Status and News from LHCb experiment

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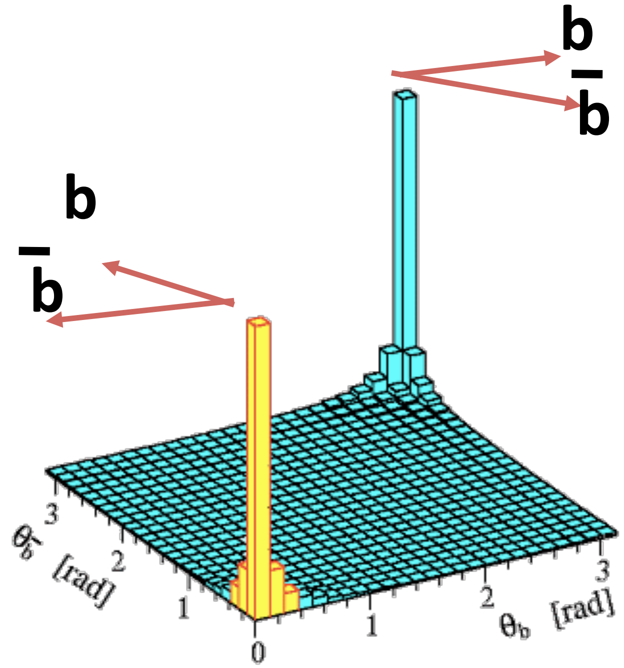
on behalf of the LHCb Collaboration

Outline:

- ***Physics Goals***
- ***Validation of the detector performance with data***
- ***Recent News***

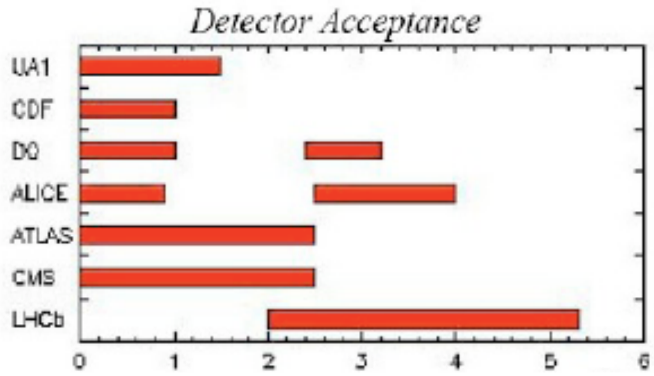
Analysis of the first data and first physics results will be covered in the talks of Olivier Schneider, Walter Bonivento and Julien Cogan

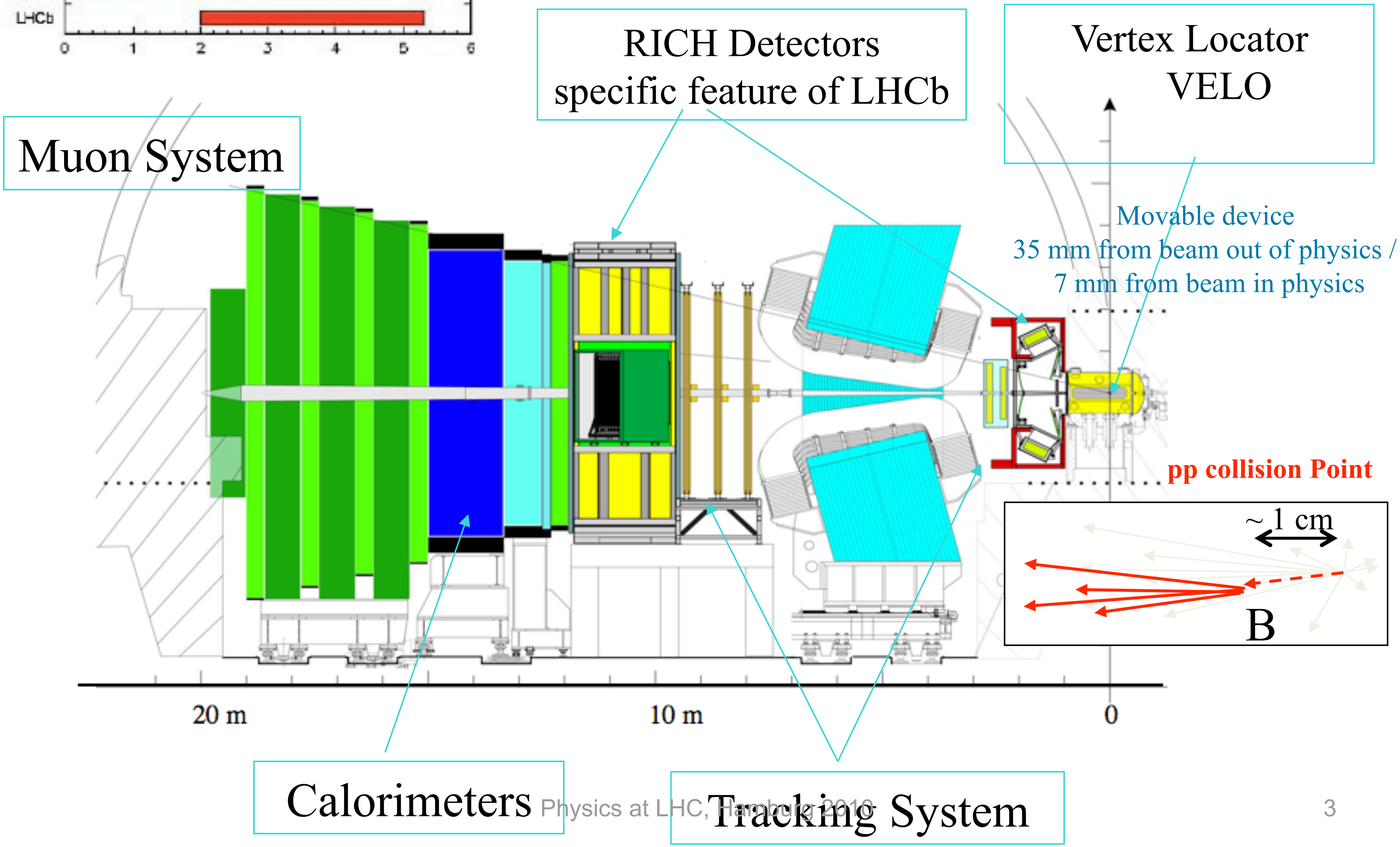
The LHCb Experiment



- ☐ *Advantages of beauty physics at hadron colliders:*
  - *High value of bb cross section at LHC:*
    $\sigma_{bb} \sim 300 - 500\ \mu b$ *at 10 - 14 TeV*
    (e+e- cross section at Y(4s) is 1 nb)
  - *Access to all quasi-stable b-flavoured hadrons*
- ☐ *The challenge*
  - *Multiplicity of tracks (~30 tracks per rapidity unit)*
  - *Rate of background events:* $\sigma_{inel} \sim 60$ *mb at* $\sqrt{s} = 7$ *TeV*
- ☐ *LHCb running conditions:*
  - *Luminosity limited to ~*$2\times10^{32}\ cm^{-2}\ s^{-1}$ *by not focusing the beam as much as ATLAS and CMS*
    - *Maximize the probability of single interaction per bunch crossing*
      At LHC design luminosity pile-up of >20 pp interactions/bunch crossing while at LHCb ~ 0.4 pp interaction/bunch
    - *LHCb will reach nominal luminosity soon after start-up*
  - ***2fb^{-1} per nominal year (10^7s), ~ 10^{12} bb pairs produced per year***

The LHCb Detector (forward spectrometer)

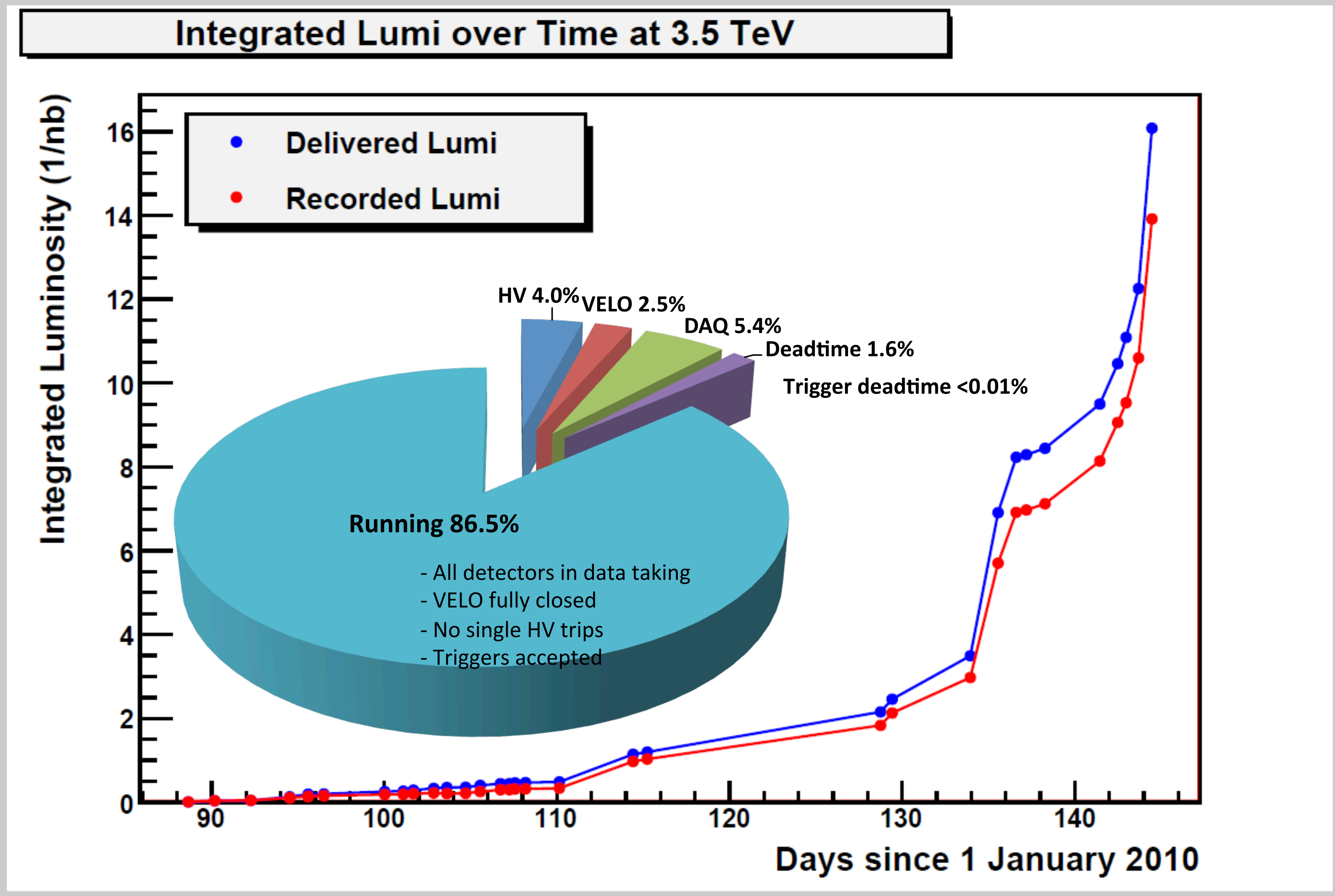




LHCb Collaboration *(day of the 1st collisions)*

LHCb shift *(typical day of data taking)*

LHCb Operation



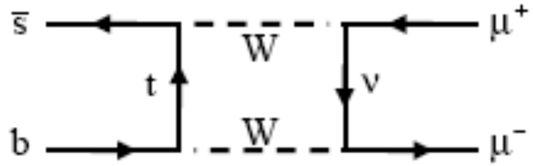
Main LHCb Physics Objectives

Search for New Physics in CP violation and Rare Decays

See talks by Justine Serrano, Geraldine Conti and Joerg Marks

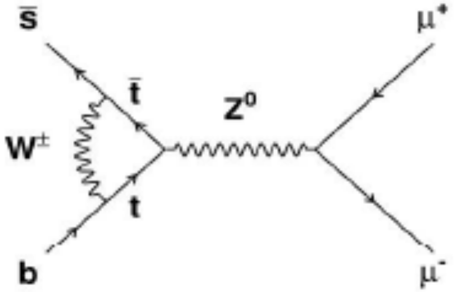
CPV:

- Φ_s
- γ *in trees and loops*
- *CPV asymmetries in charm decays*



Rare Decays:

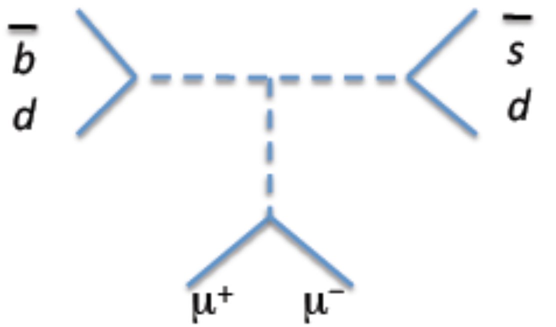
- *Helicity structure in* $B \rightarrow K^*\mu\mu$ *and* $B_s \rightarrow \phi\gamma, \phi ee$
- *FCNC in loops* ($B_s \rightarrow \mu\mu$, $D \rightarrow \mu\mu$) *and trees*



Footnote: Examples of FCNC in trees

Leptonic: $B_{d,s} \rightarrow 4\mu, 4e$

Semileptonic: $B_{d,s} \rightarrow K^*\mu\mu, \phi\mu\mu$



Hadronic: $B_{d,s} \rightarrow J/\psi\phi, \phi\phi$

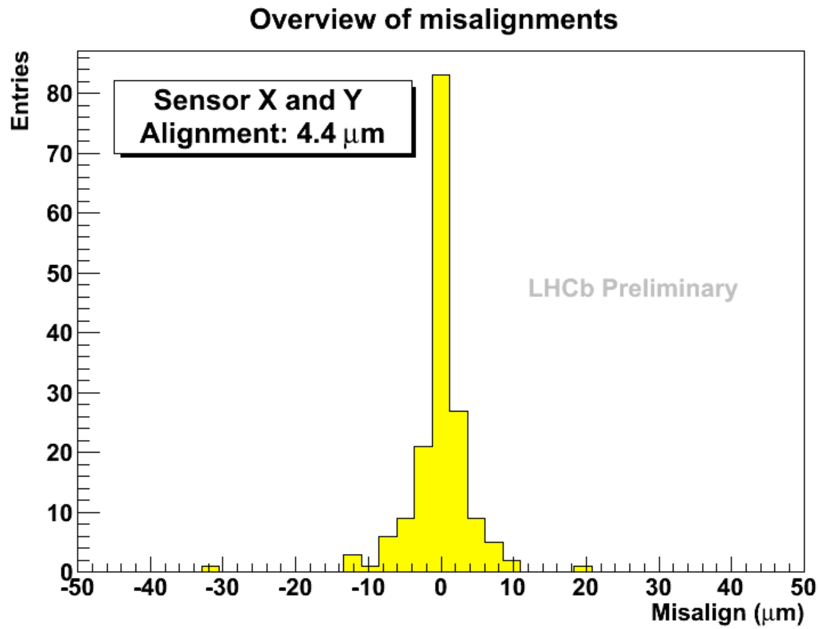
Key ingredients of physics performance

See talks by Florin Macius, Philip Xing and Dirk Wiedner

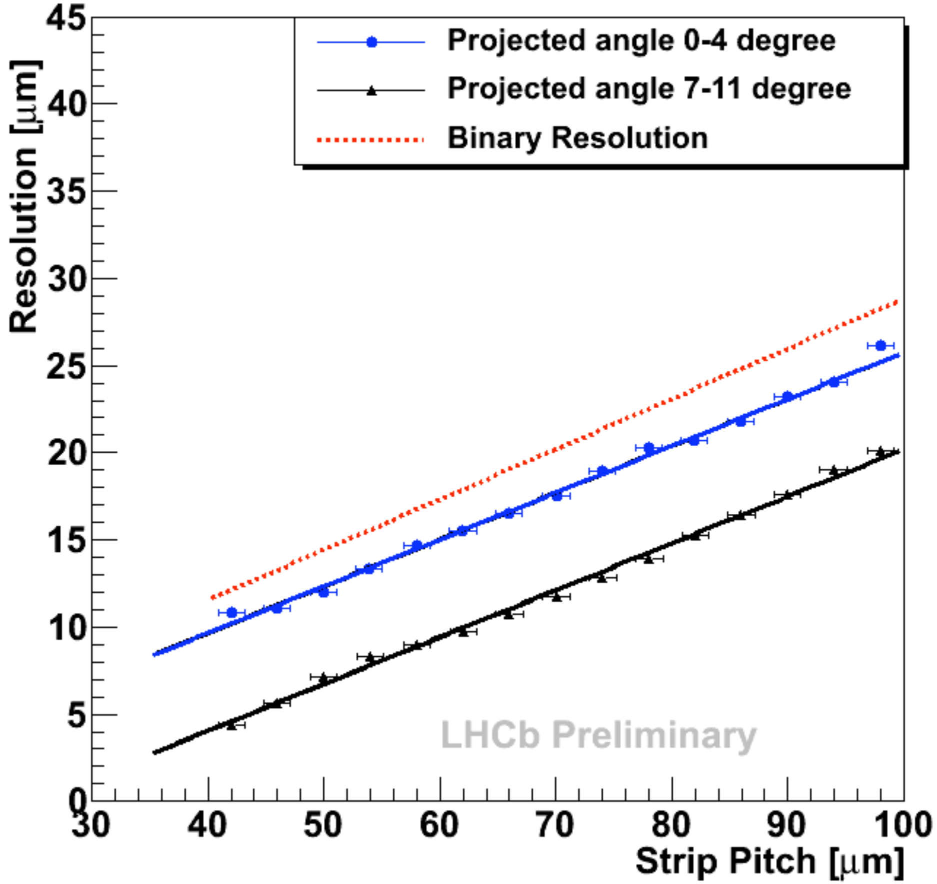
- *Detector alignment*
- *Tracking efficiency*
- *IP & Vertex reconstruction*
- *PID (hadron, muon, electron, photon)*
- *Trigger efficiency*
- *Lifetime & Mass resolutions*

VErtex LOcator (VELO)

VELO sensors aligned within 4.4 μm
Accuracy and stability of two VELO halves is better than 10 μm in X/Y and 25 μm in Z

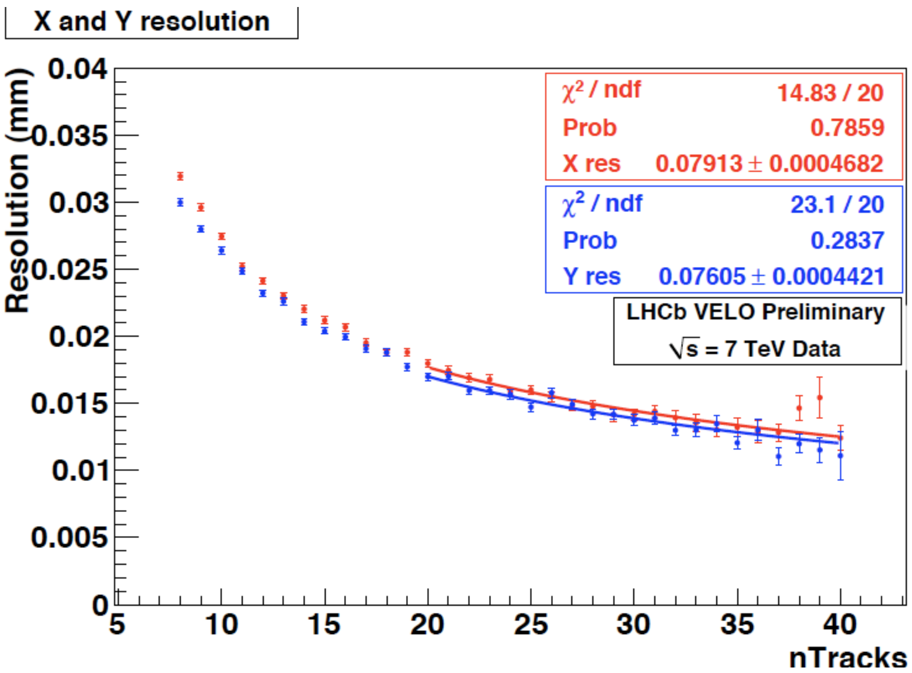


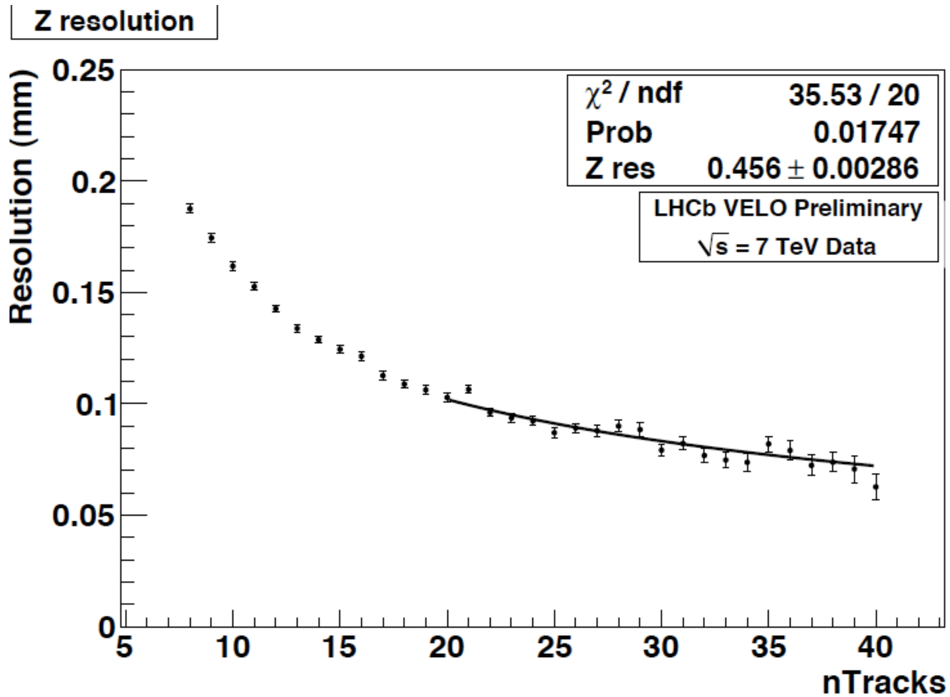
Best VELO hit resolution is 4 μm
Great achievement !!!



Primary Vertex (PV) resolution

Evaluated in data using random splitting of the tracks in two halves and comparing vertices of equal multiplicity



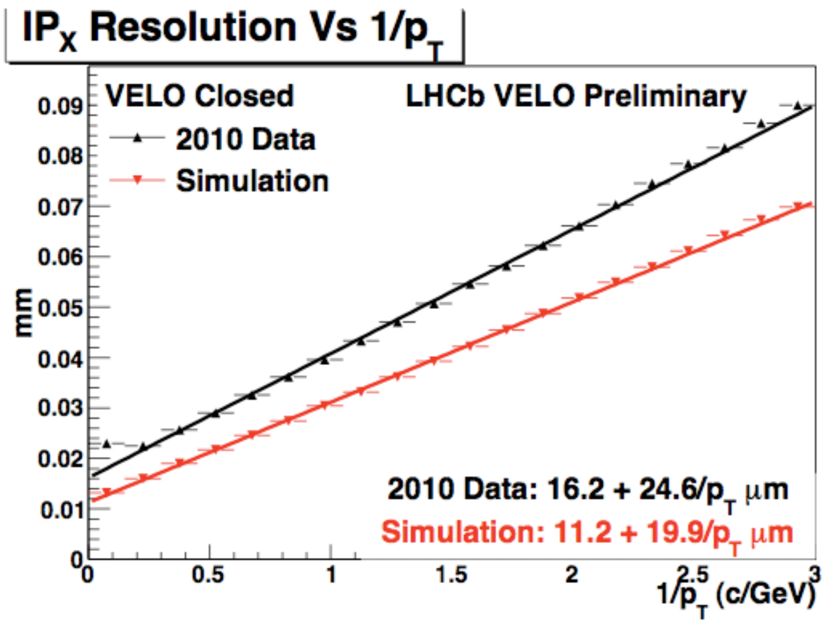


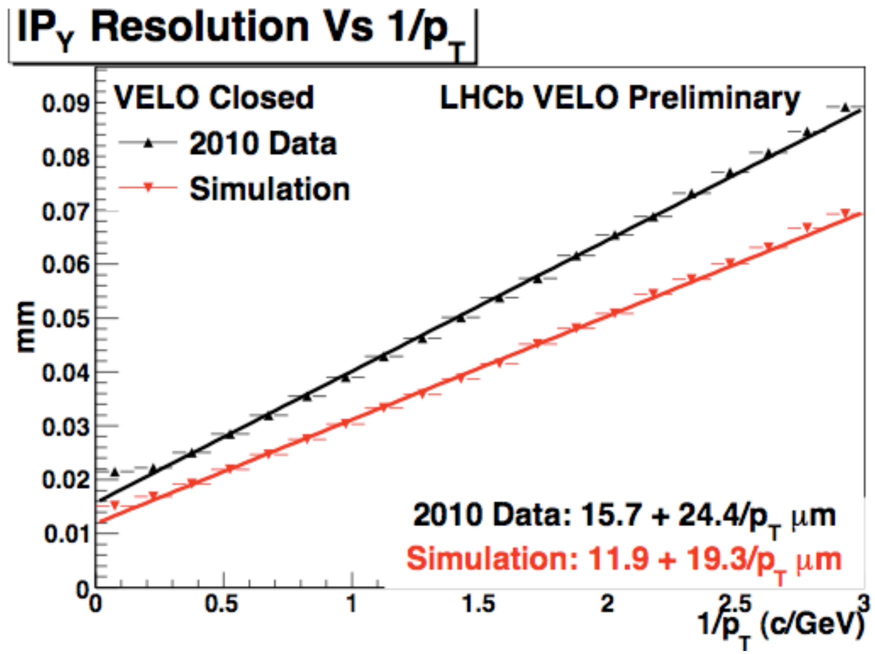
Resolution for PV with 25 tracks

~ 15 μm for ***X*** *&* ***Y*** *and ~ 90 μm for Z*

Further improvement is expected with better VELO sensor and module alignment

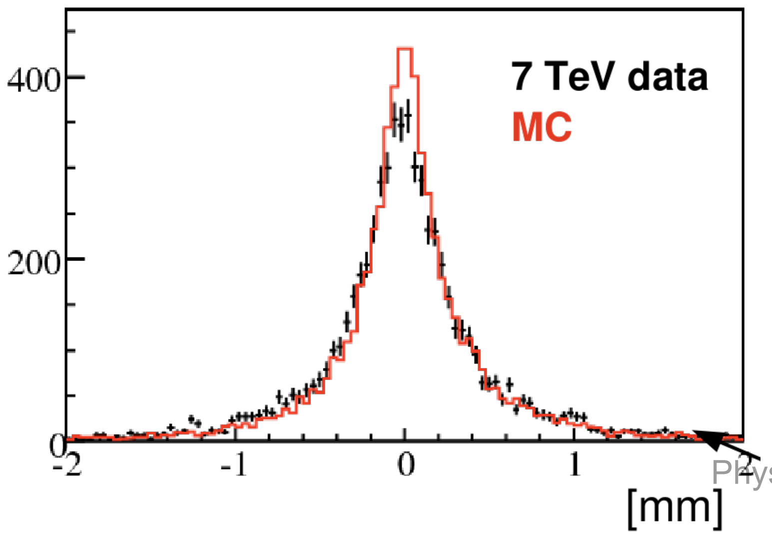
Impact Parameter resolution (~1/p_T)



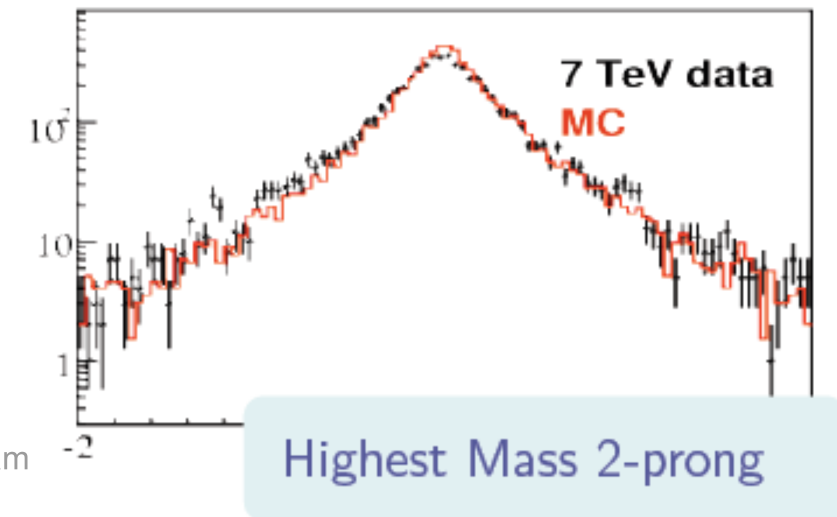


Decay length as expected

two-prong decaylength



two-prong decaylength



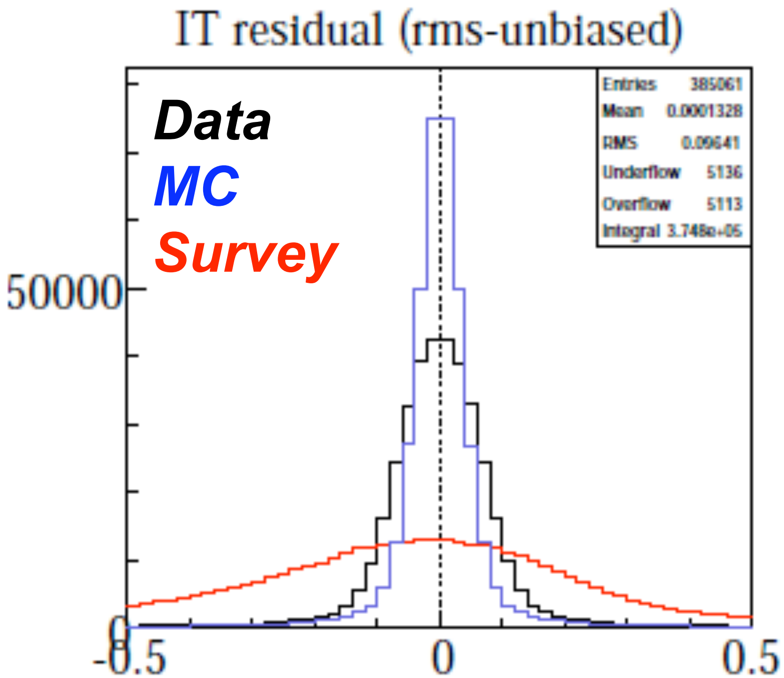
Silicon Trackers (IT & TT)

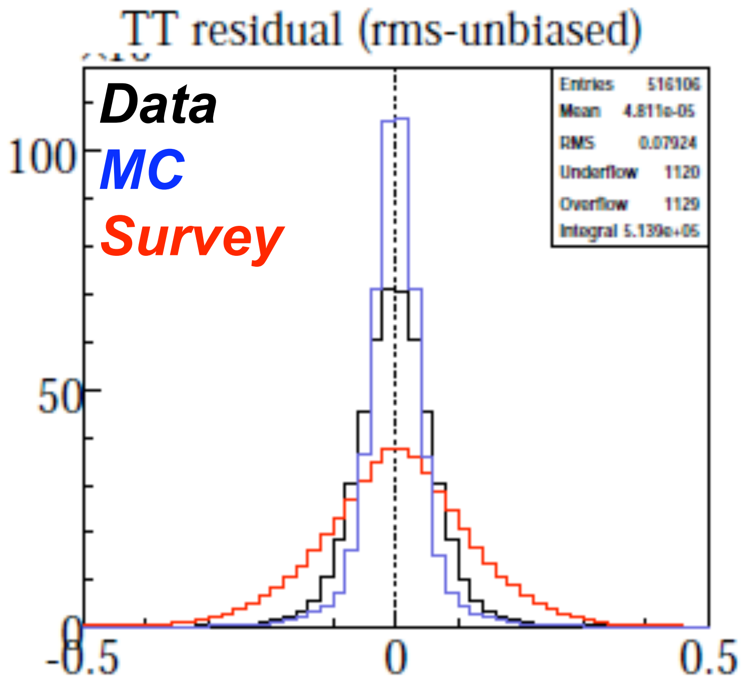
Alignment is ongoing

Current status:

Width of residuals in data ~ 65 μm

MC expectation is 50 μm

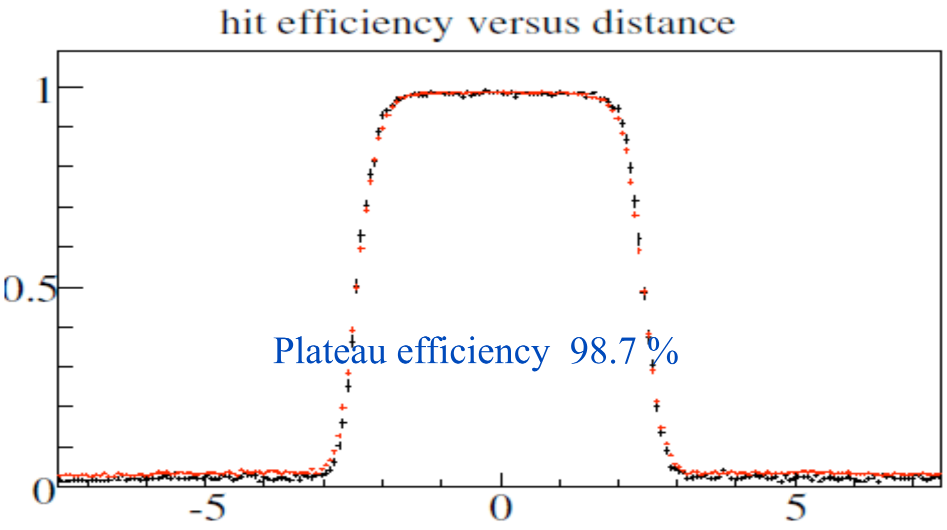




Outer Tracker (OT)

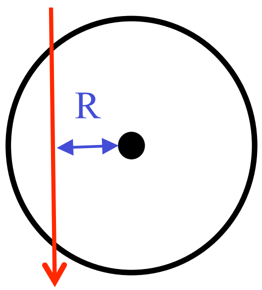
Cell efficiency profile:

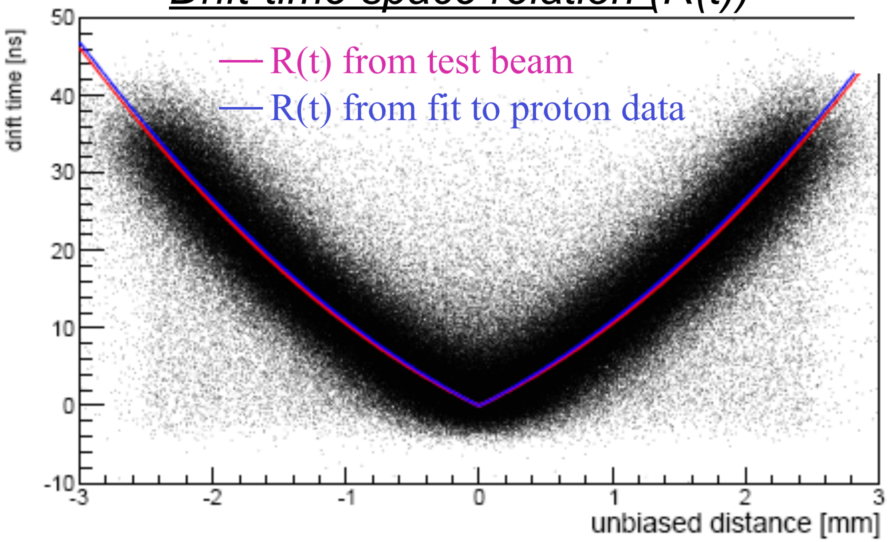
Efficiency vs. distance in mono layer plane



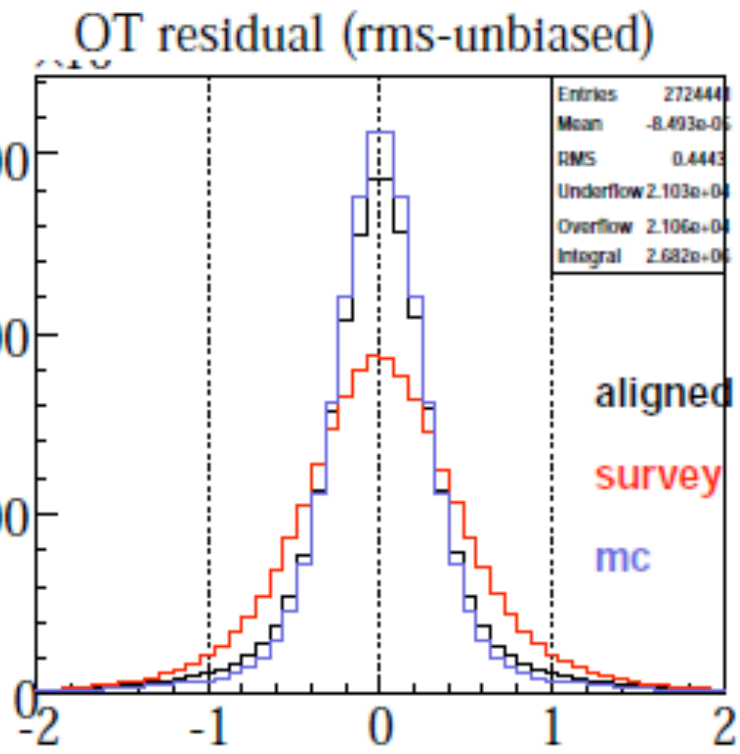
Drift-time space relation (R(t))

straw tube



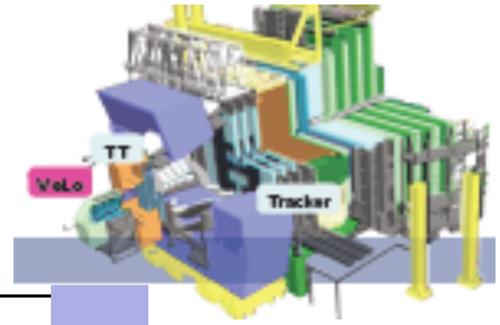


Hit residuals:

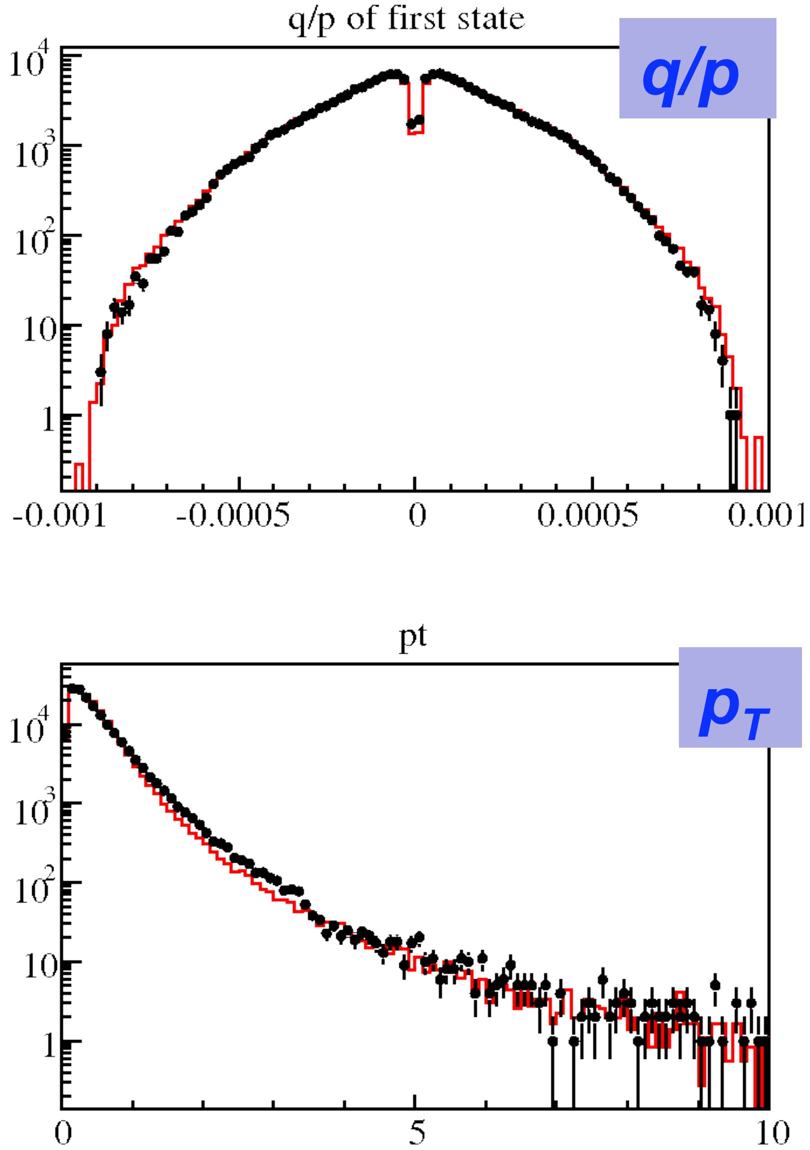


OT aligned reasonably well

Tracking performance

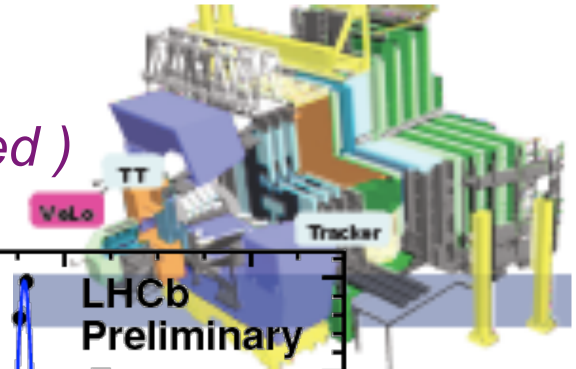


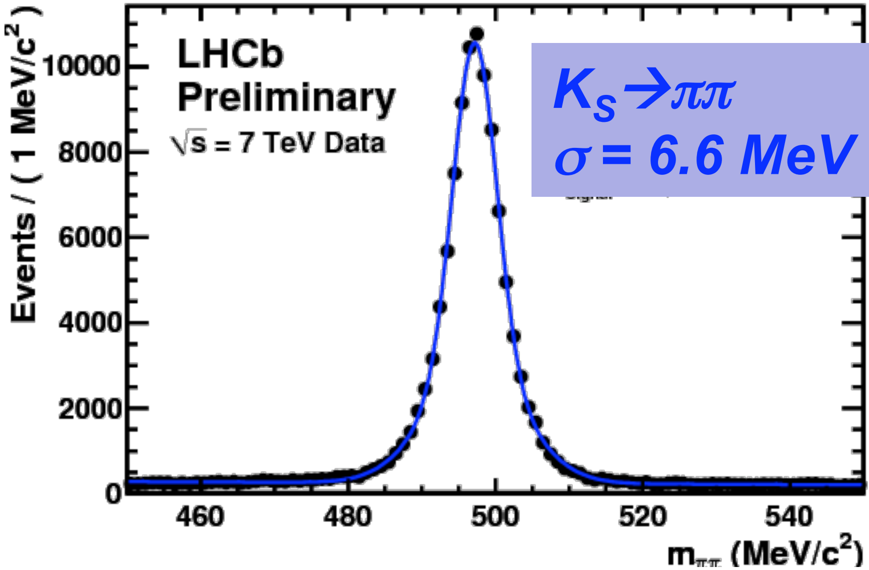
Good agreement between data and MC



Tracking performance

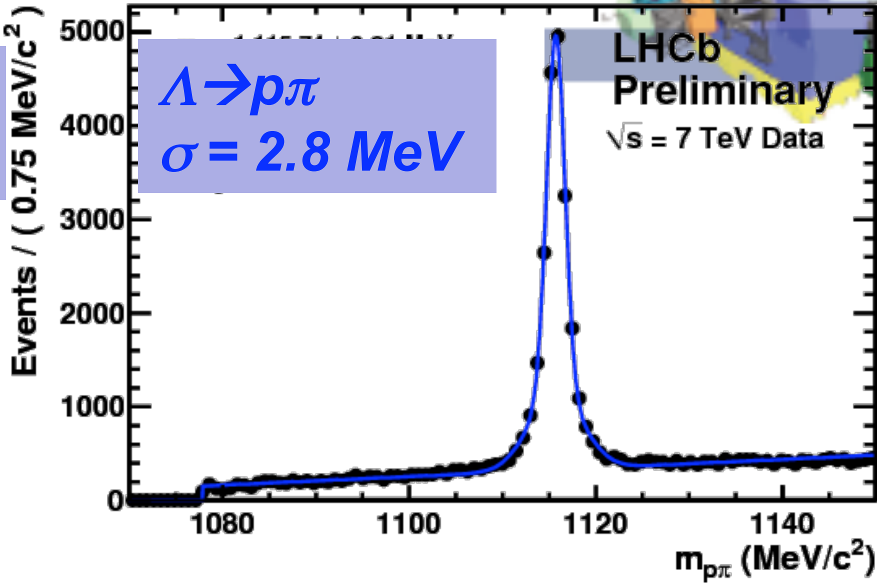
(mass resolution of reconstructed particles as expected)





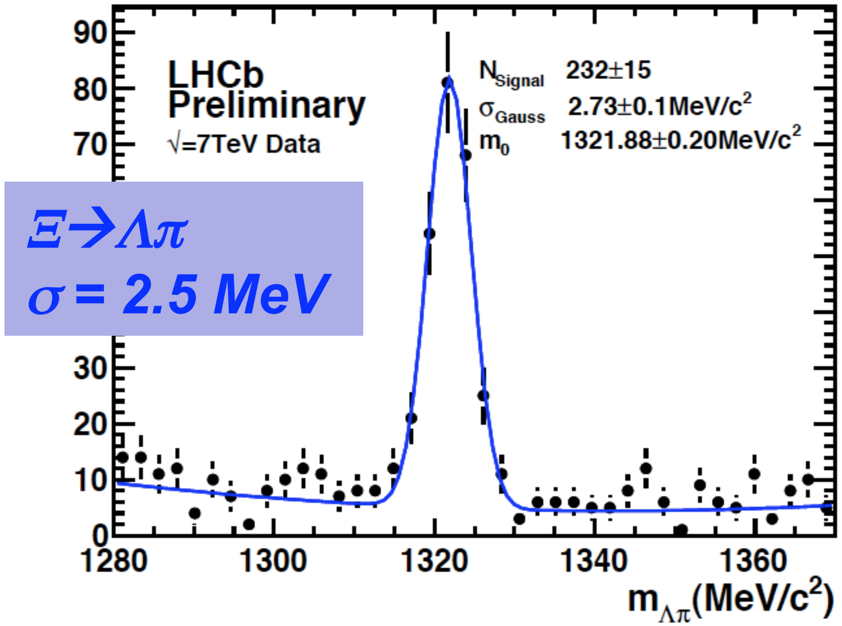
$K_S \rightarrow \pi\pi$

$\sigma = 6.6$ MeV



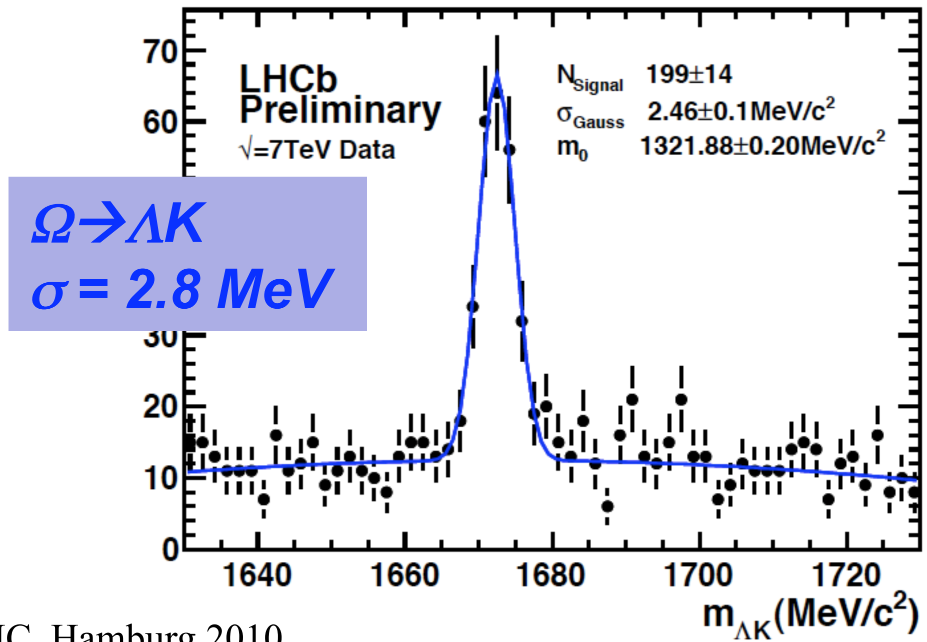
$\Lambda \rightarrow p\pi$

$\sigma = 2.8$ MeV



$\Xi \rightarrow \Lambda\pi$

$\sigma = 2.5$ MeV



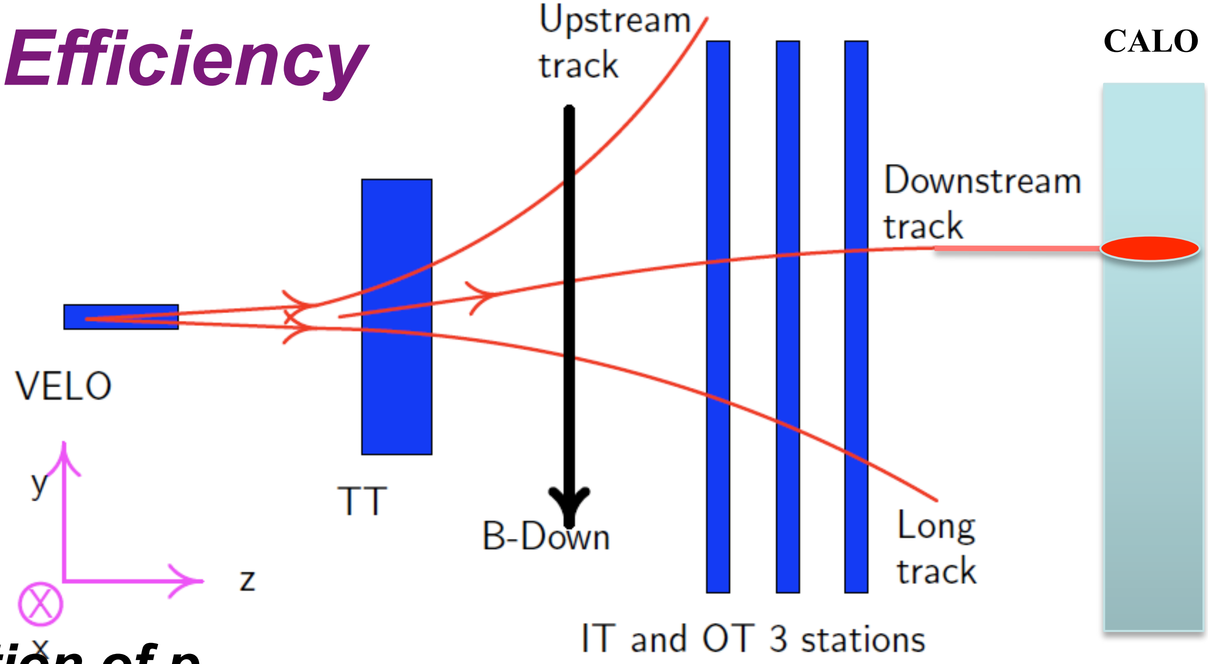
$\Omega \rightarrow \Lambda K$

$\sigma = 2.8$ MeV

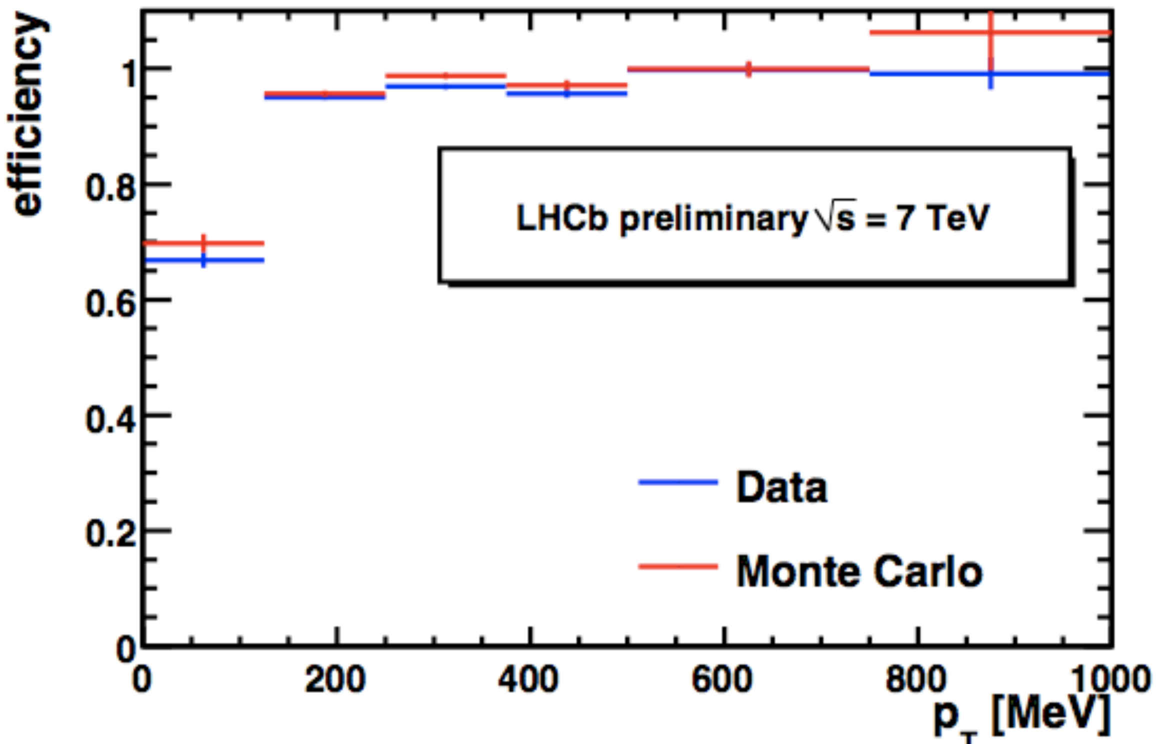
Tracking Efficiency

Obtained using K_S candidates:

$$\varepsilon = \frac{Tracks^{(VELO + IT/OT+CALO)}}{Tracks^{(VELO + CALO)}}$$



Efficiency as a function of p_T



Limitation of the method:

- *VELO tracking eff. is not probed*
- *Restrictive phase-space, i.e. K_S decay products phase space*

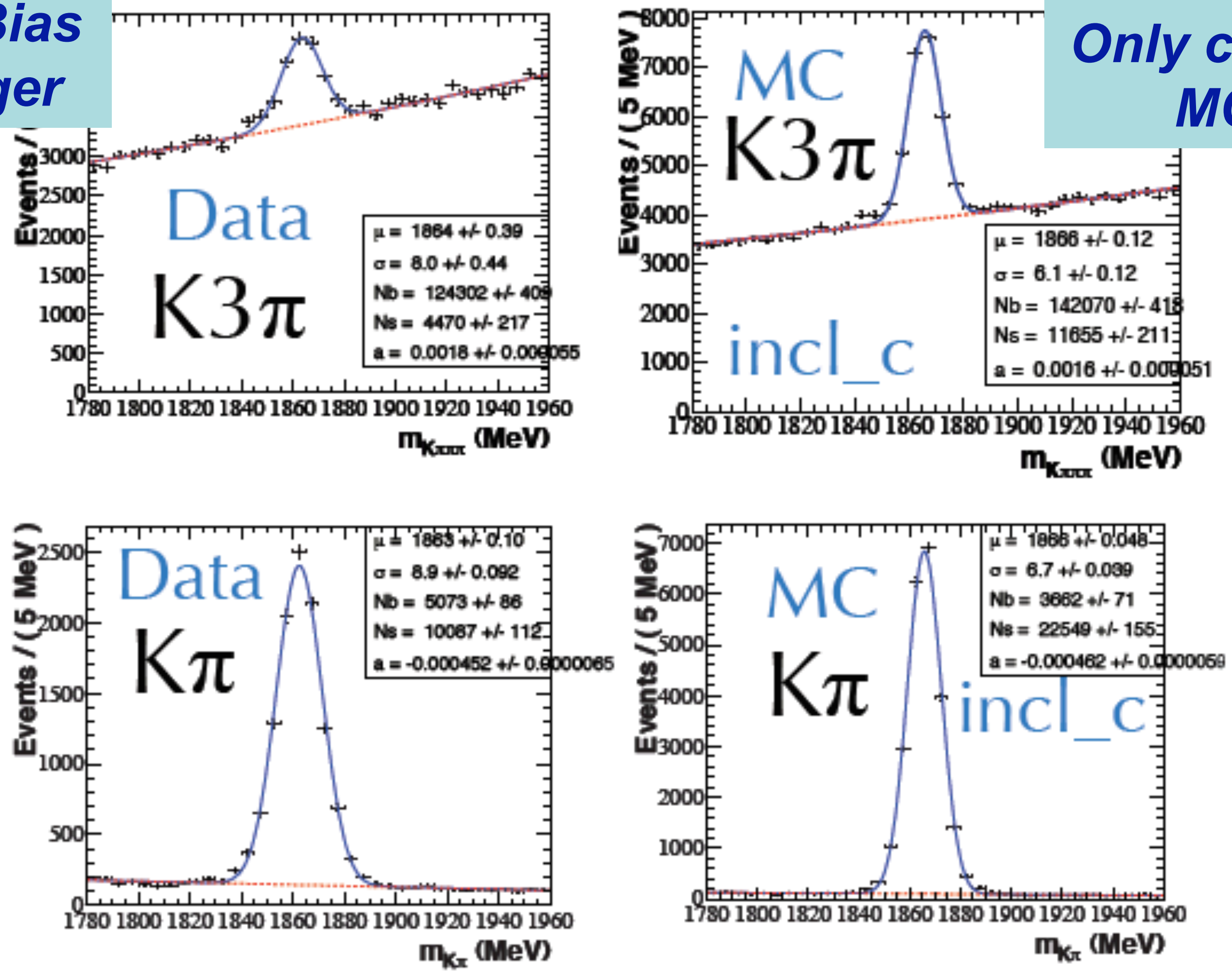
Tracking efficiency systematics

(D→Kπ vs D→K3π)

$\varepsilon(\text{Track}) \propto \sqrt{N(K\pi\pi\pi)/N(K\pi) * BR(K\pi)/BR(K\pi\pi\pi)}$

Min.Bias Trigger

Only charm MC

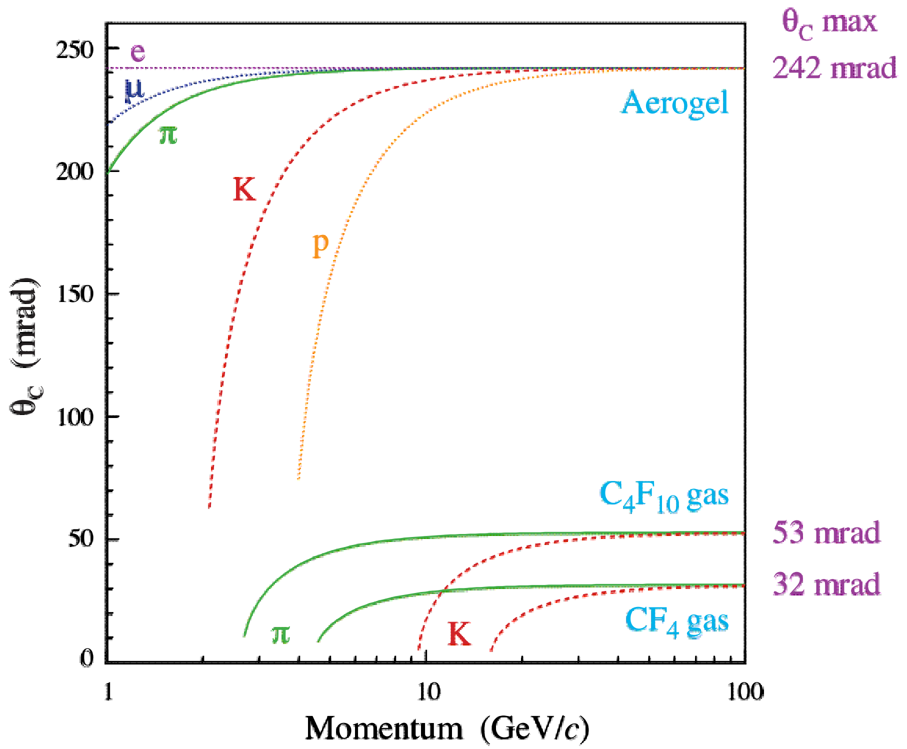


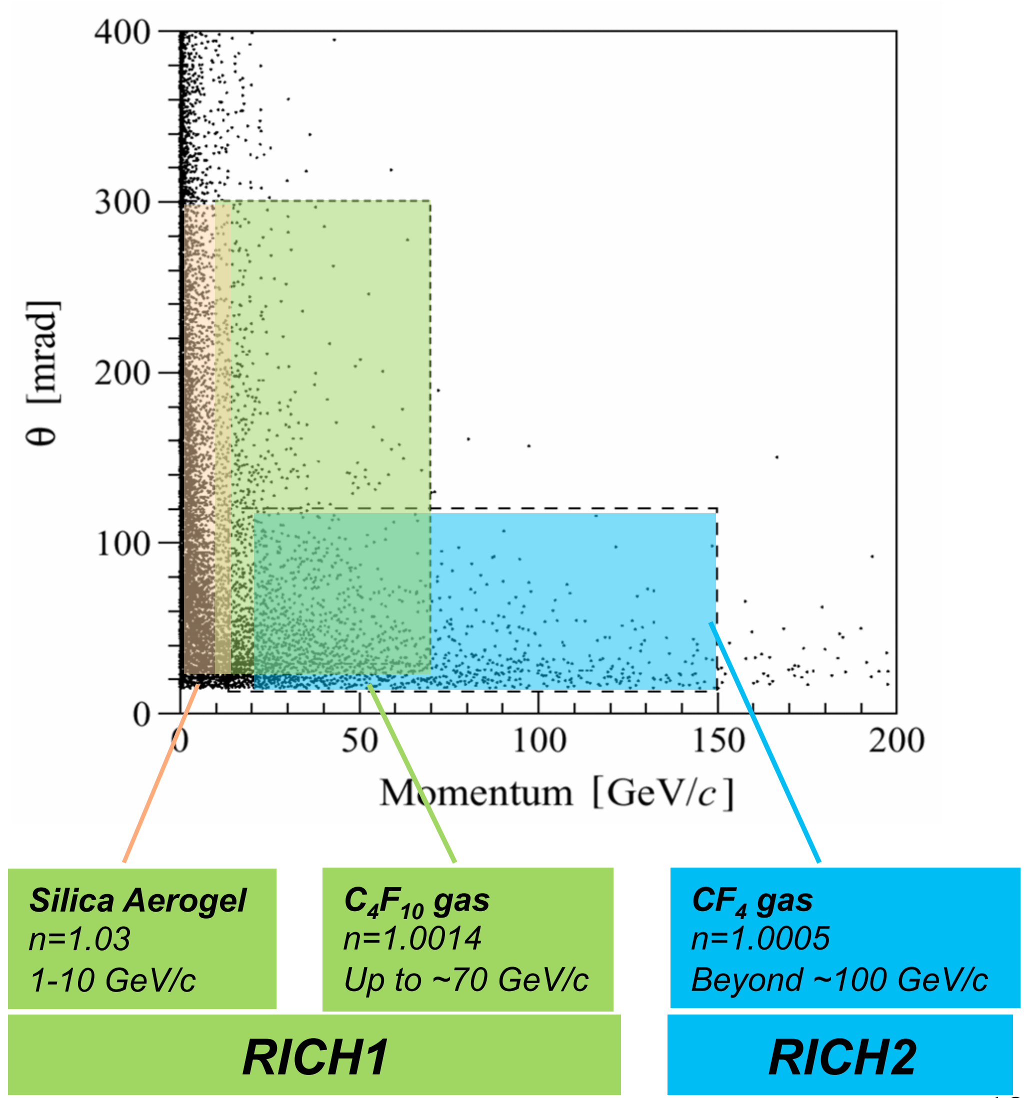
ε(Data) / ε(MC) = 1.03 ± 0.03

Particle Identification (RICH, CALO, MUON)

RICH provides π / K / p separation

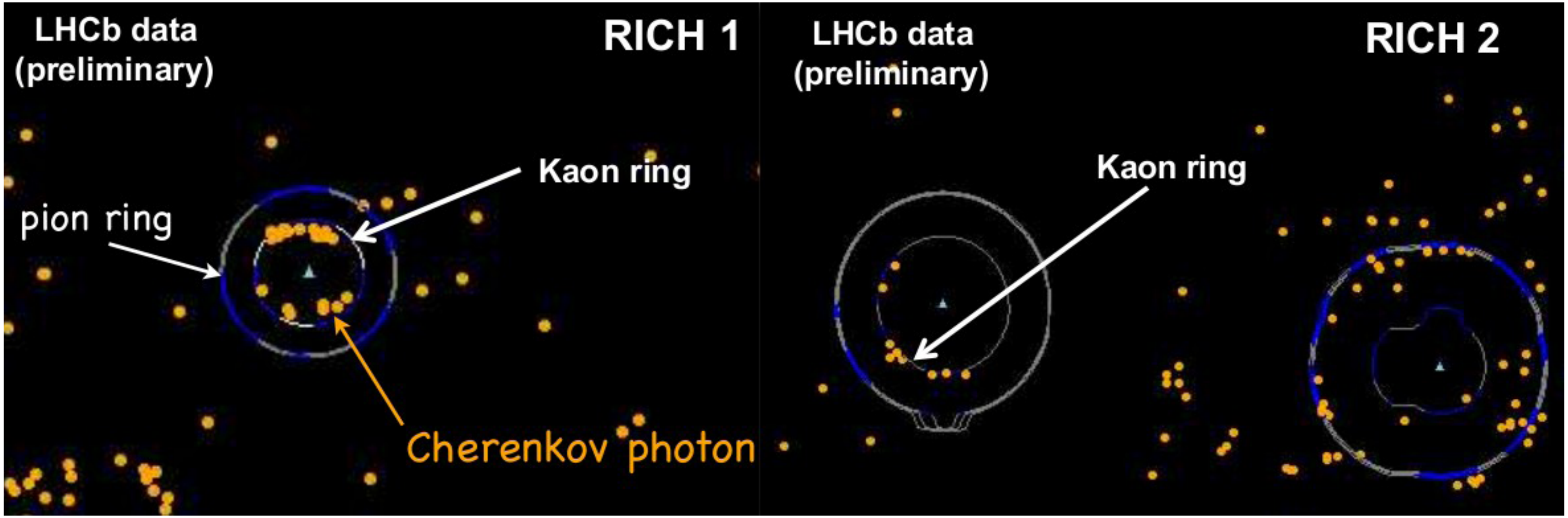
- *3 radiators*
- *1-100 GeV coverage*





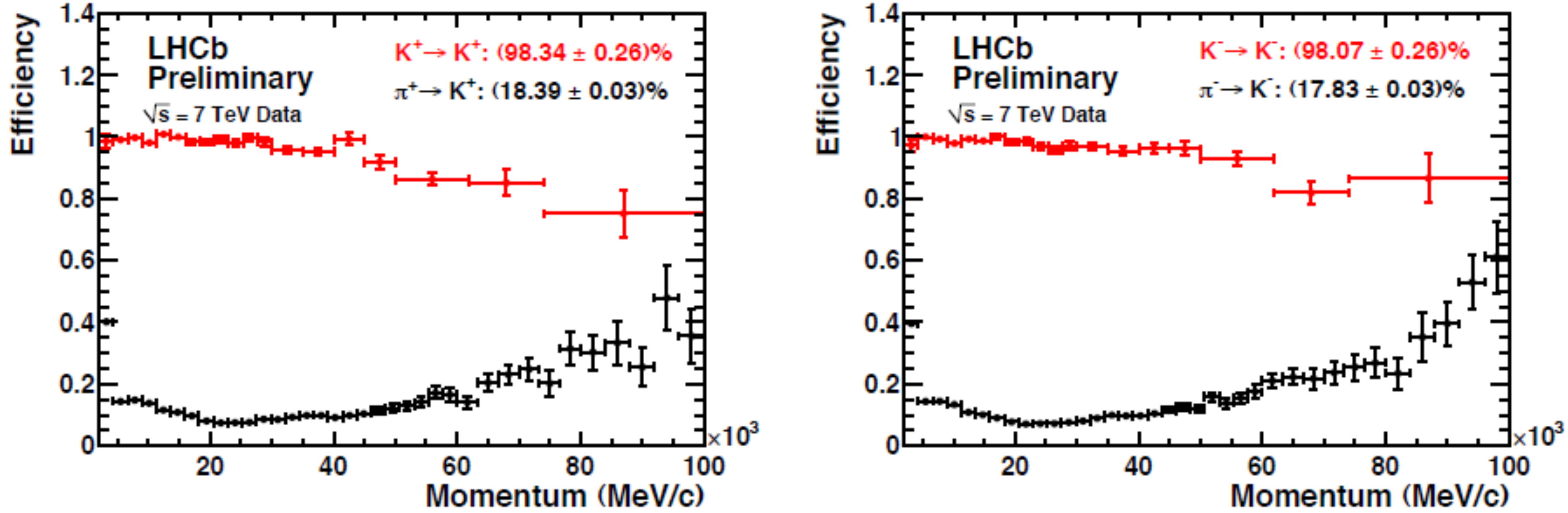
PID with RICH

- *RICHes aligned with tracking system;*
- *Clear kaon and pion rings seen:*

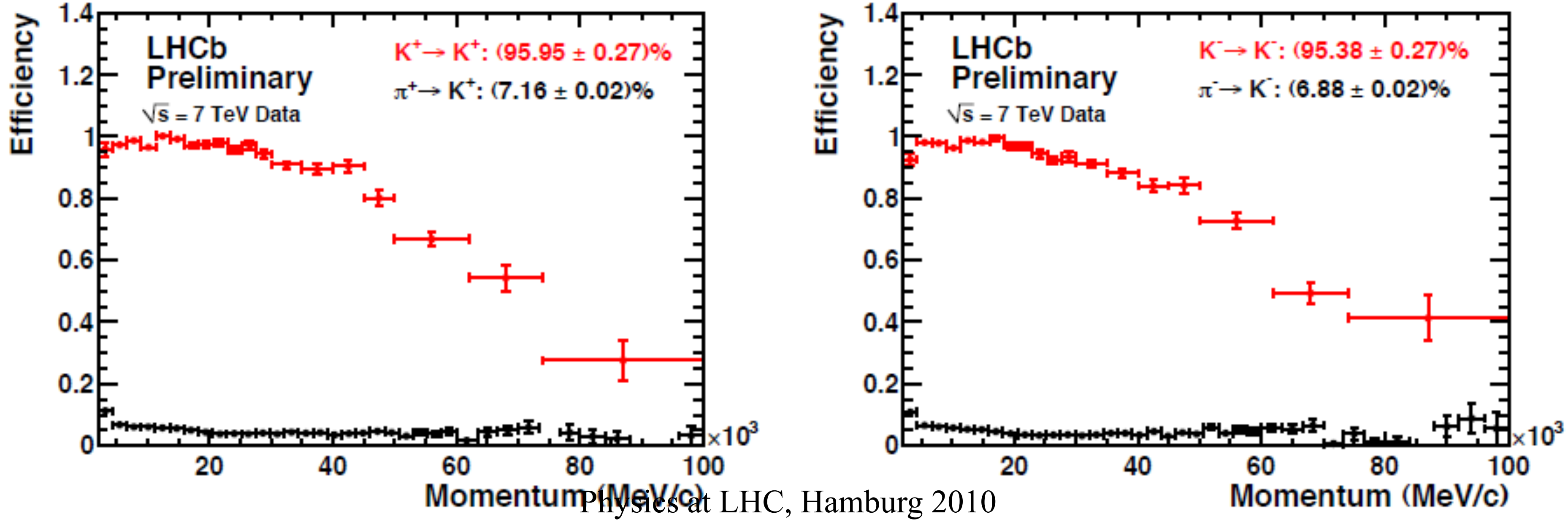


PID with RICH

$$\Delta \log \mathcal{L}(\mathrm{K} - \pi) > 0$$

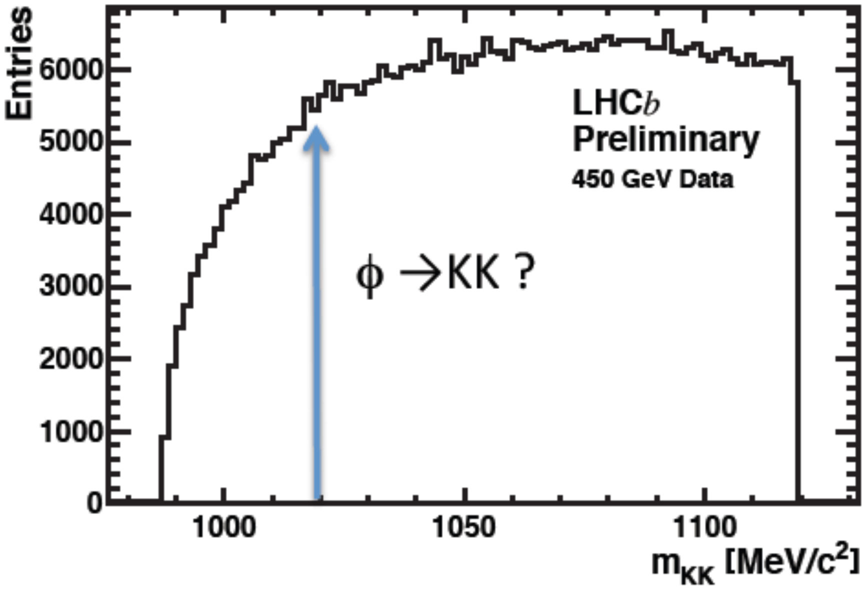


$$\Delta \log \mathcal{L}(\mathrm{K} - \pi) > 5$$

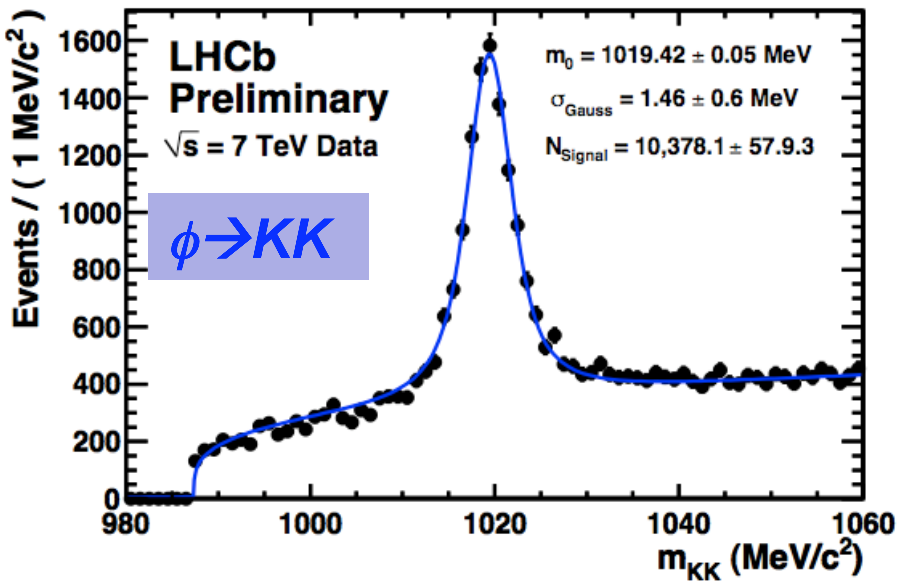


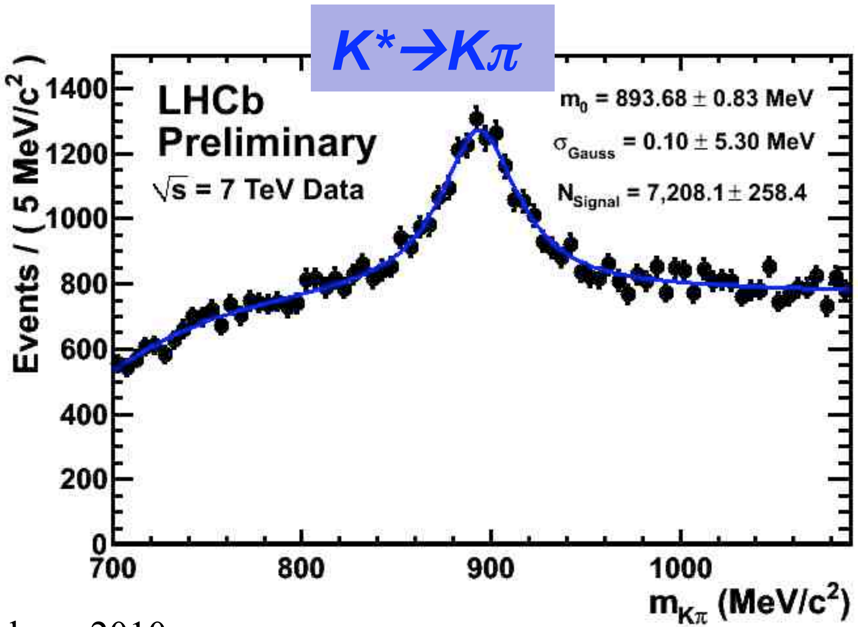
PID with RICH

without RICH



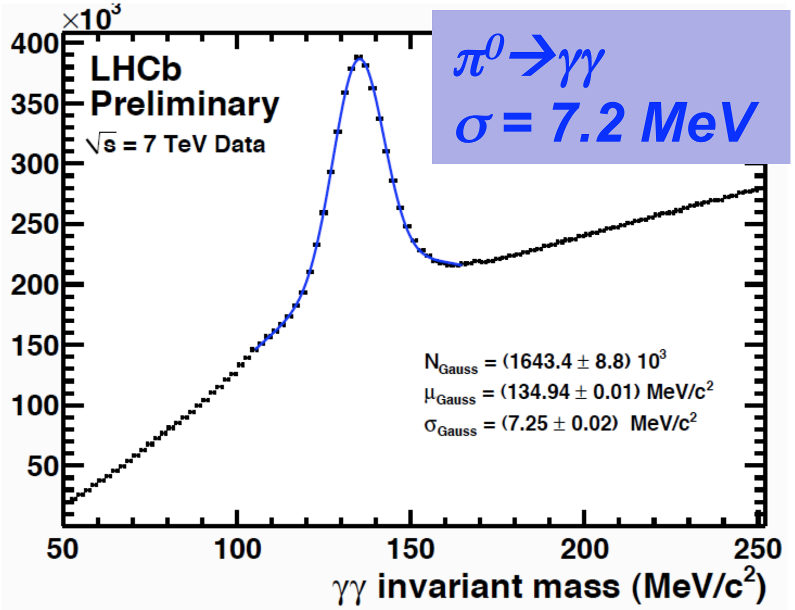
with RICH





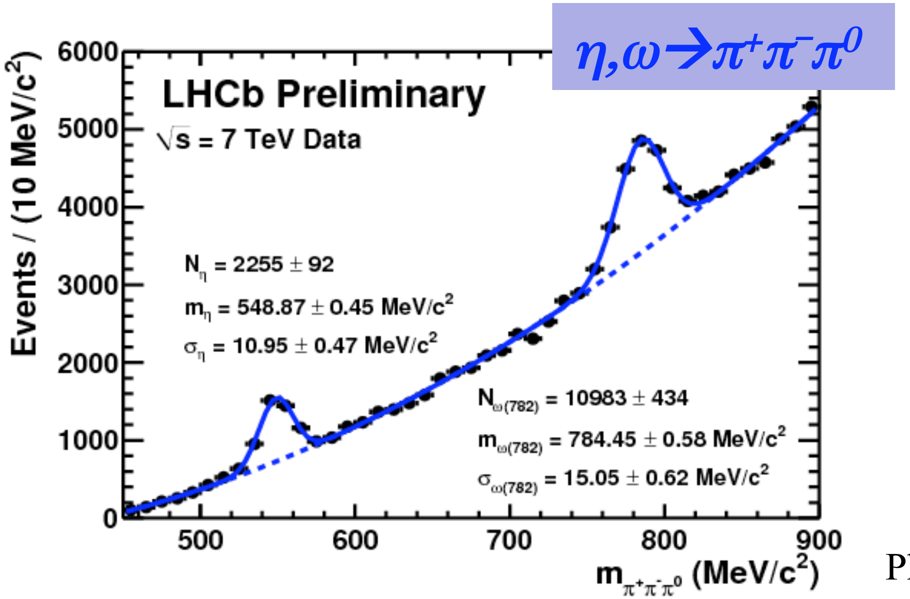
PID with Calorimeter

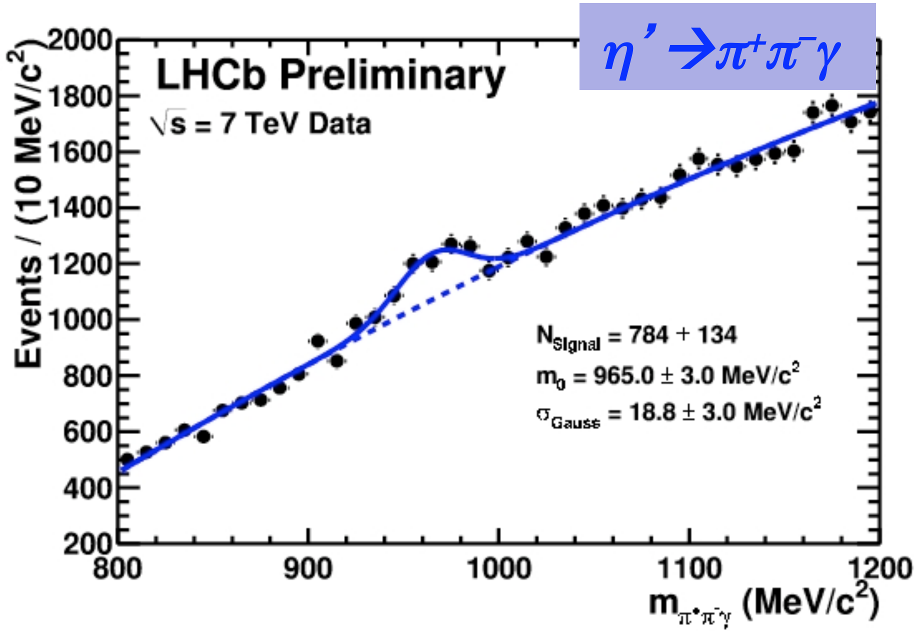
(identification of electrons and photons)



ECAL is calibrated to 2% level
π^0 resolution is better than expected

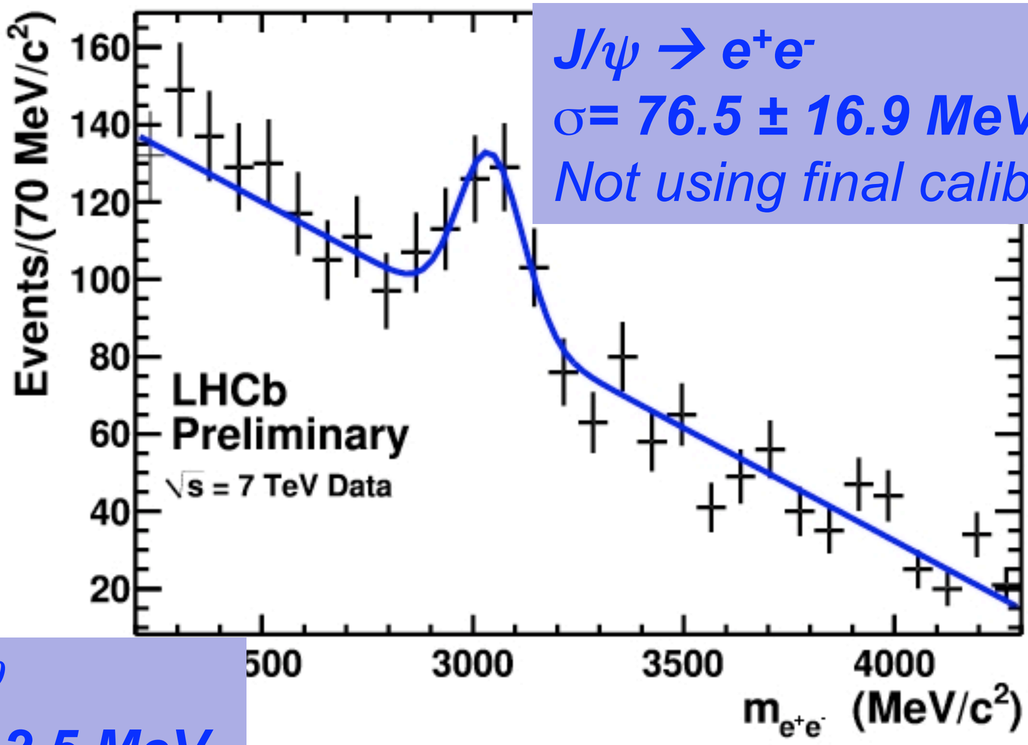
Many signals with neutrals in the final states have been reconstructed !!!



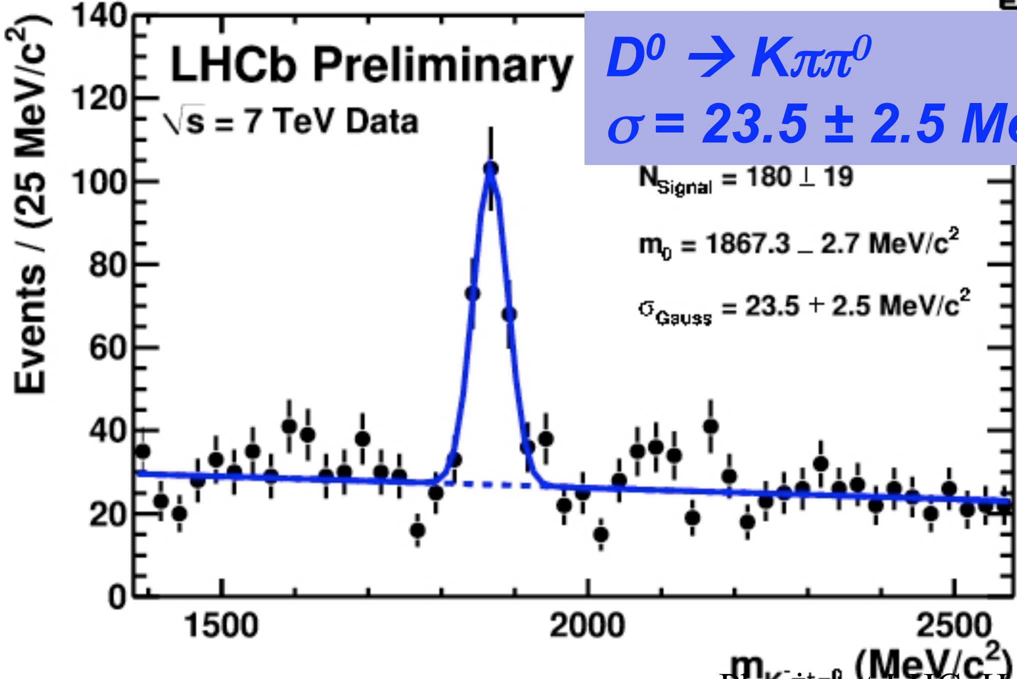


CALO performance for the core program

Clear J/ψ signal is reconstructed in e^+e^- decay mode. Resolution (Gaussian fit) is only slightly worse than expected



J/ψ → e^+e^-
σ= 76.5 ± 16.9 MeV
Not using final calibration

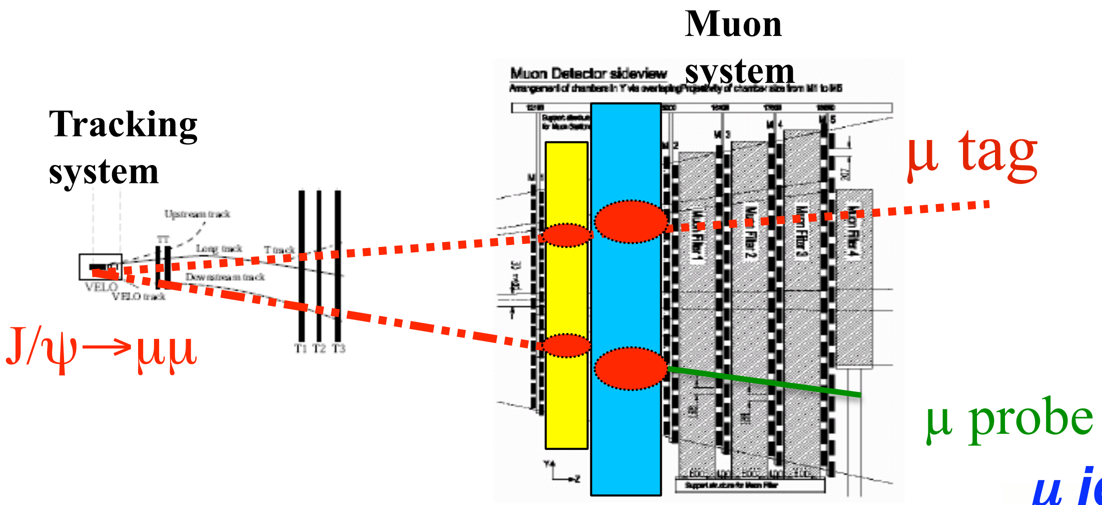


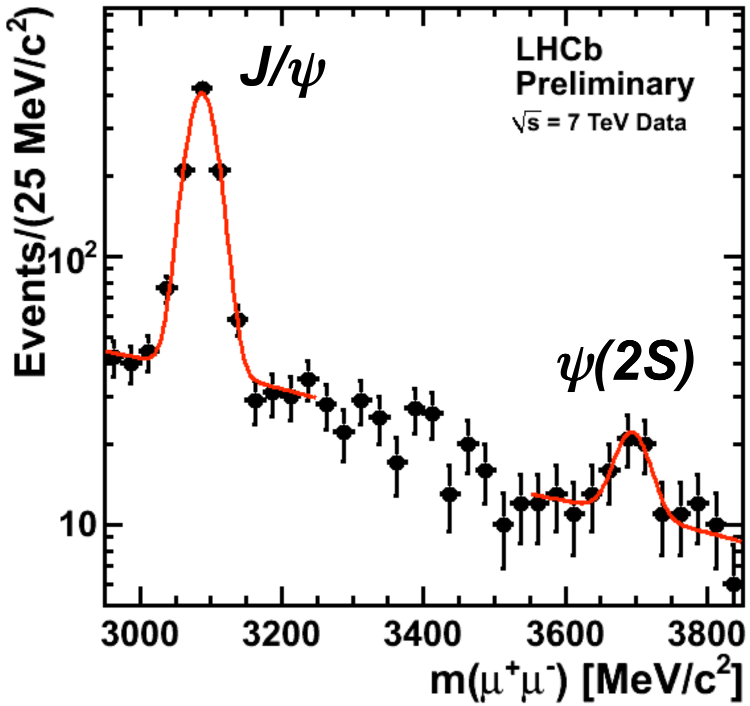
D^0 → $K\pi\pi^0$
σ = 23.5 ± 2.5 MeV

Reconstruction of D decays in the final states with neutrals looks encouraging !

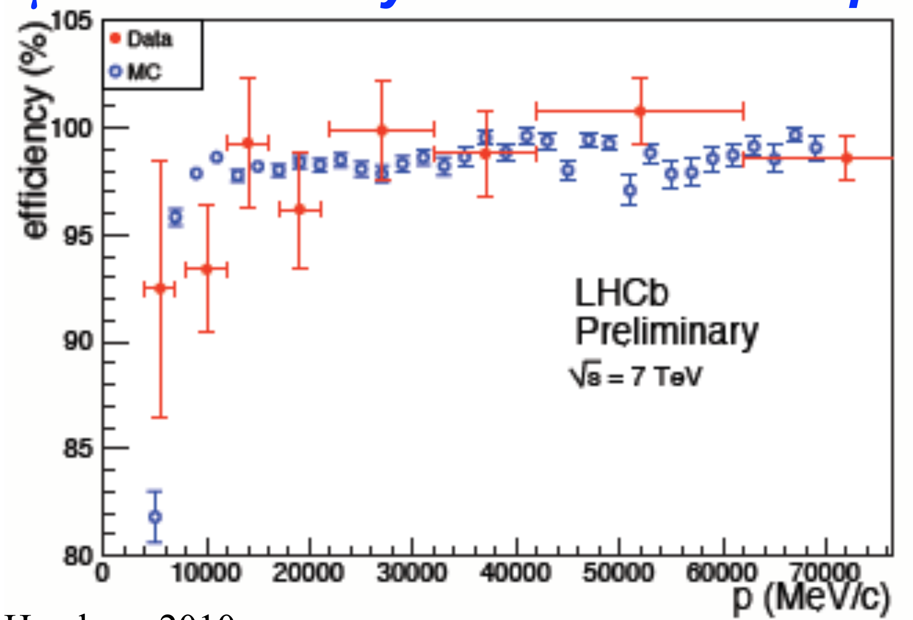
PID with MUON

(muon identification efficiency using reconstructed J/ψ)





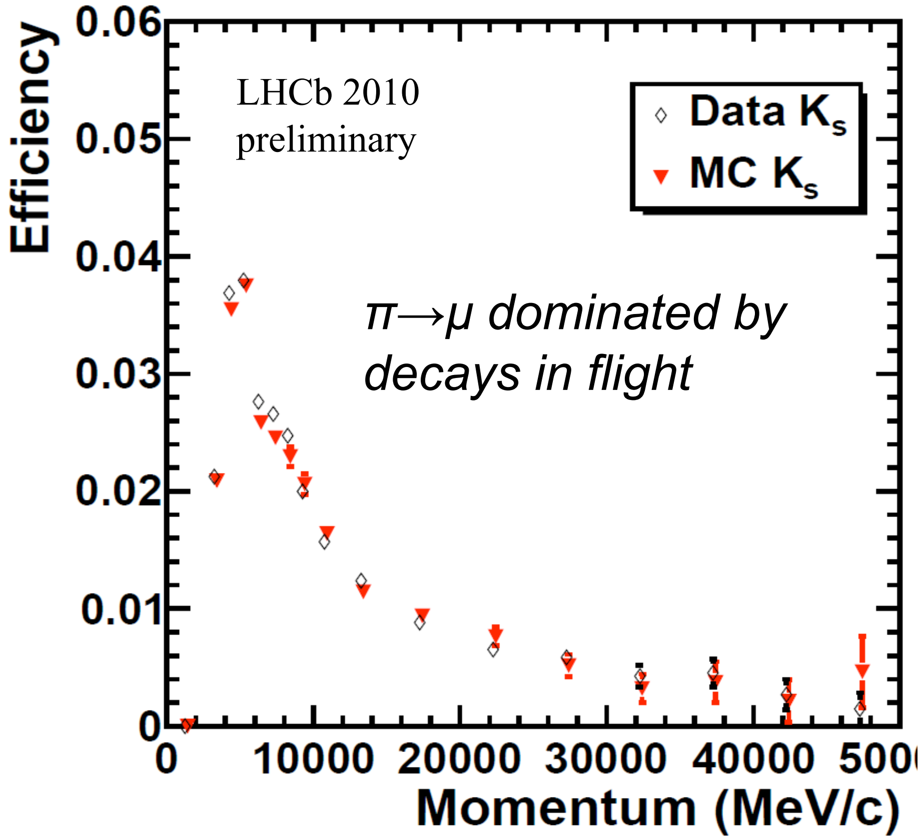
μ id. efficiency as a function of p

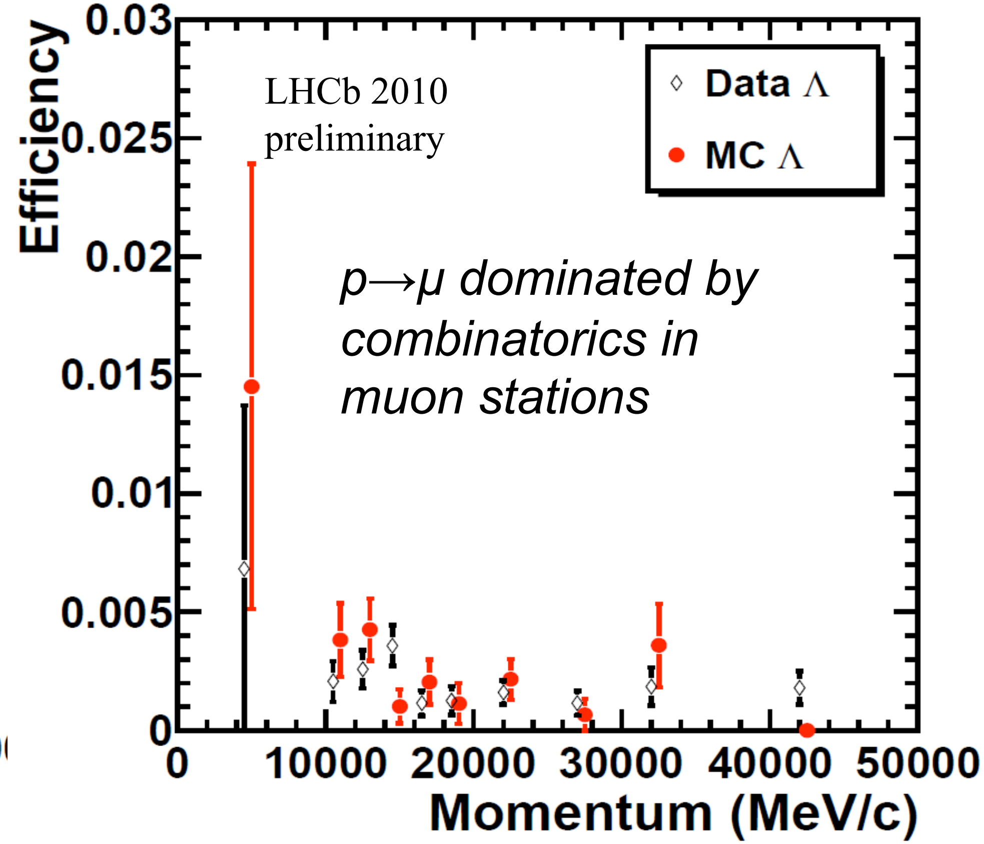


$\varepsilon(\mu) = (\ 97.3 \pm 1.2\ )\%$

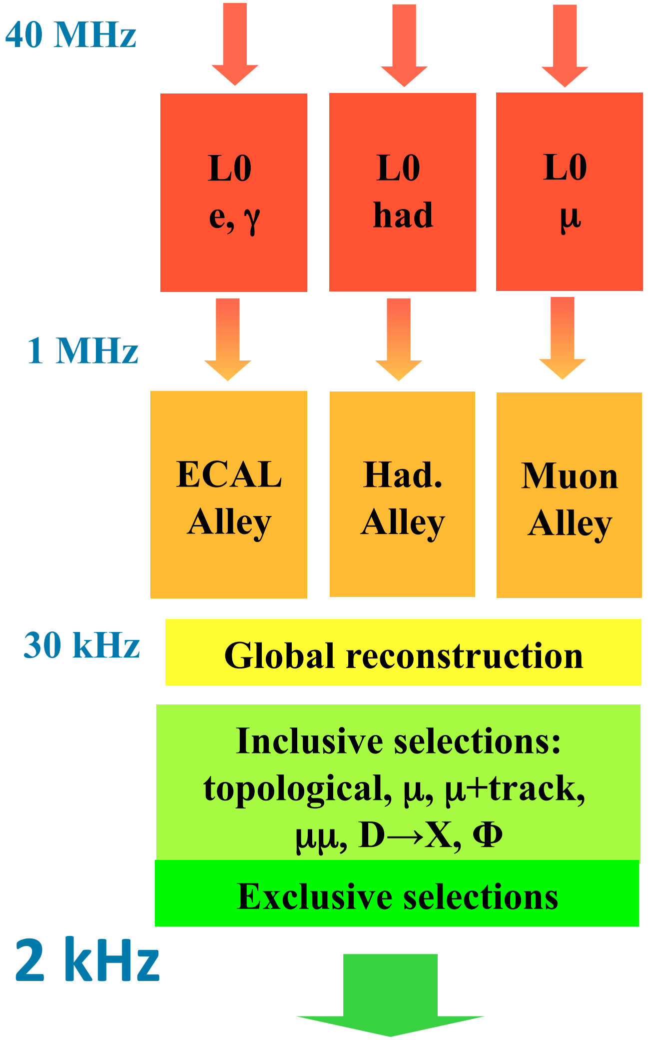
PID with MUON

$\mu-\pi$ and $\mu-p$ misidentification rates have been determined using large samples of $K_S \rightarrow \pi\pi$ and $\Lambda \rightarrow p\pi$ decays





LHCb Trigger



Level-0

'High-pt' signals in calorimeter & muon systems

HLT1

Associate L0 signals with tracks, especially those in VELO displaced from PV

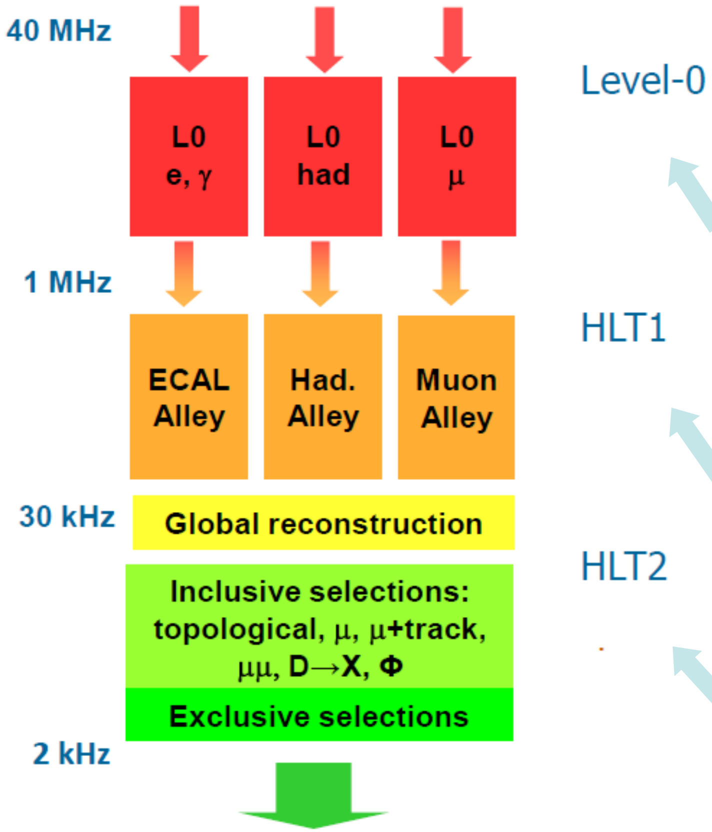
HLT2

Full detector information available. Continue to look for inclusive signatures, augmented by exclusive selections in certain key channels.

At LHCb design luminosity (2 x 10^{32} cm^{-2} s^{-1}) all thresholds must be optimised for B-physics, and consequently trigger efficiency for D decays from prompt-production is as low as ~ 10%. Still adequate for accumulating very large samples, but corresponding efficiencies for hadronic B-decays ~4x higher

LHCb Trigger in 2010

For bulk of running foreseen this year, with luminosities up to a few 10^{31} cm^{-2} s^{-1} , we can afford to relax many of our trigger cuts, with large benefits for efficiencies



2010 approach

Apply very low pt cuts – main purpose of L0 is now to seed HLT1 regions of interest

Reduce requirements on track impact parameter w.r.t. nominal settings

Not needed at all initially, then introduce with rather loose suppression requirements

Boost trigger efficiencies for hadronic decays of promptly produced D's by factor 4-5 w.r.t. nominal settings. Golden opportunity for charm physics studies ! Total efficiencies for hadronic B decays now 75-80%, with those for leptonic decay modes >90%.

Strategy for trigger settings in 2010

Few fills at injection energy

- *450 GeV, 2-4 bunches $5 \cdot 10^{10}$ p colliding,*
  $\beta^* = 10$ => rate ~(few) 100 Hz

Ramp in energy

- *3.5 TeV, 2 bunches $1 \cdot 10^{10}$ p colliding,*
  $\beta^* = 10$ => rate ~100 Hz

Squeeze of β^*

- *3.5 TeV, 2 bunches $1 \cdot 10^{10}$ p colliding,*
  $\beta^* = 2$ => rate ~500 Hz

Increased bunch charge

- *3.5 TeV, 2 bunches $2 \cdot 10^{10}$ p colliding,*
  $\beta^* = 2$ => rate ~1 kHz

Increasing number of bunches

- *3.5 TeV, 19 bunches $2 \cdot 10^{10}$ p colliding,*
  $\beta^* = 2$ => rate ~20 kHz

Evolution of luminosity in first few months

mbias triggers based on Level 0 objects: muon p_T, hadron p_T, Pile-Up System

L0 and HLT optimized for prompt Charm and Beauty + (mbias & random triggers) downscaled

Prompt charm efficiency increased by more than a factor 4 w.r.t. design settings without loss in b-physics

Optimized for Beauty Physics

- ***When moving to crossing angle and 50 ns bunch spacing we expect $L \sim 1\text{-}2 \cdot 10^{32}$ cm^{-2}s^{-1} with ~200 pb^{-1} in 2010 and ~1 fb^{-1} in 2011***

  (~1/2 of a nominal year for LHCb)

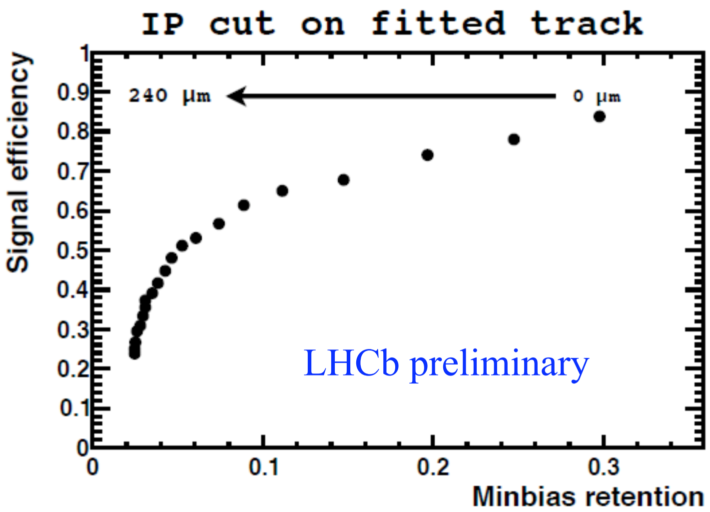
Trigger Efficiencies

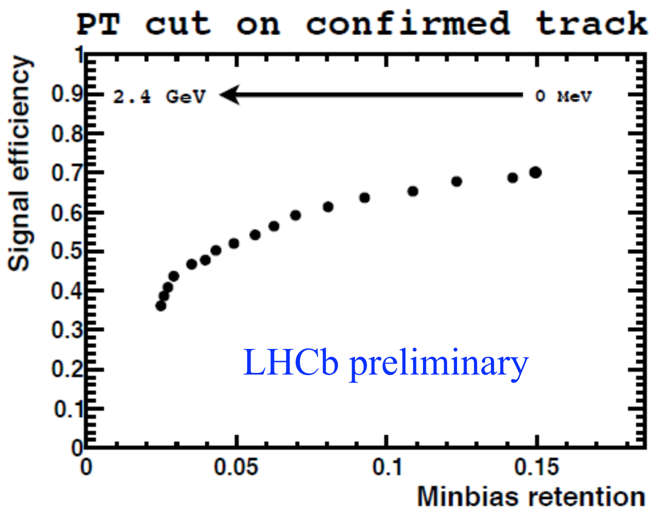
Take D*, $D^0 \rightarrow K\pi$ signal collected in minimum bias events
&
Evaluate L0*HLT1 performance with 2010 low luminosity trigger settings

good agreement with MC

Eff-trig$_{L0*HLT1}$(data) = 60 ± 4 %
MC expectation = 66 %

Performance of single-hadron HLT1 line on data

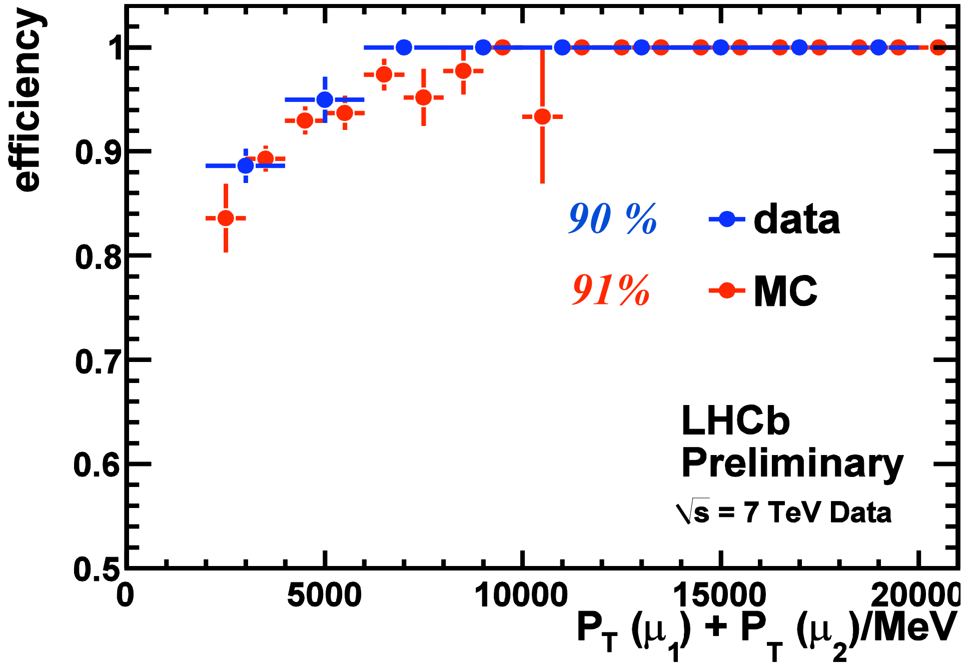




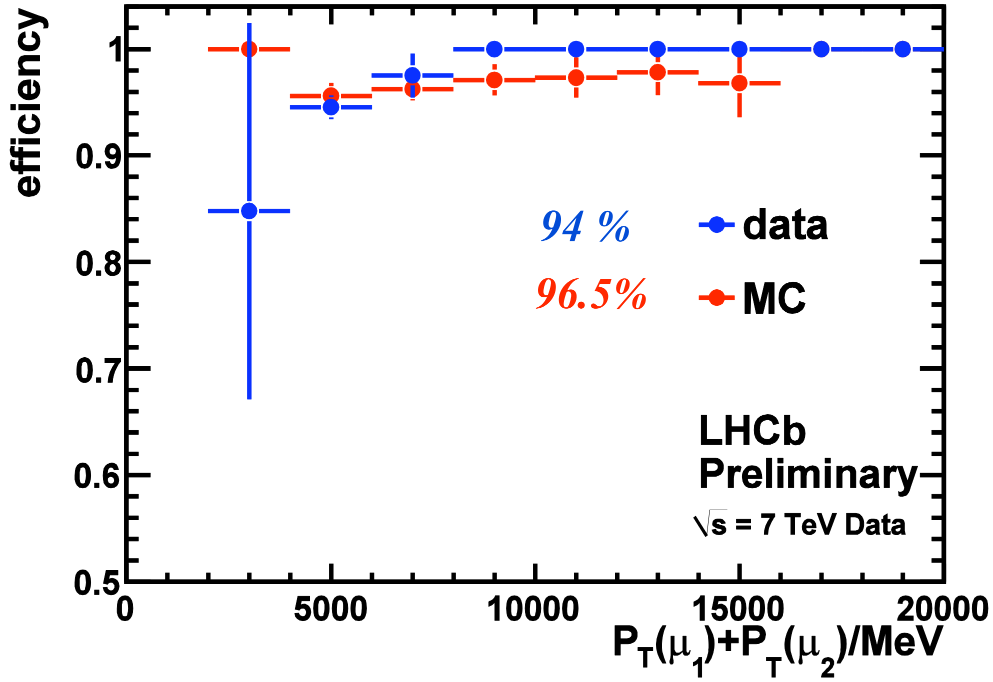
Trigger Efficiencies

- *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

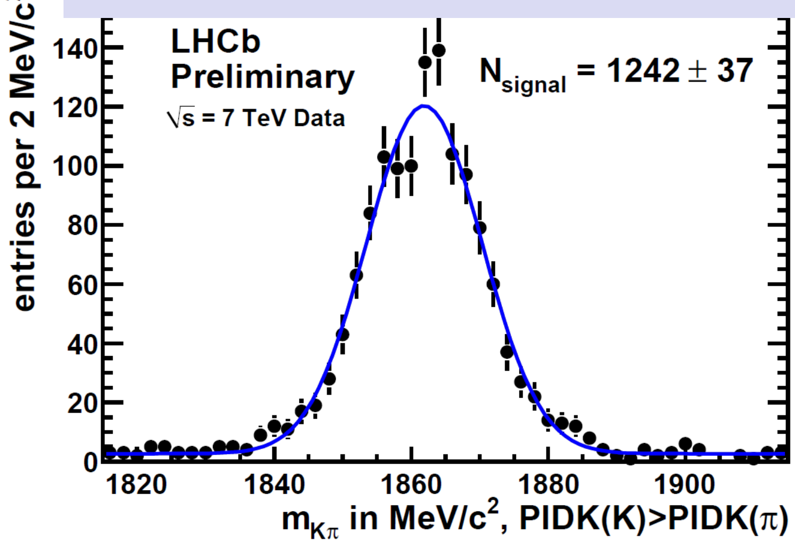
LHCb trigger concept has been proven with data !!!

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

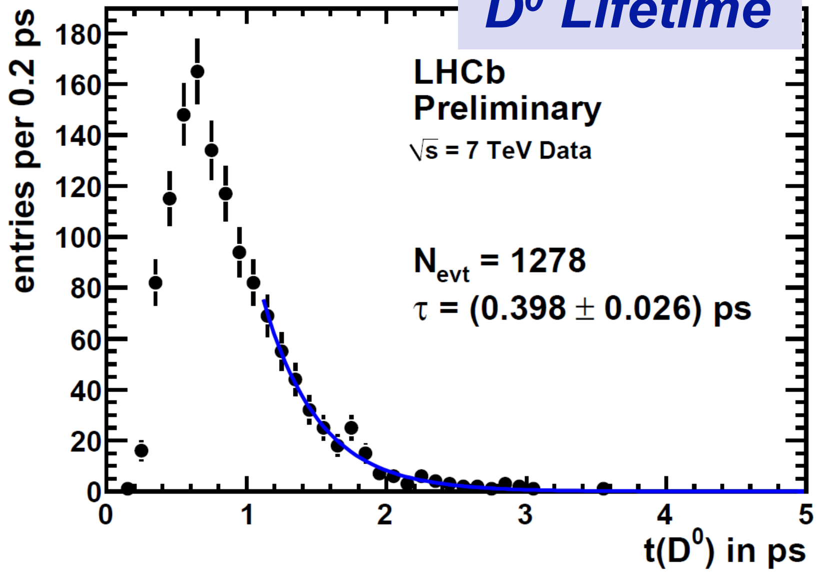
Proper Lifetime

(use sample of D^0 for calibration; D^0 lives 3.5 times shorter than B^0)

Clean sample of untagged $D^0 \rightarrow K\pi$



D^0 Lifetime



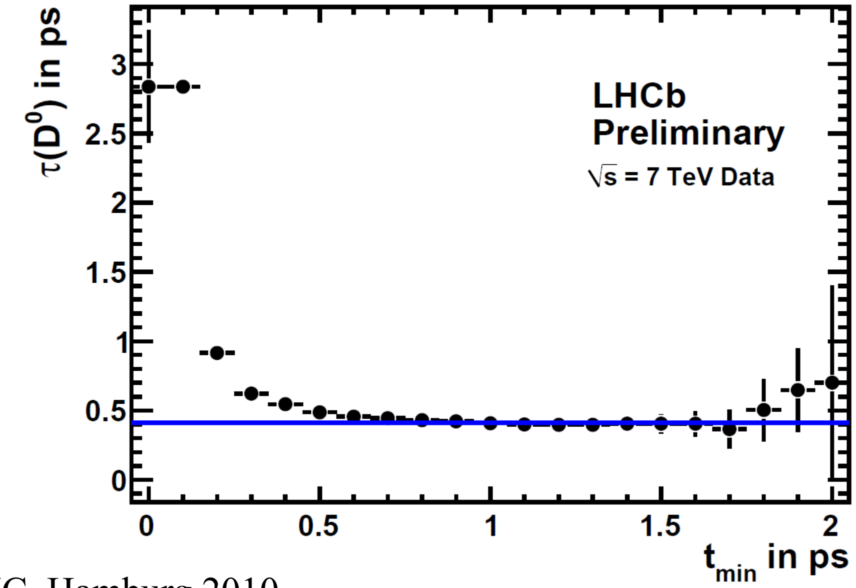
LHCb Lifetime fit gives:

$$\tau(D^0) = (0.398 \pm 0.026)\ \text{ps}$$

In good agreement with PDG:

$$\tau(D^0) = (0.4101 \pm 0.0015)\ \text{ps}$$

The fit is insensitive to the lower Bound of the lifetime, t_{min}, within a wide range

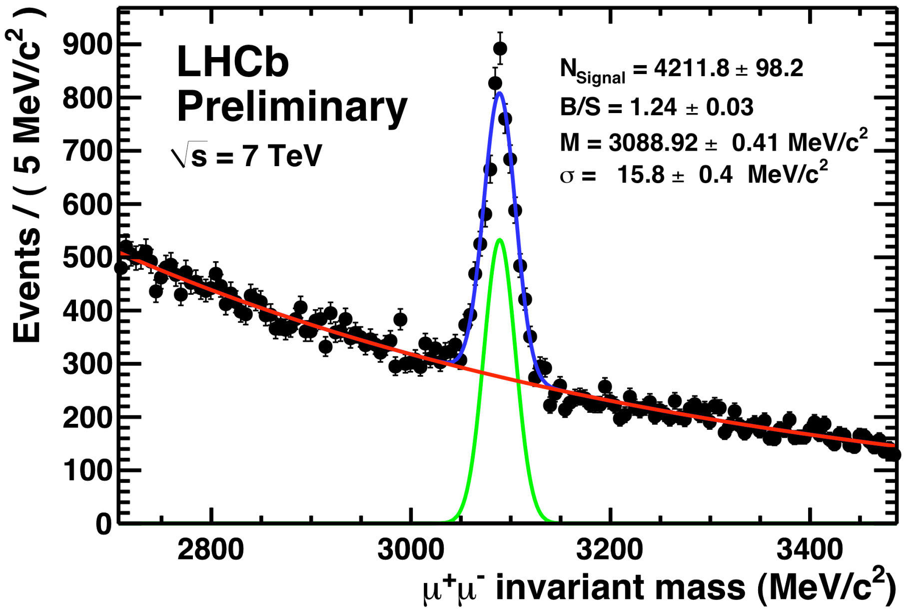


Recent News from LHCb

Reconstruction of B mesons

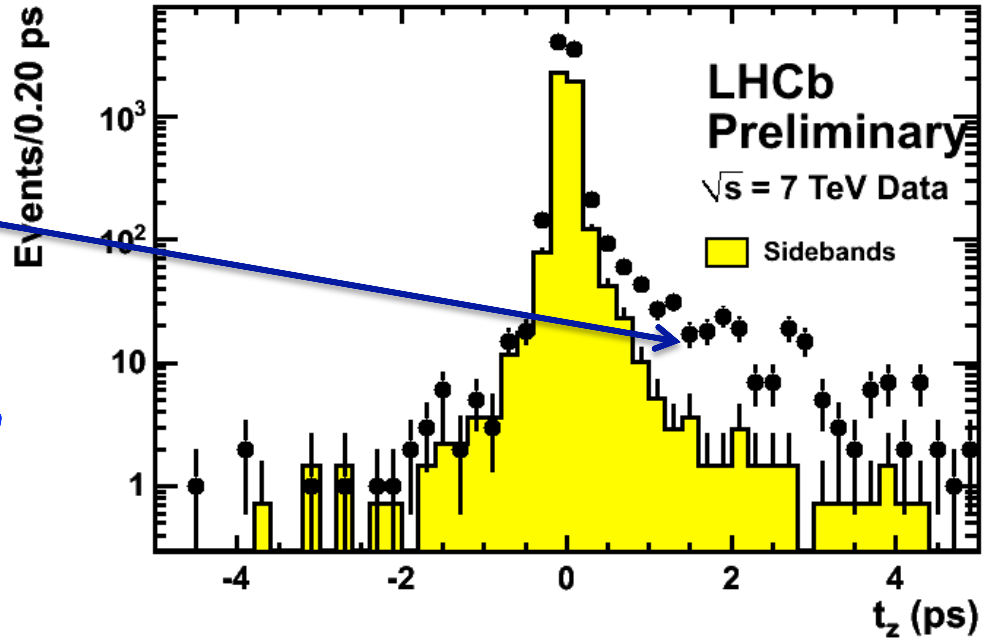
(for more details see talk of Olivier Schneider on Wednesday)

J/psi effective lifetime



A total of 4200 $J/\psi \rightarrow \mu\mu$ decays reconstructed

Signal window & normalized sideband

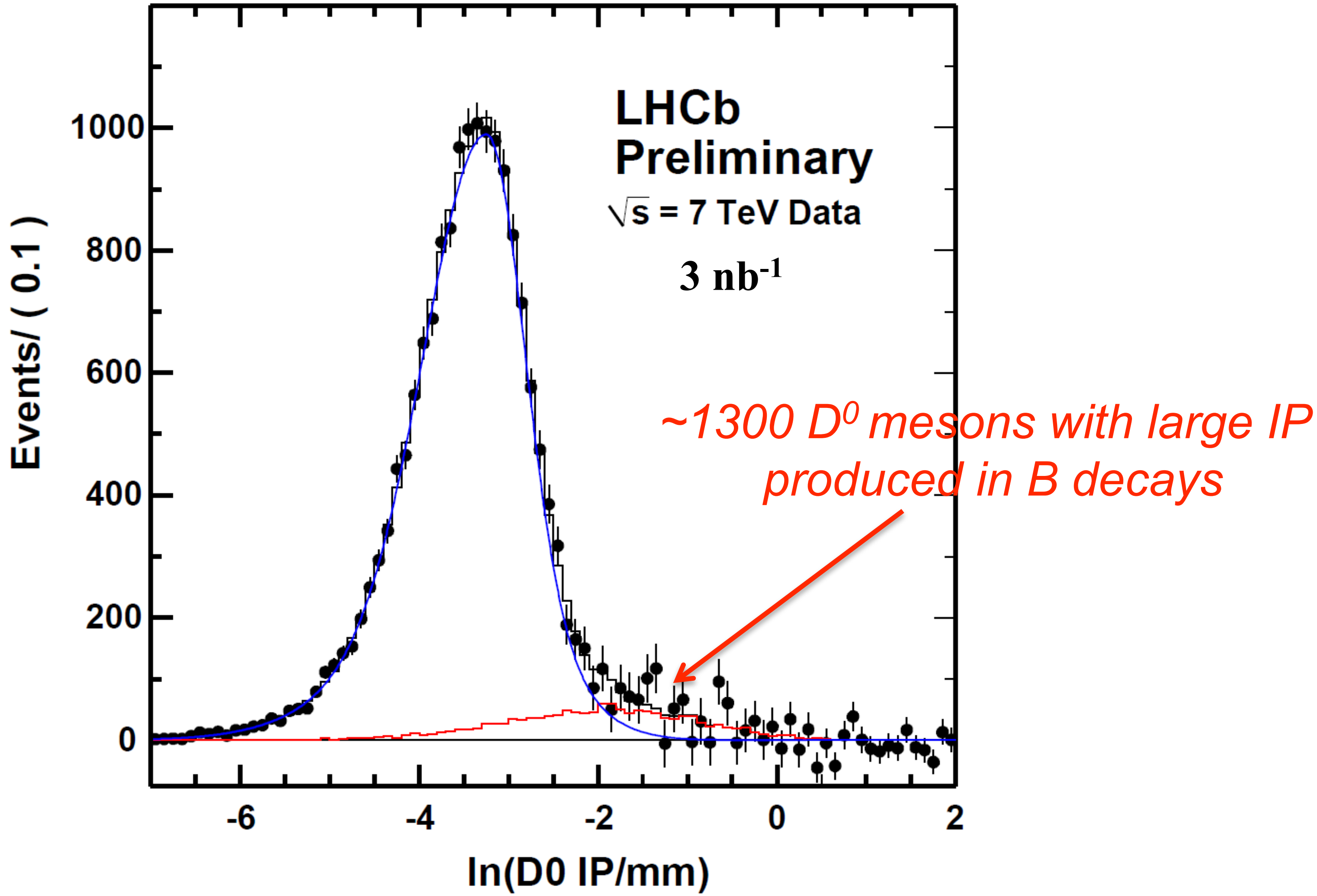


Proper life time distribution shows clear evidence for J/ψ produced in B decays

Solid prospects to measure production cross-sections for prompt J/ψ and $b\bar{b}$ at $\sqrt{s}$ = 7 TeV

Impact Parameter (IP) for $D^0 \rightarrow K\pi$

IP of D^0 candidates

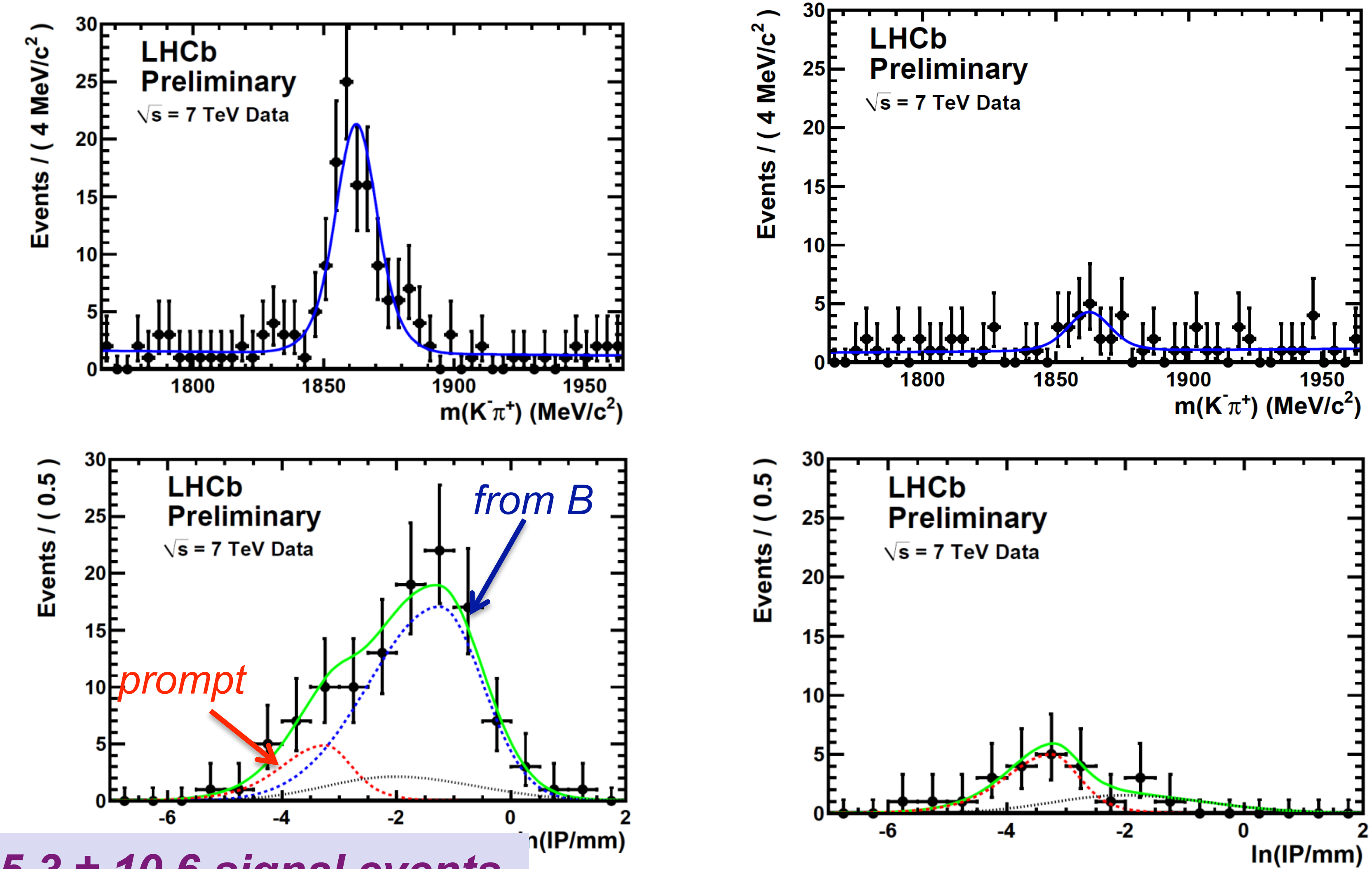


$B^0 \rightarrow D^0 \mu\nu$ with $D^0 \rightarrow K\pi$

Correlate D^0 with the muon of the right (wrong) sign

Right sign

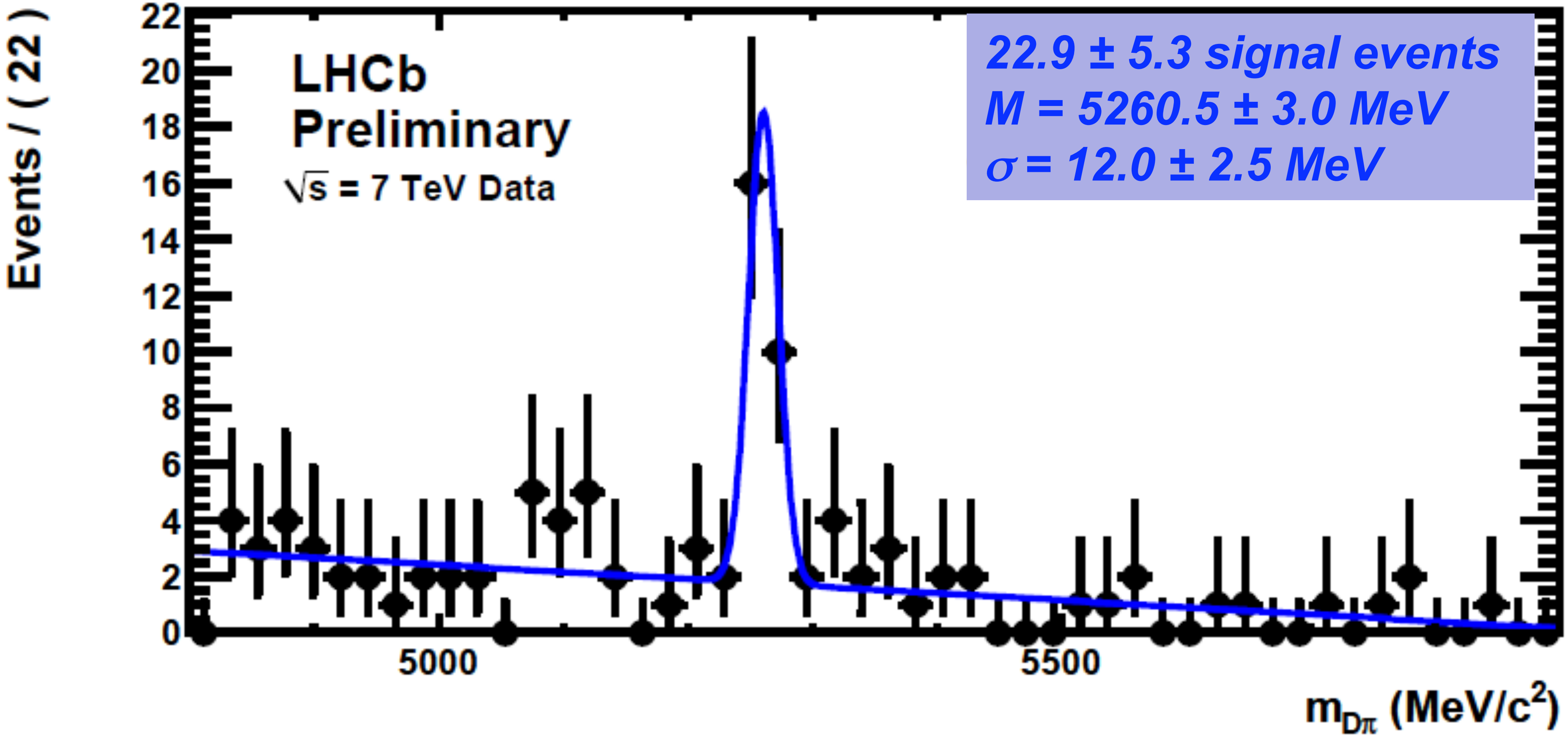
Wrong sign



85.3 ± 10.6 signal events with D from B

First fully reconstructed B mesons

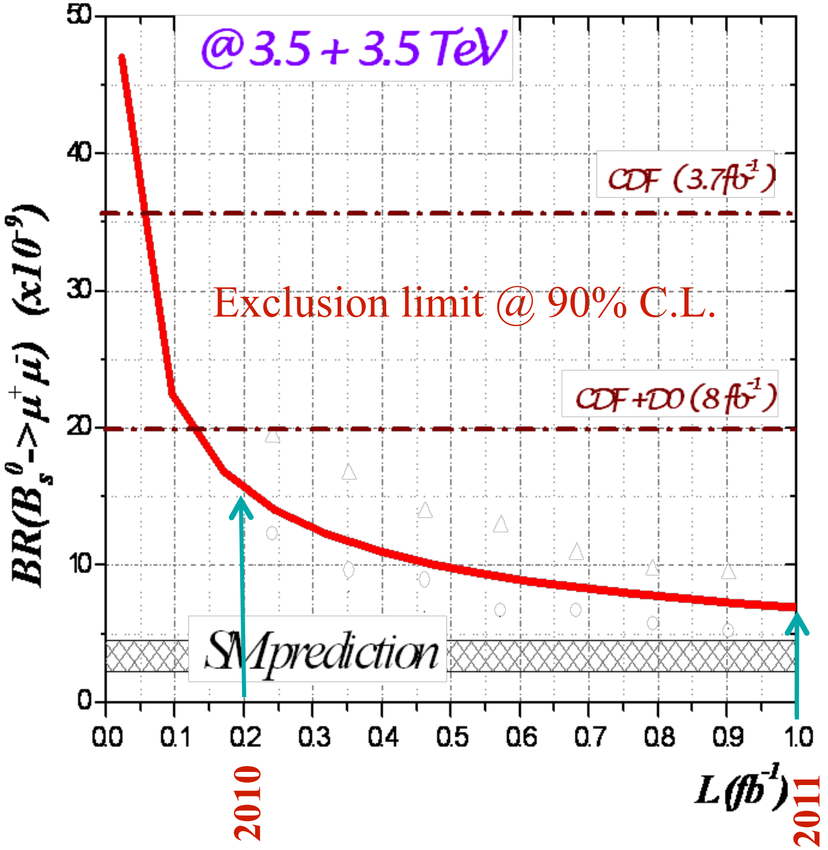
$B^0 \rightarrow D^+\pi^- \; + \; B^+ \rightarrow D^0\pi^+$

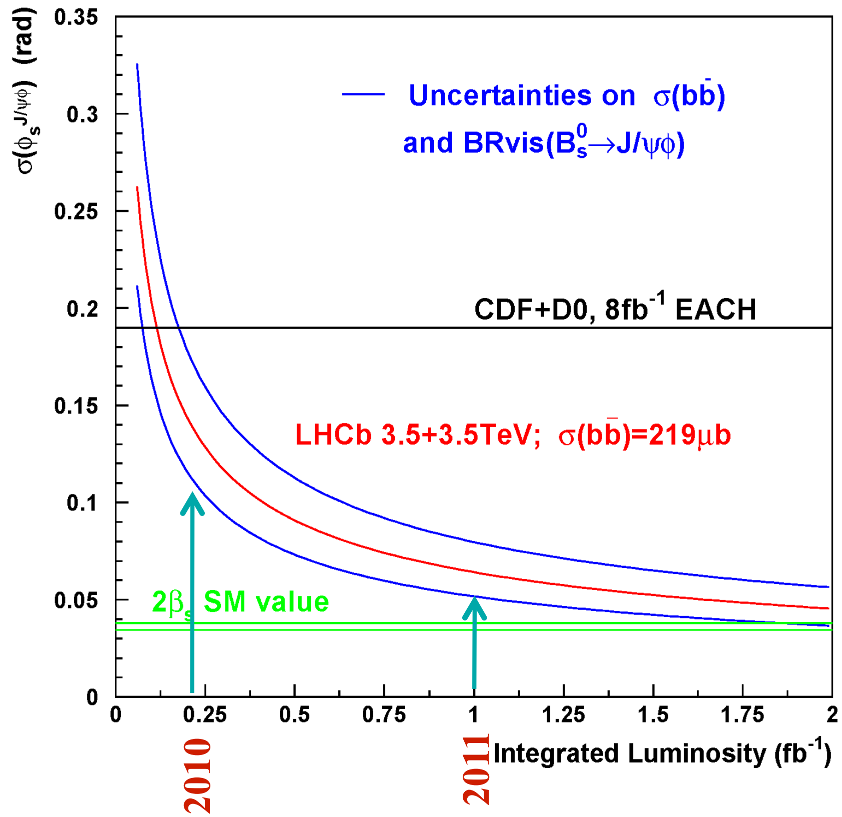


Calibration of the mass scale and B-field is ongoing

Expected B-physics reach in 2010-2011

➢ Assume ~200 pb^{-1} in 2010 and ~1 fb^{-1} in 2011





<u>*Sensitive probe for MSSM with large tanβ:*</u>

Br $(B_S \to \mu^+\mu^-) \sim \tan\beta^6 / M_A^4$

Conclusion & Outlook

- *First data are being used for calibration of the detector and trigger in particular*

  - First results of low Pt physics are available at LHC energies

  - LHCb trigger concept has been proven with data

  - Charm resonances and B mesons have been reconstructed

- *Some high class measurements in the charm sector may be possible with 50 pb^{-1}*

Conclusion & Outlook

- *Good prospects for exciting discoveries*

  With ~ 200 pb^{-1} data sample LHCb will reach Tevatron sensitivity in a few golden channels in the beauty sector

- ***Preparation for LHCb upgrade to collect data at 5-10 times higher luminosity is underway***

  The strongest part of the LHCb physics case is a flexibility to be prepared for the exploration of New Physics

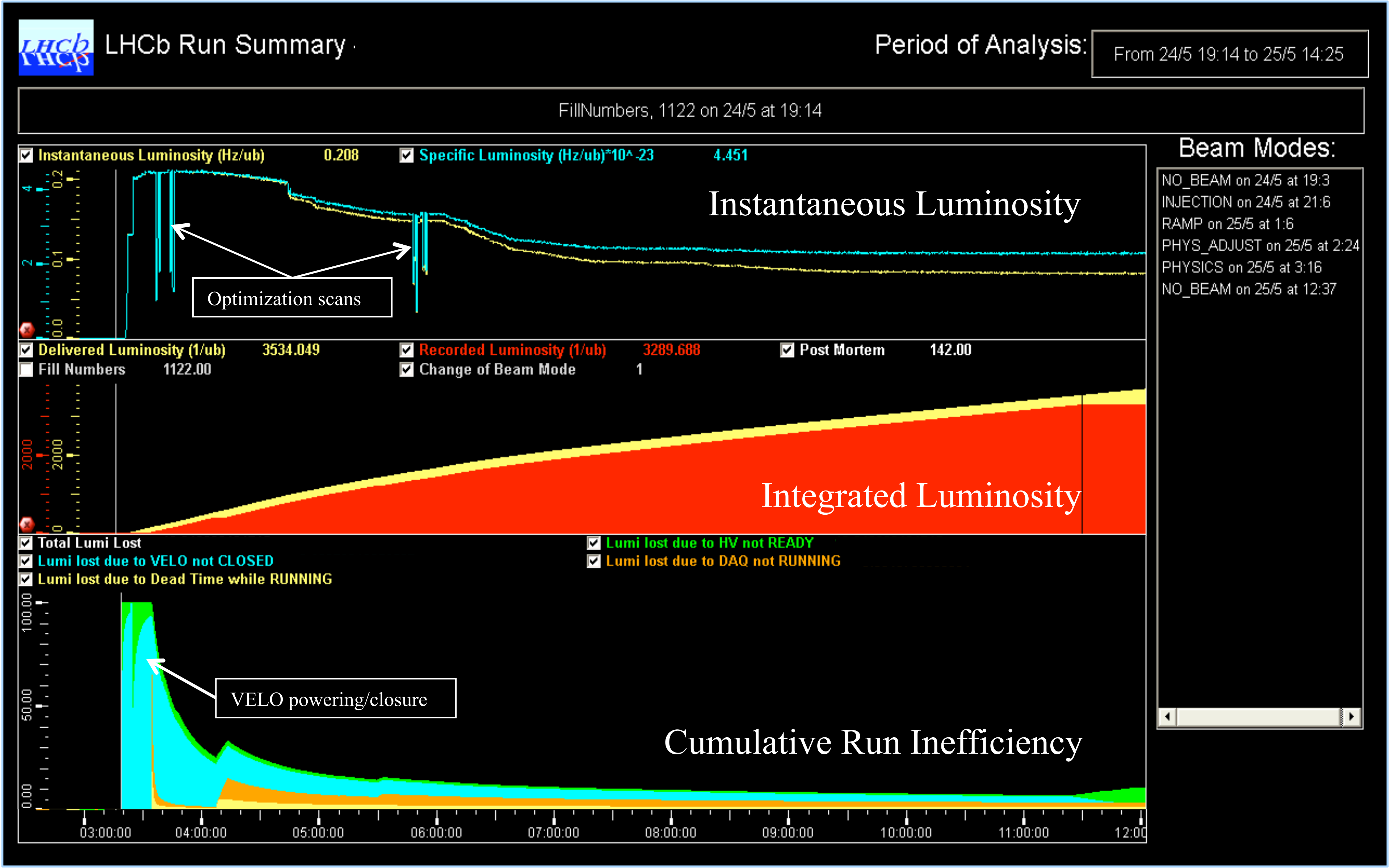
  → First stage: Full Software Trigger

  - Upgrade to 40 MHz read out keeping sub-detectors unchanged wherever possible

  - Construct new Vertex Detector

Back up Slides

LHCb Operation

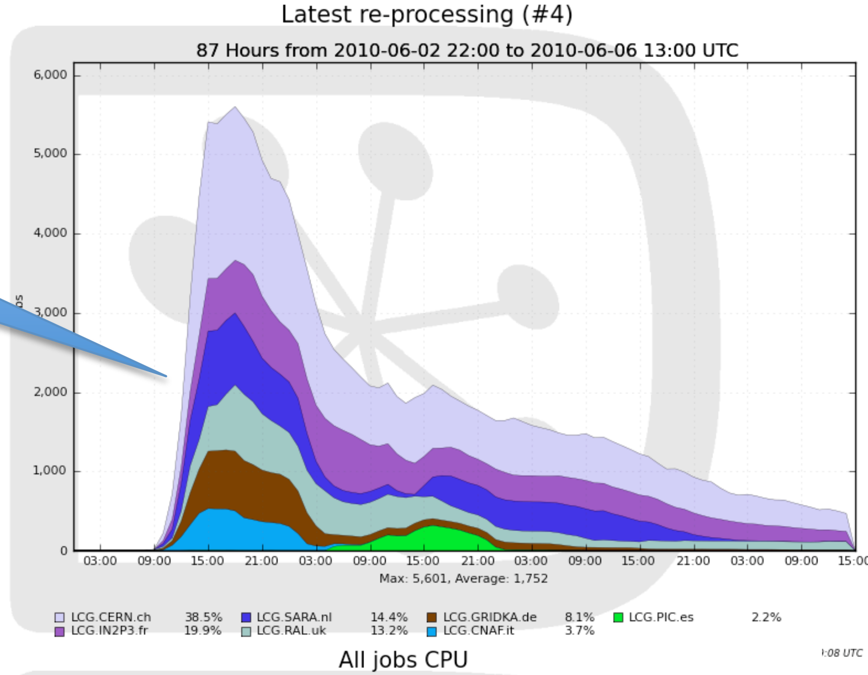


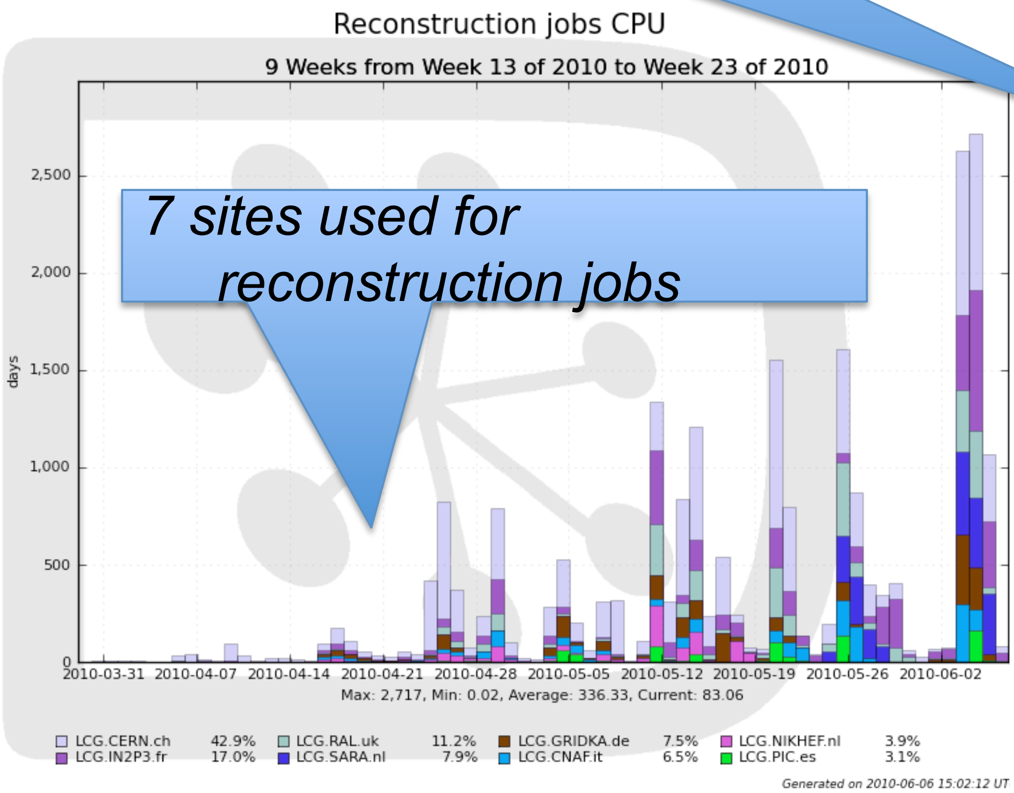
Data processing

- ***Data Quality loop now well in place***
  - *Express stream (5 Hz) promptly reconstructed*
  - *Online DQ + express stream DQ: green light for full processing*
- ***Data distributed to 6 Tier1s***
  - *According to pledged resources*
- ***4 major (re-)processing passes so far***
  - *Takes place at CERN and Tier1s*
  - *Few hiccoughs with sites' stability*
    - *Oracle CondDB access*
    - *Storage overload*
- ***Analysis going on in parallel at Tier1s***
- ***Simulation in background at Tier2s***

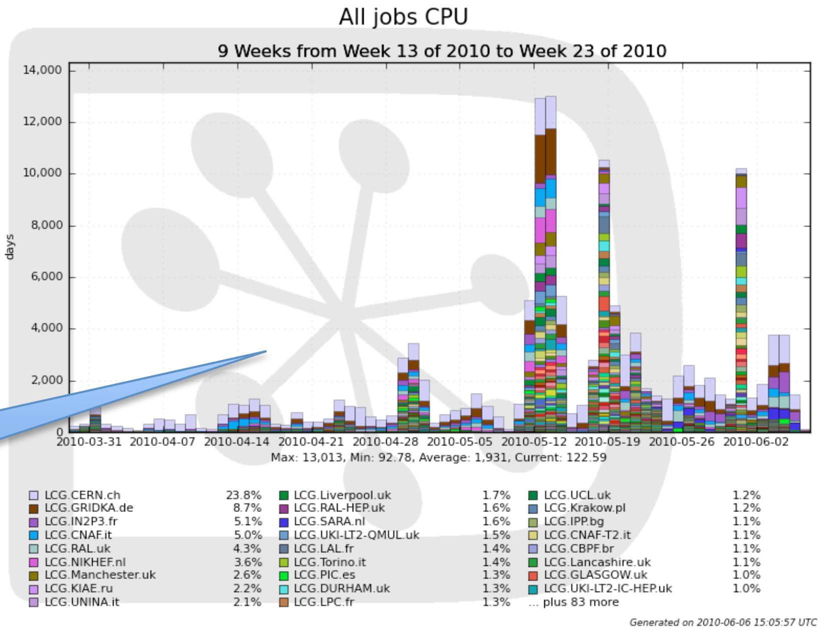
Production jobs

Latest re-processing took 3 ½ days





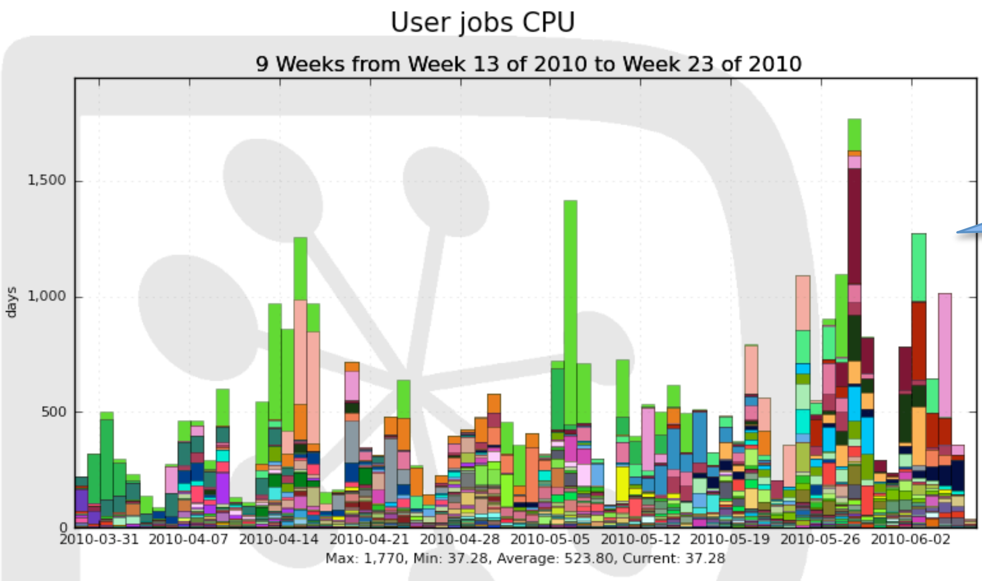
7 sites used for reconstruction jobs



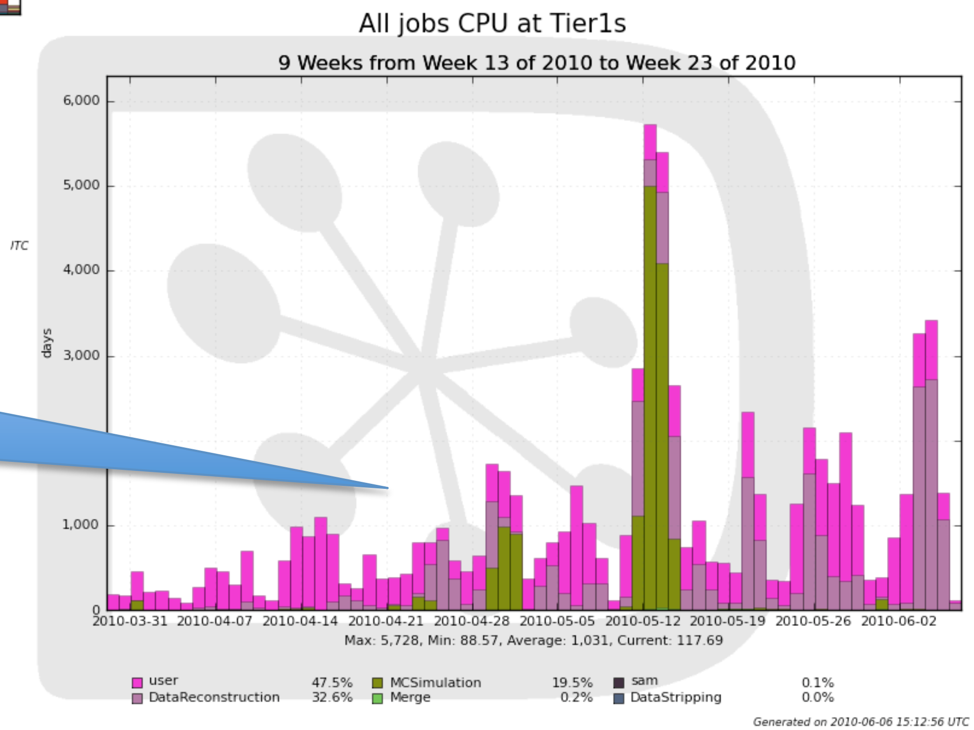
109 sites used in total

– *Now stopped running simulation at Tier1s*

Distributed computing at Tier1s



183 users have been running analysis jobs on the Grid



Resources used by user jobs comparable to (re-)processing