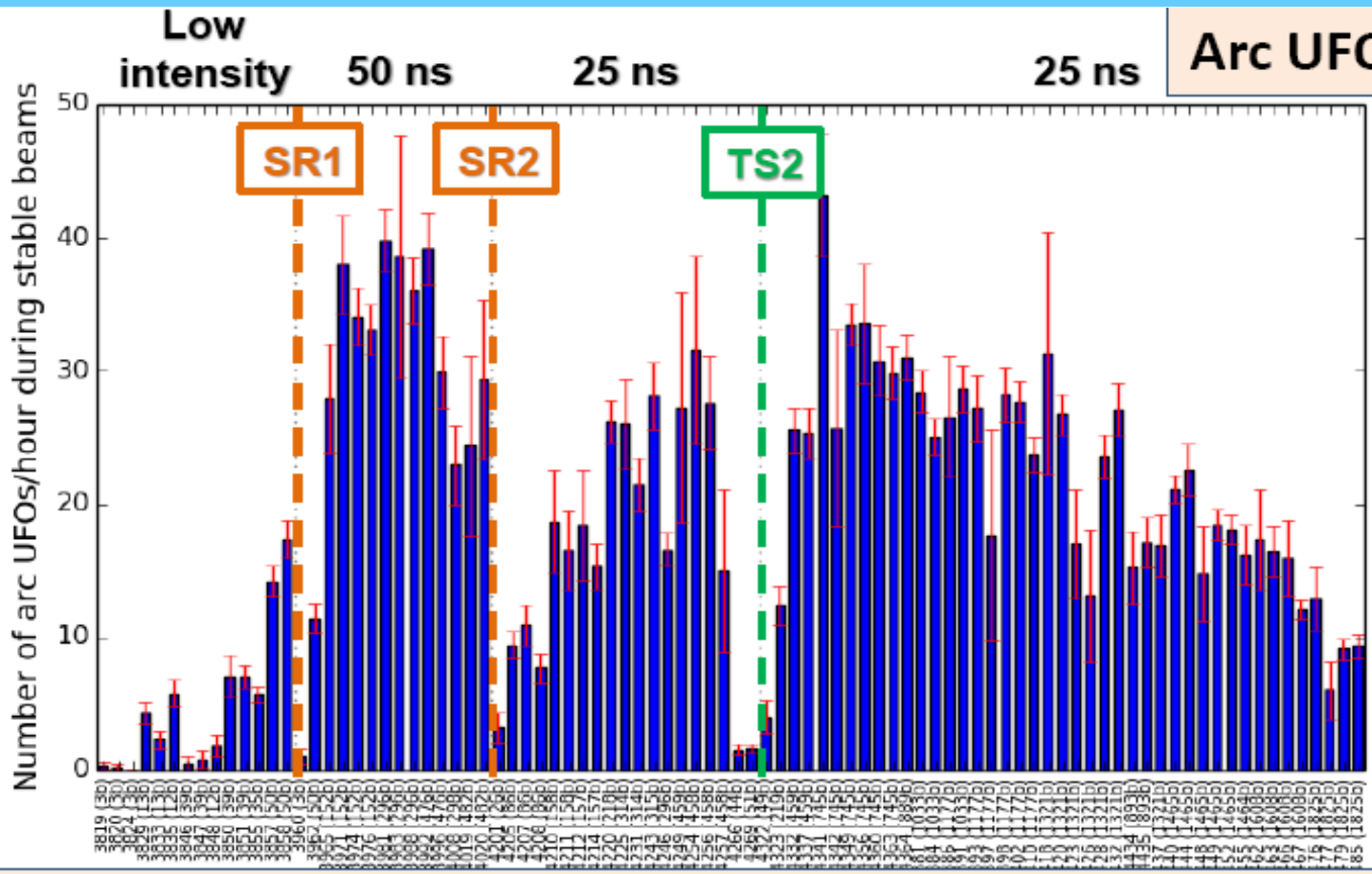




- The origin of these particles is unclear
- They are more-or-less evenly distributed around the machine
- The good news is that they seem to ‘condition’ away

Th

Arc UFO's/h in Physics



- Over the last month ~20% of fills which reached stable beams have been dumped by a UFO
- Most are very small, ~5% exceed 10% of the dump threshold
- Only a very few have caused Quenches
- Clear signs of conditioning ... Things are getting better!

Wichtige Leitungsfunktionen von deutschen Wissenschaftlern in den Experimenten

Deputy Spokesperson:	Kerstin Borras (DESY, CMS) Johannes Wessels (Münster, ALICE)
Physics Coordinator:	Karl Jakobs (Freiburg, ATLAS)
Deputy Physics Coordinator:	Silvia Masciocchi (GSI, ALICE)
Deputy Technical Coordinator:	Wolfram Zeuner (DESY, CMS)
Run Coordinator:	Stefanie Zimmermann (Freiburg, ATLAS) Chilo Garabatos (GSI, ALICE)
Trigger Coordinator:	Ken Oyama (Heidelberg, ALICE)
Collaboration Board Chair:	Siegfried Bethke (MPP München, ATLAS) Gregor Herten (Freiburg, ATLAS) Bernhard Spaan (Dortmund, LHCb) Peter Braun-Munzinger (EMMI, ALICE)

Leiter von Physik-Analysegruppen:

ATLAS: U. Blumenschein (SM-Physik), M. Cristinziani (Top-Physik),
S. Glazov (SM-Physik), S. Kortner (Higgs), K. Mönig (Exotics),
M. Schumacher (Higgs)

CMS: H. Jung (Vorwärtsphysik) , A. Meyer (Top-Physik), F.-P. Schilling (Top-Physik),
R. Ulrich (Vorwärtsphysik)

LHCb: M. Vesterinen (Semi-leptonic B decays), S.Hansmann-Menzemer (oscillations),
J. Marks (Mixing, CPV), M. Schmelling (Hadron Spectroscopy)

ALICE: A. Andronic (Heavy Flavour), R. Averbeck (Heavy Flavour),
C. Klein-Boesing (Jets), J.-F. Grosse-Oetringhaus (Correlations),
K. Reygers (Gammas), H. Buesching (Jets), O. Busch (Jets),
S. Masciocchi (Heavy Flavour)

+ zahlreiche Leiterfunktionen (Projektleiter) in Subdetektorprojekten,

+ zahlreiche Leiter von sog. Performance-Arbeitsgruppen,

Problems with Helium cooling for the magnet

- Since March 2015 the "Cold Box" (CB) that produces liquid He for the operation of the CMS magnet has had problems, following a compressor oil pollution of the CB circuit.
- For a definitive recovery, the system requires an overall cleanup which takes several months.
- Meanwhile, the CERN cryogenics group, in collaboration with the CMS Technical Coordination group, has been trying to find a way to operate the Cold Box with a reasonable Duty Cycle (> 70%) that would allow operation of the magnet synchronized with physics operation of the LHC until the Year End Technical Stop.
- During TS2: augmented surface filters were installed; in addition, a special "regeneration cycle" has resulted in allowing a continued magnet operation since.

Primary Oil Removal System (PORS)
-ordered, delivery 1 Jan 2016
(coalescers will be later – mid March), but can be installed in parallel

300m warm He transfer line (surface to underground)
-surface pipe done, work started in PM 54 shaft

80K Ads tank spares
- first one ready in CERN shops
- second one in order from Air Ilquide

Cold box cleaning
-cleaning machine ordered, delivery Dec 2015
-selecting solvent –
-and defining cleaning sequence