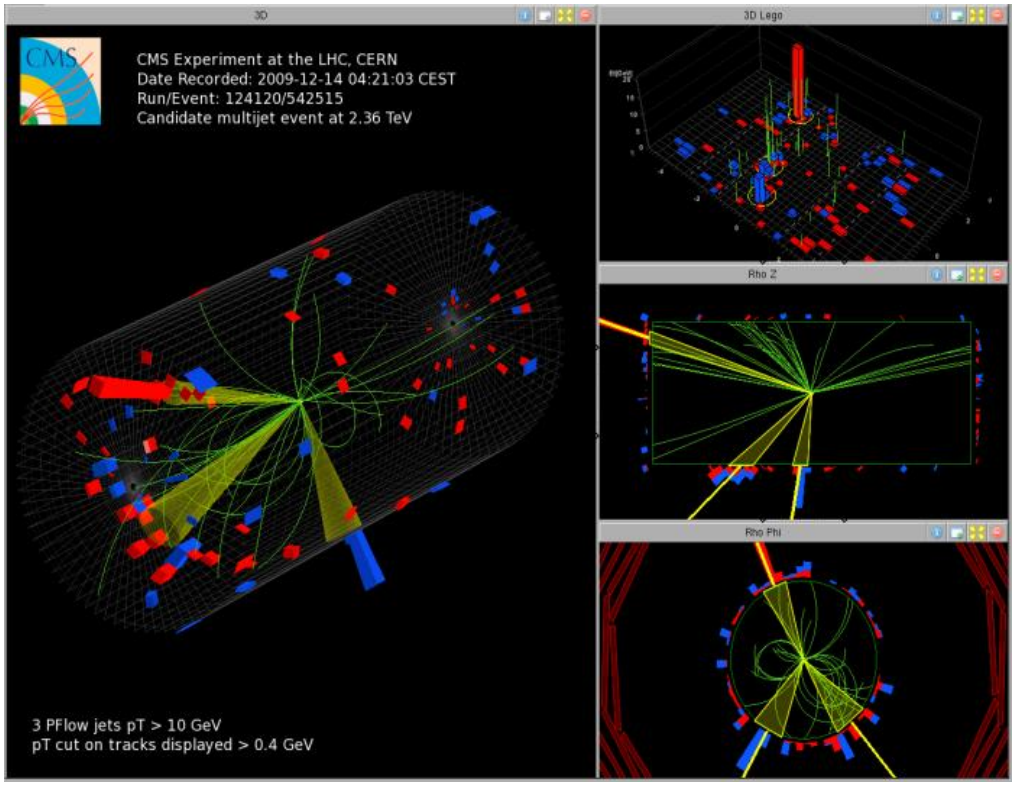
Status of the LHC Detectors



Talk to March 11, 2010 Meeting of HEPAP

J. Butler

Fermilab/CMS

Outline

- General observations
- ATLAS
- CMS
- ALICE
- LHCb
- Prospects and Conclusions

ATLAS and CMS have very large U.S. involvement relative to ALICE and LHCb. I will spend more time on them.

General Status - Preparation

- All 4 experiments had >97% of all installed channels working
- Detectors did extensive cosmic runs
- The detector simulations were done in great detail and were tuned with input from test bench, test beam, and cosmic runs
- Computing systems, reconstruction software, and analysis systems were exercised at “full scale” in several “challenges”

General Status - Execution

- In November and December of 2009, there were collisions in all four interaction regions
- All four experiments recorded good data at
  - 0.45 TeV x 0.45 TeV; and
  - 1.18 TeV x 1.18 TeV
- All experiments were ready with their tools for reconstructing and analyzing this early data
  - to understand the detectors; and
  - to extract whatever physics can be learned
- These efforts have already led to publication of results

Estimated Luminosities and Events Collected

Luminosity at 0.9 TeV (approximate)

ALICE 9.5 μb^{-1}

ATLAS 12 . μb^{-1} (stable) 19 μb^{-1} (total)

CMS 9.5 μb^{-1} (quiet or stable) 16 μb^{-1} (total)

LHCb 6.7 μb^{-1} (stable)

Event collection at 0.9 TeV and 2.136 TeV

ALICE: ~470k (360K B on, 100K B off, 10K B rev)

ATLAS: ~540k (of which 220k not nominal fields)

CMS: ~410k (of which 60k not nominal field)

LHCb: ~320k (of which ~3k with dipole off)

At 2.136 TeV:

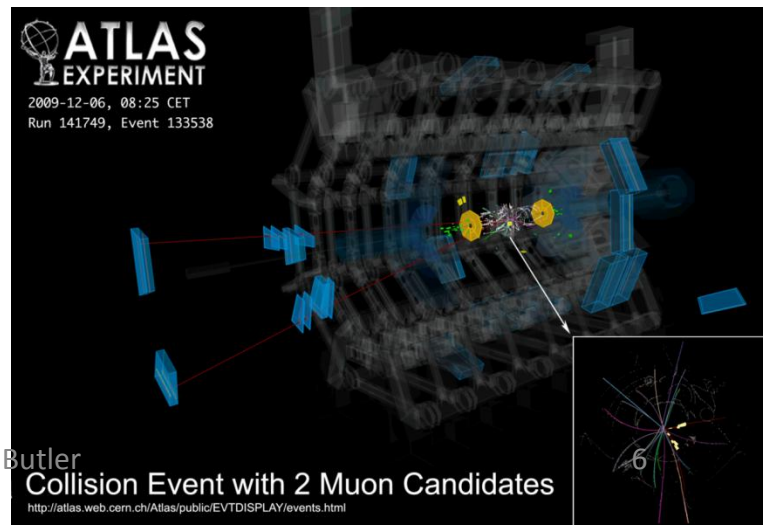
ALICE: 30K events

ATLAS: 34K events, ~1 μb^{-1}

CMS: 17K events,~0.6 μb^{-1}

LHCb: 40K events

ATLAS STATUS



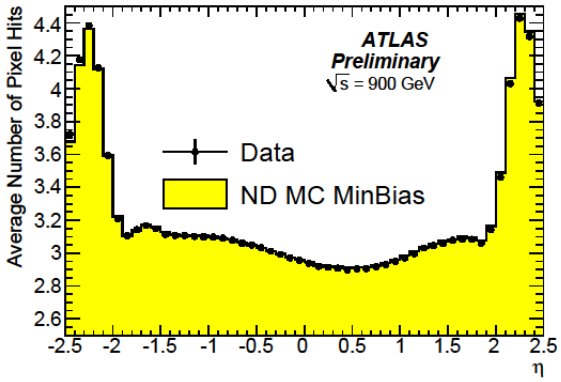
ATLAS Status

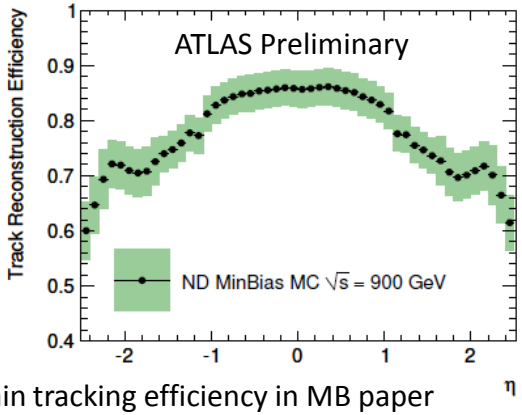
- Impressive startup on Nov 23, 2009 – over 97% channels operational
- Excellent overall performance with remarkably good understanding of detector for this stage – in agreement often within 1% of Monte Carlo
- First physics – plots from "Minimum Bias" 900 GeV running released by collaboration

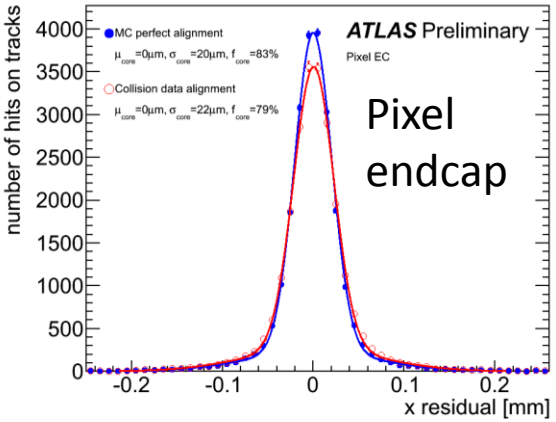
Subdetector	Channel count	~Operational Fraction
Pixels	80M	97.5%
SCT Silicon Strips	6.3M	99.3%
TRT Transition Radiation Tracker	350k	98.2%
Lar EM Calorimeter	170k	98.6%
Tile Calorimeter	9800	98.0%
Hadronic endcap Lar Calorimeter	5600	99.9%
Forward Lar Calorimeter	3500	100%
LVL1 Calorimeter Trigger	7160	99.5%
MDT Muon Drift Tubes	350k	99.7%
CSC Cathode Strip Chambers	31k	98.5%
RPC Barrel Muon Trigger	370k	99.5%
TGC Endcap Muon Trigger	320k	100%

Inner Detector

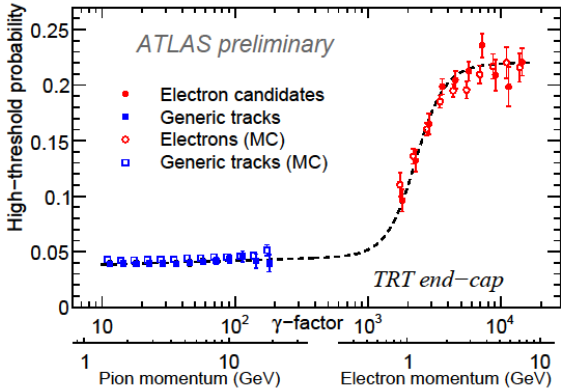
- Pixel, SCT, and TRT performing well with beam and in excellent agreement with Monte Carlo





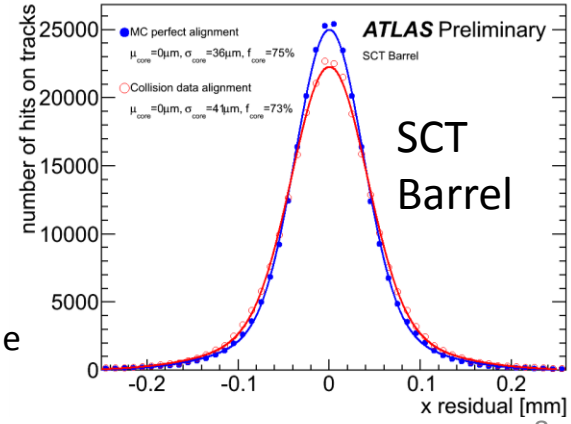


Pixel hits vs η agree well with MC, used to obtain tracking efficiency in MB paper



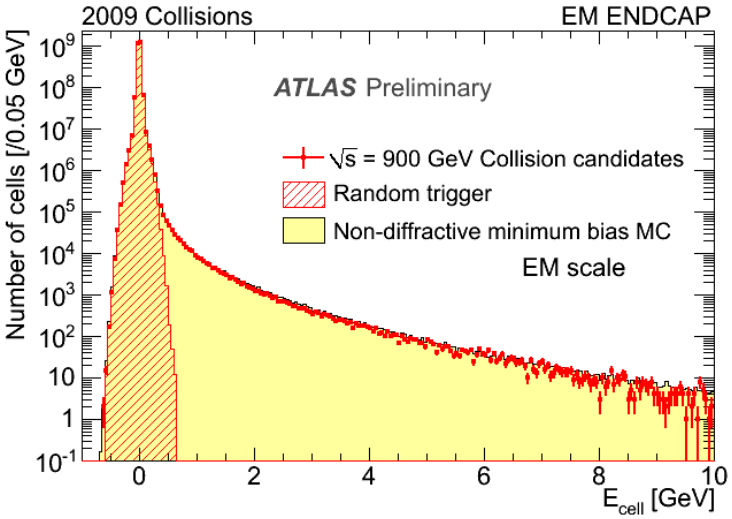
Onset of transition radiation in TRT as predicted

Measured resolutions in Pixel and SCT approaching expectations (red = data, blue = MC)

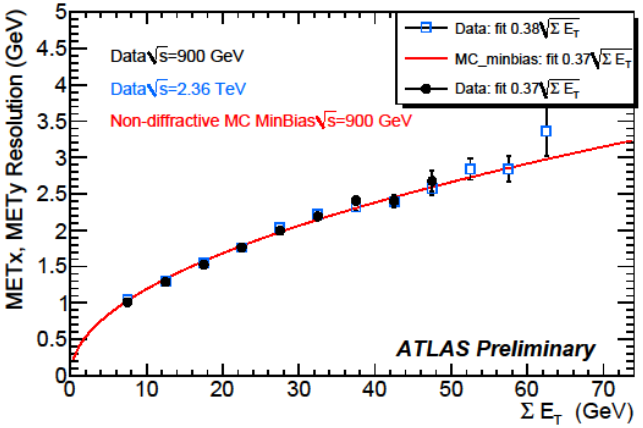


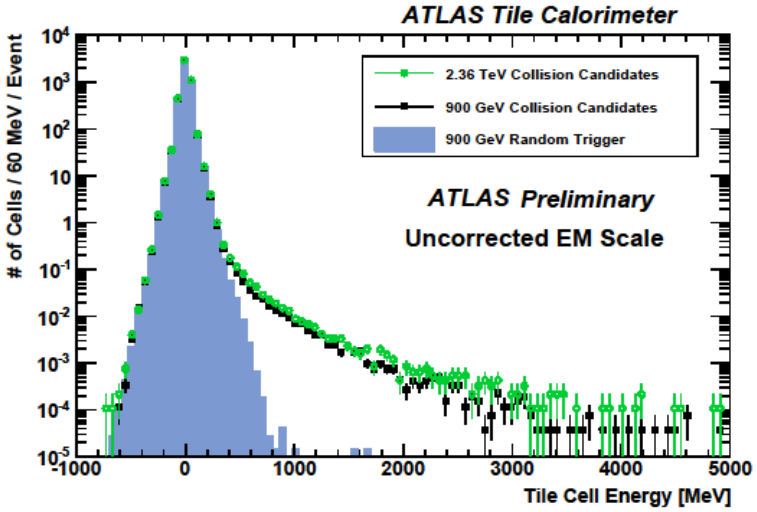
Calorimeters

- LAr calorimeter cell energy distributions for 900 GeV collisions very well described by MC
- Similarly for Tile calorimeter, where 900 GeV and 2.36TeV data are shown



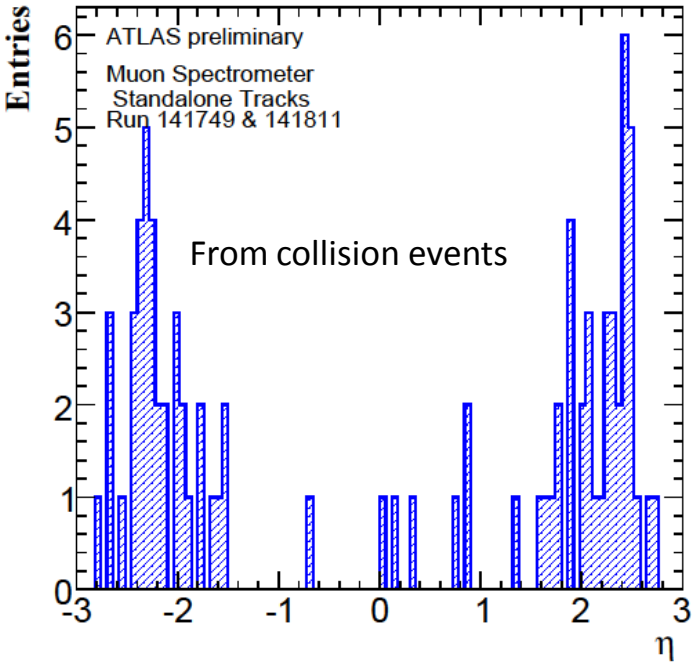
Missing E_T looks quite good for this early stage – both 900 GeV and 2.36TeV min bias data compared to MC

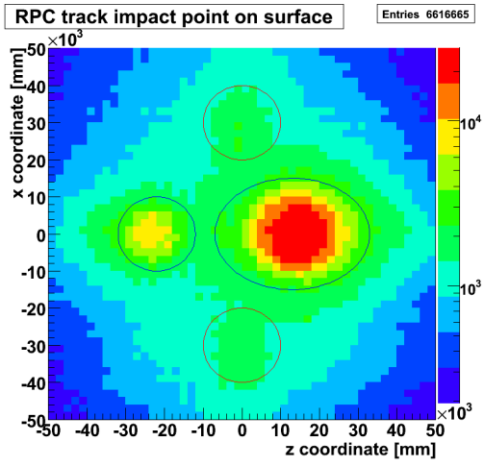




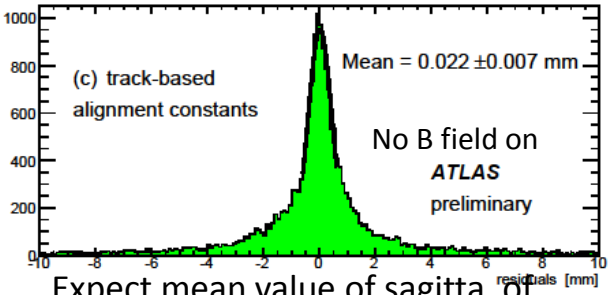
Muon System

- Not many muons yet from collisions
  - Handfuls of candidates show expected η distribution
- Cosmics used for alignment, continually improving





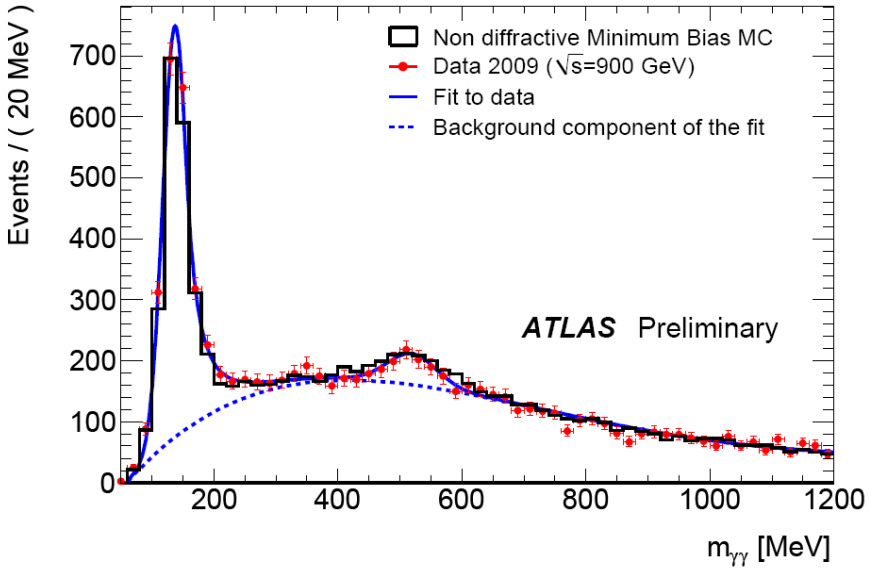
Cosmic distribution shows the shafts

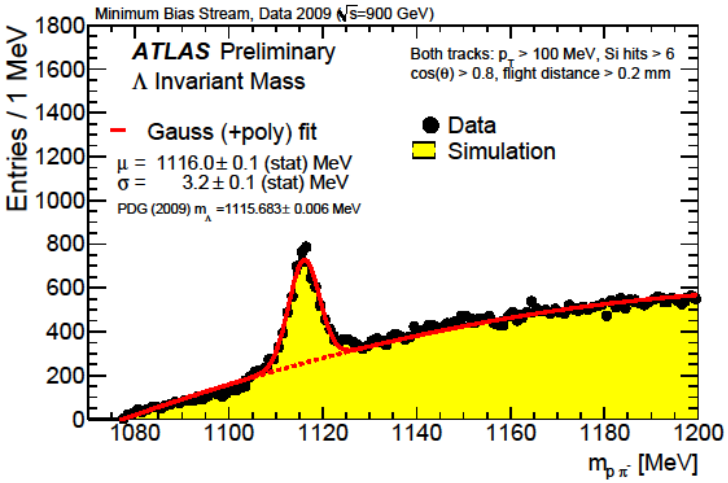


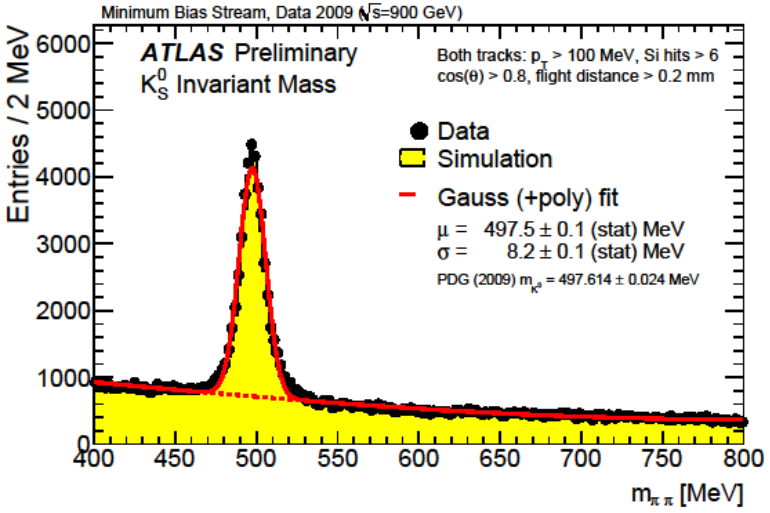
Expect mean value of sagitta of straight tracks to be <30um

Finding particles

- Where expected…
  - $\pi^0 \rightarrow \gamma\gamma$ (not yet corrected for dead material)
  - $K^0_s \rightarrow \pi^+\pi^-$
  - $\Lambda^0 \rightarrow p^+ + \pi^-$

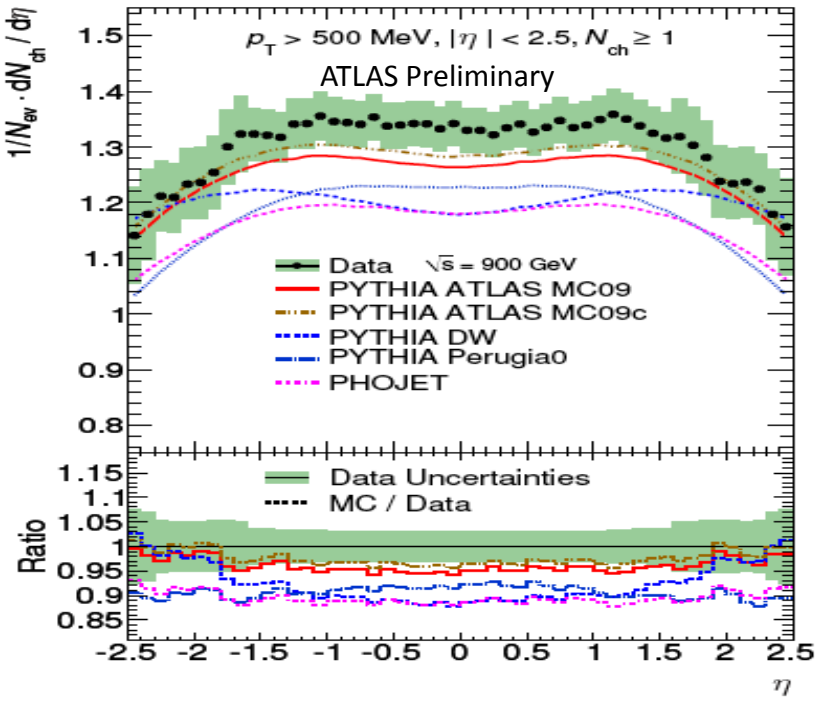




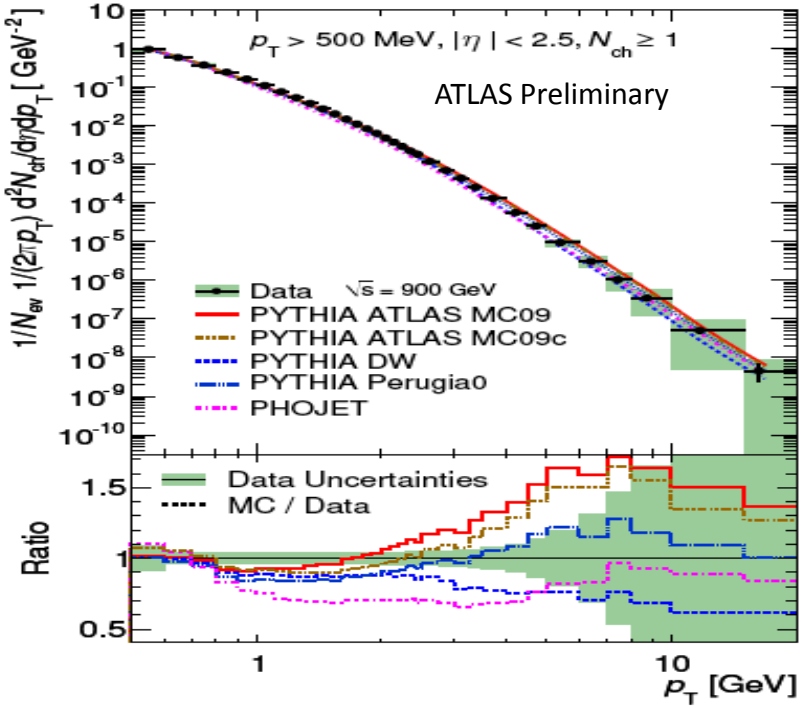


First Physics – Minimum Bias distributions

- Min Bias trigger (MBTS), primary charged particles $N_{ch} \geq 1$, $|\eta| < 2.5$, $p_T > 500$MeV



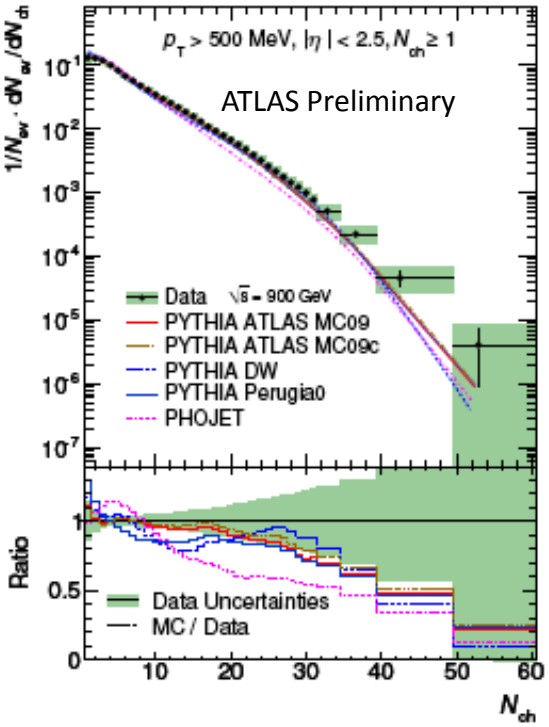
N_{ch} vs η



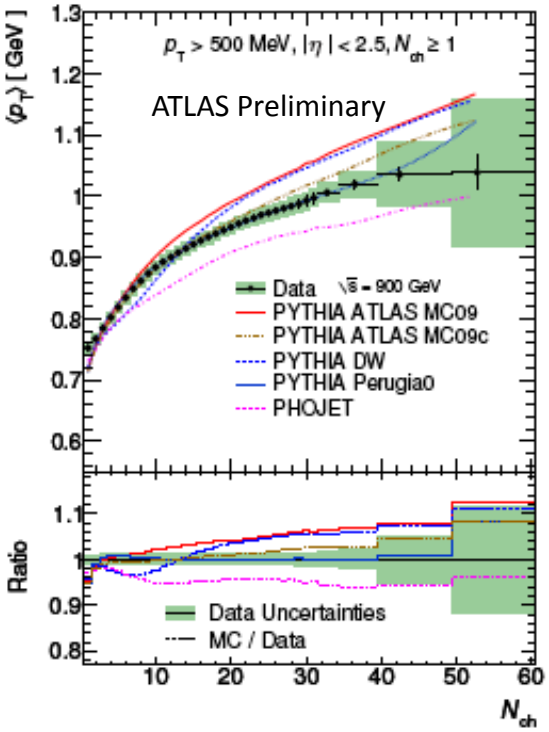
N_{ch} vs pT

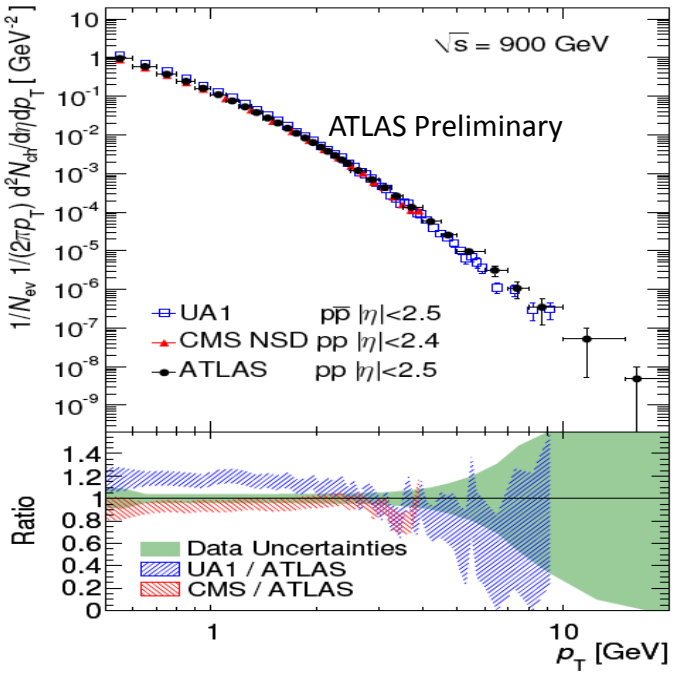
More Min Bias Distributions

Charged particle density



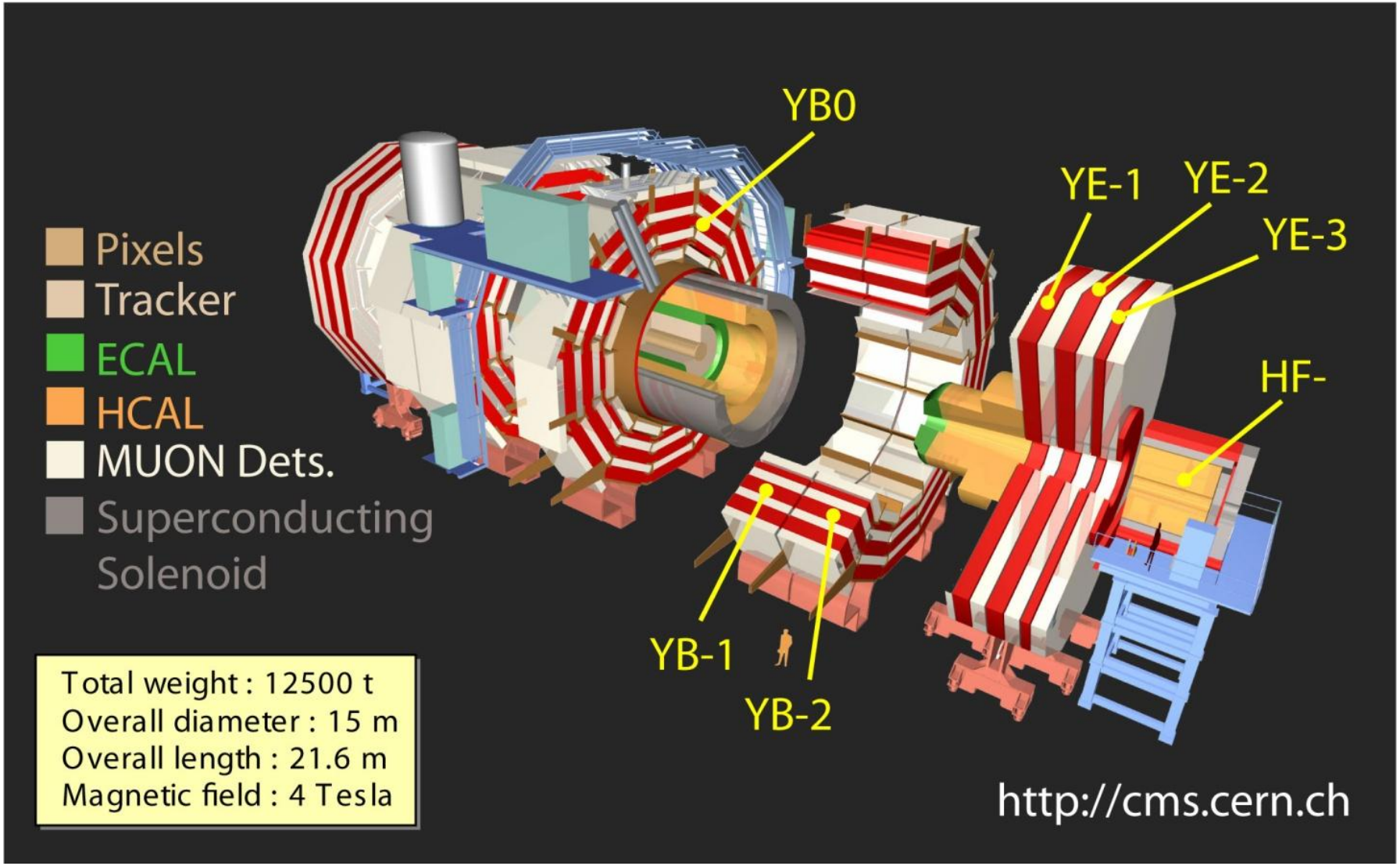
Average transverse momentum vs N_{ch}



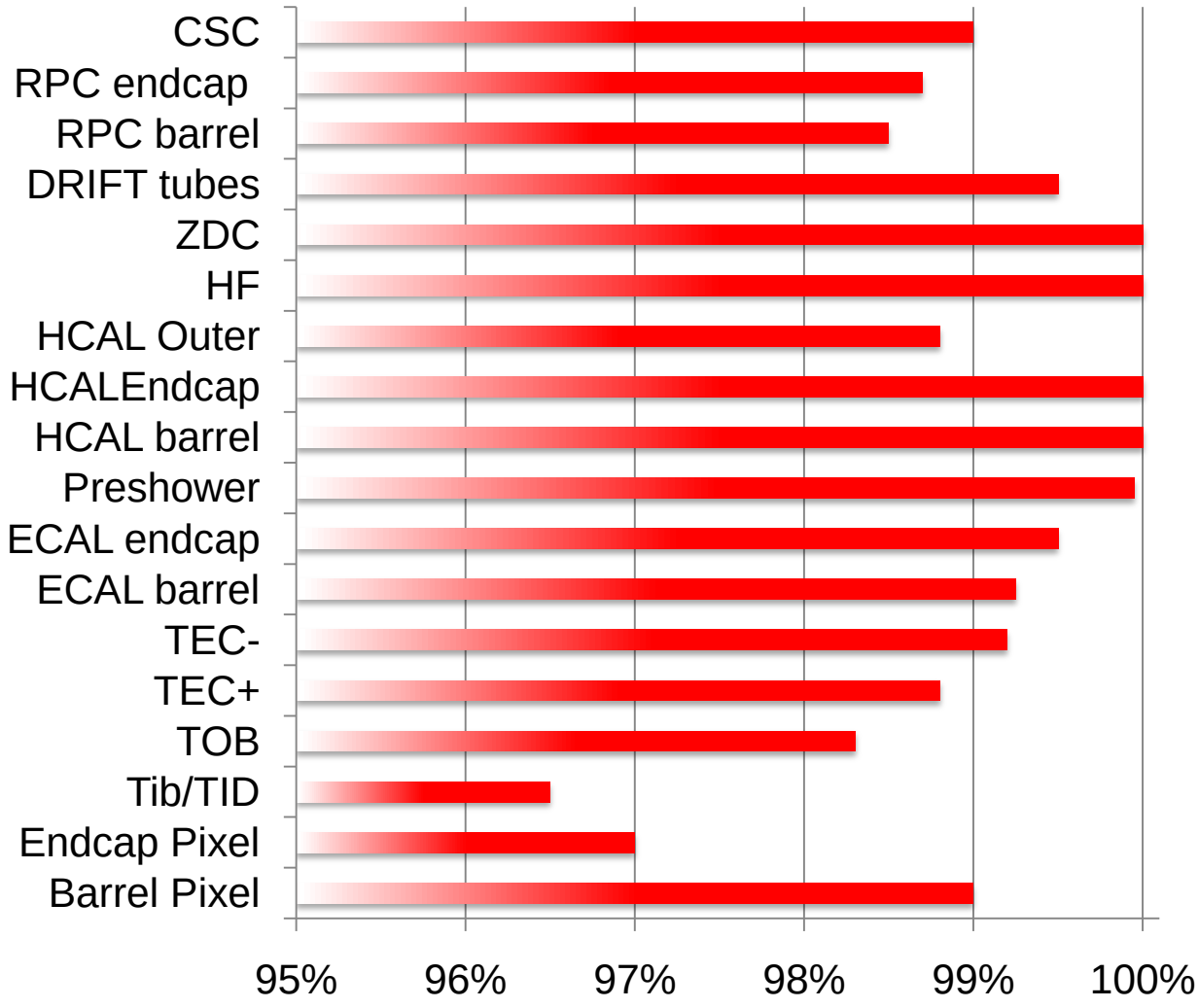


p_T spectrum of charged particle multiplicities shows agreement with CMS, and can constrain models

Status of CMS

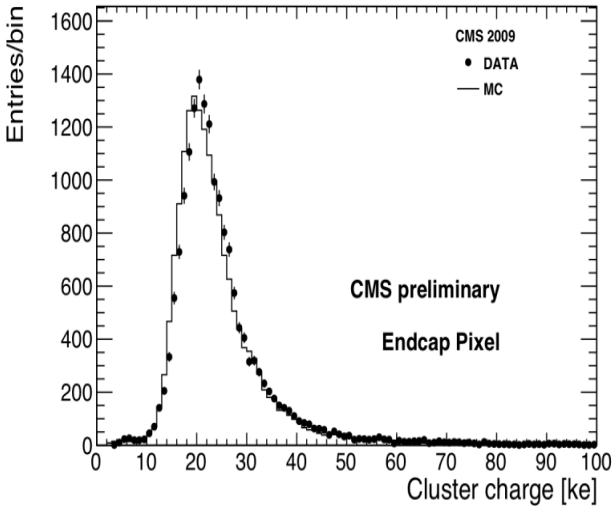


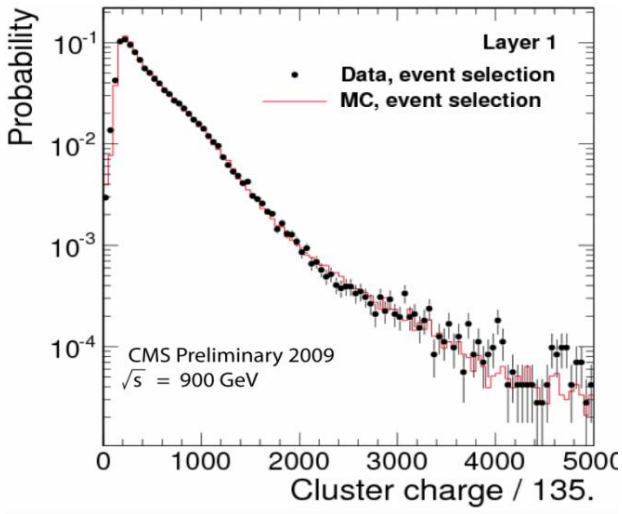
Operational Fraction

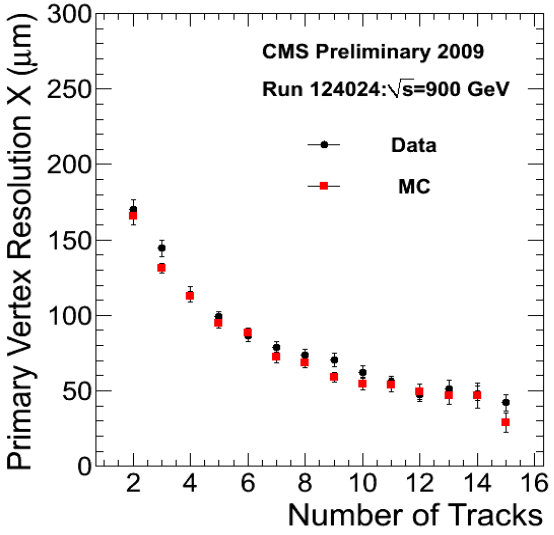


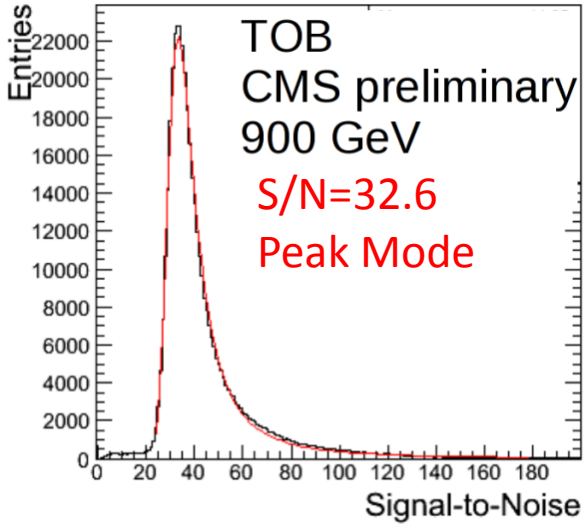
Silicon Strips and Pixels

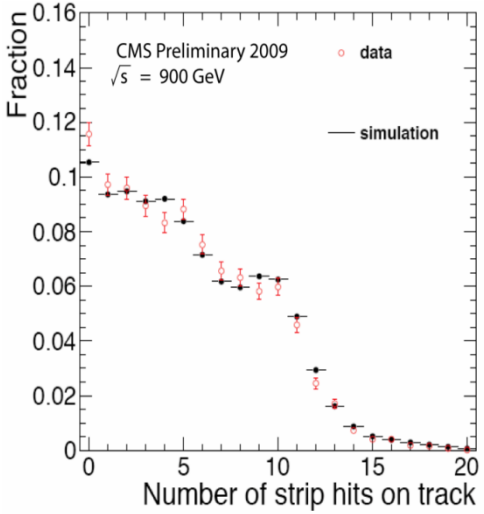
Excellent agreement data and Monte Carlo simulations

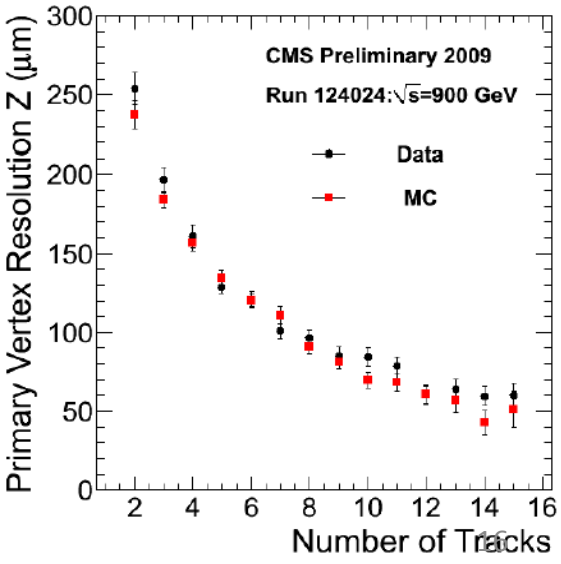




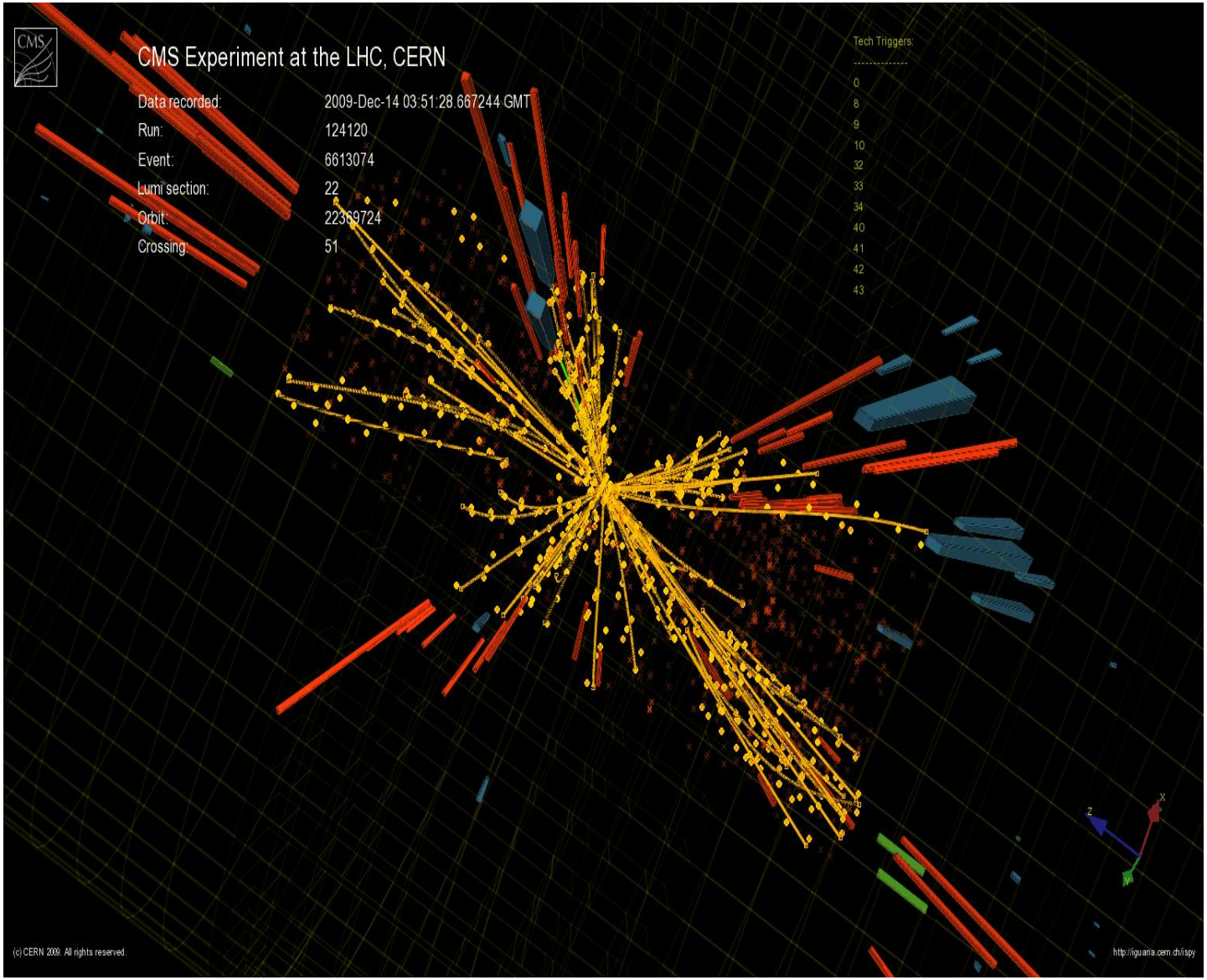






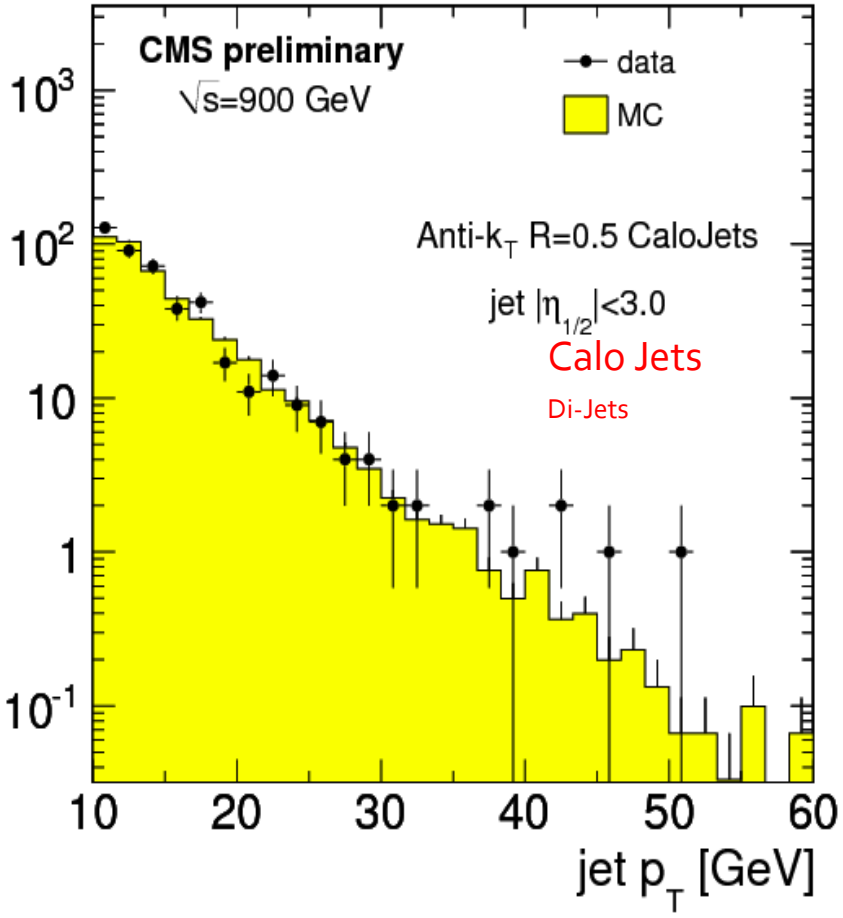


Calo performance: spectacular jets at 2.36 TeV



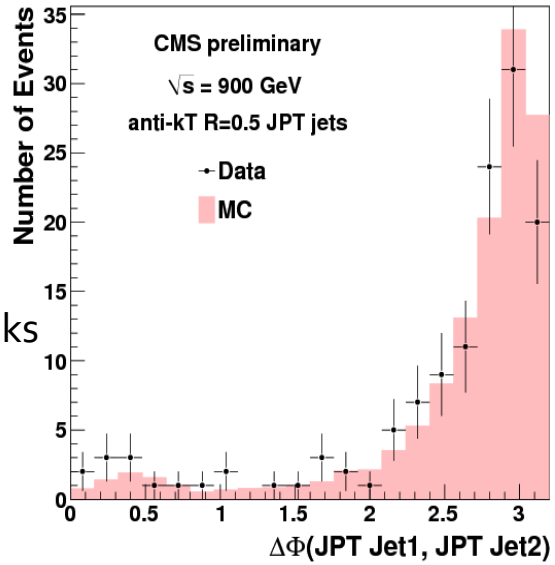
Calorimetry performance: di-jets

Good agreement between data and Monte Carlo on the p_T and angular distributions of di-jets



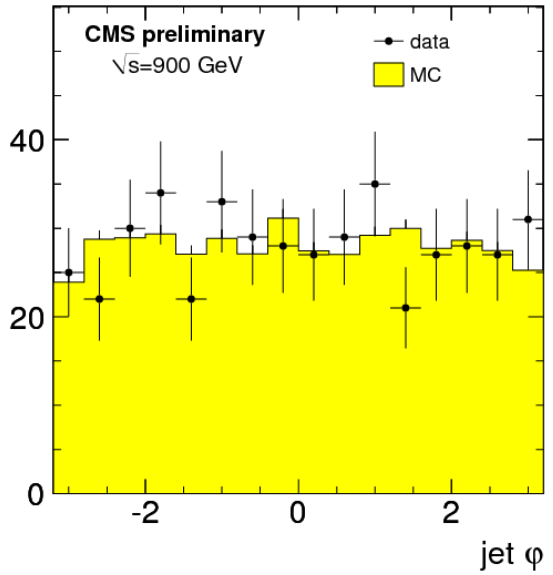
Jets+Tracks

Di-Jets

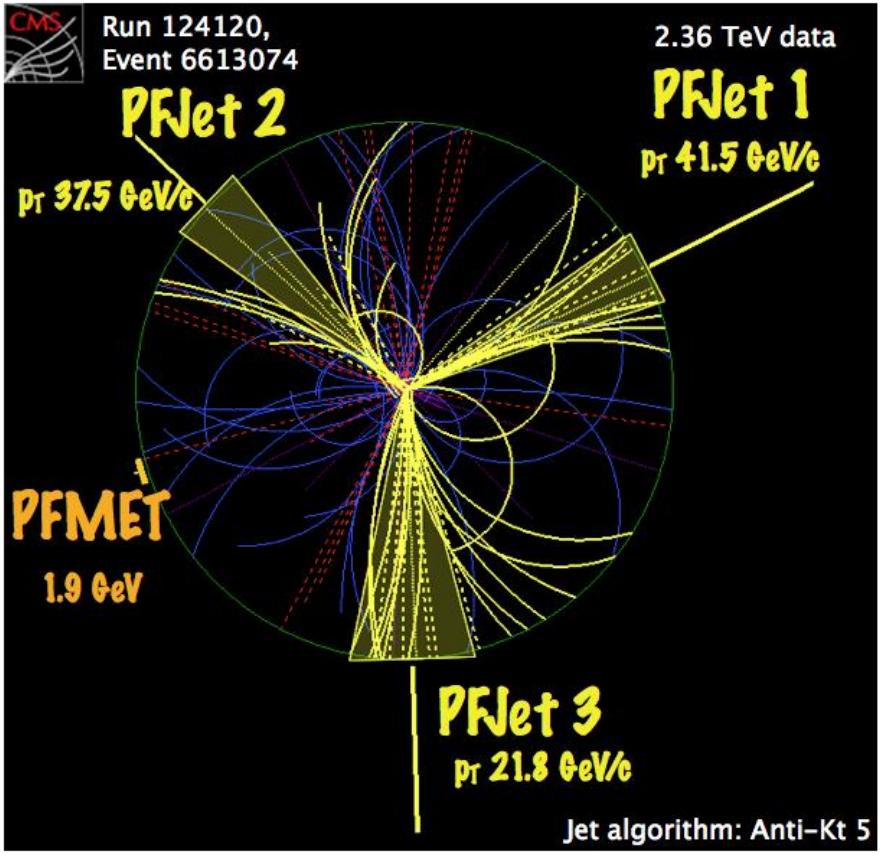


Calo Jets

Di-jets



Particle Flow: multi jet event @ 2.36 TeV



PFJets with (uncorrected) p_T > 20 GeV/c

Particle inside the jet:

- Charged hadrons
- Photons
- Neutral hadrons

Particles outside the jet:

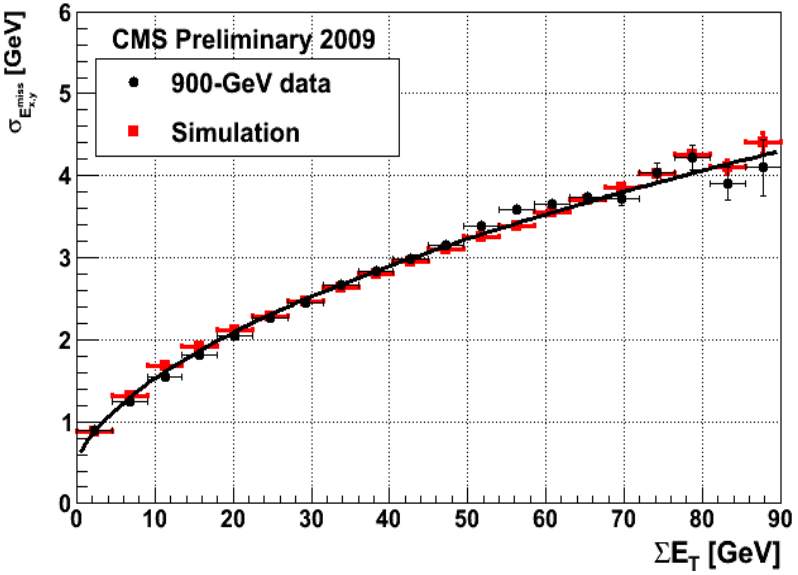
- Charged hadrons
- Photons
- Neutral hadrons

PFMET (1.9 GeV)

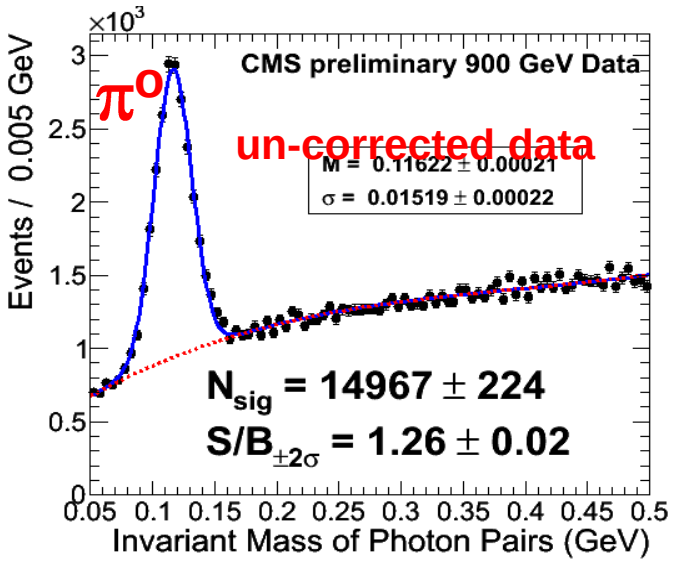
$$\sigma(E_{x,y}^{\text{miss}}) = a \oplus b\sqrt{\sum E_{\text{T}}}$$

a = 0.55 GeV

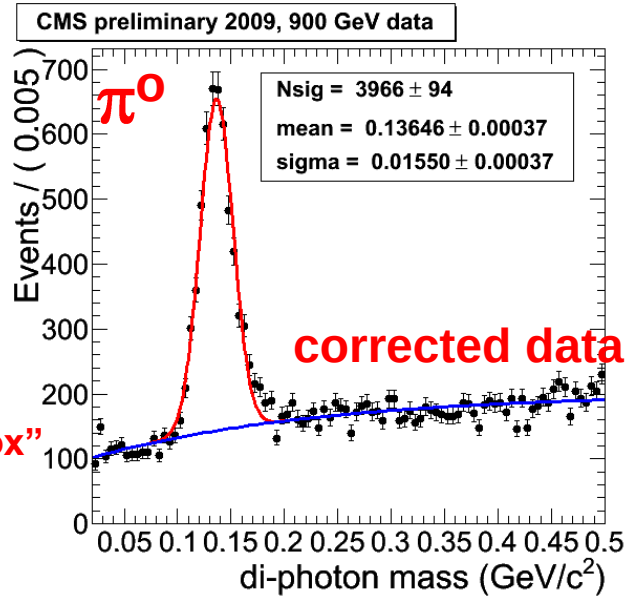
b = 45 % (PFlow)



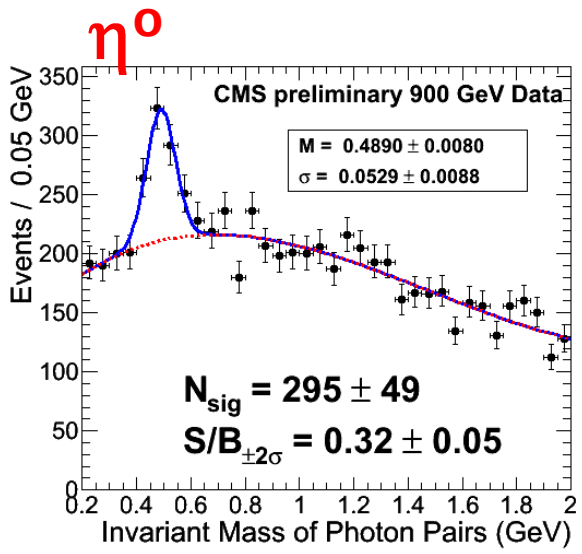
Reconstructing resonances: π^o and η^o



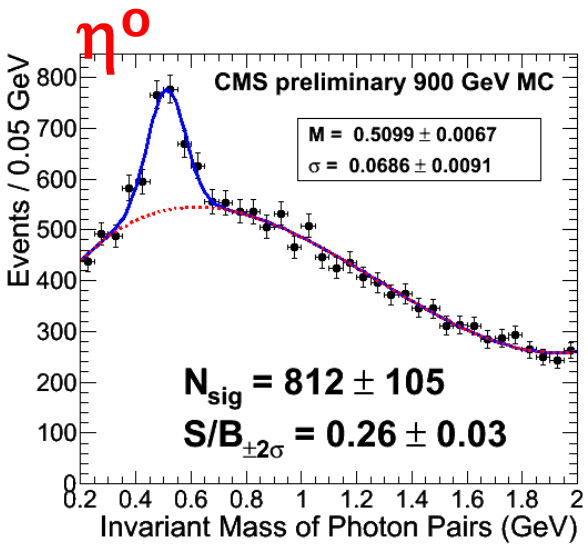
π^o mass with "out-of-the-box" Monte Carlo correction factors.



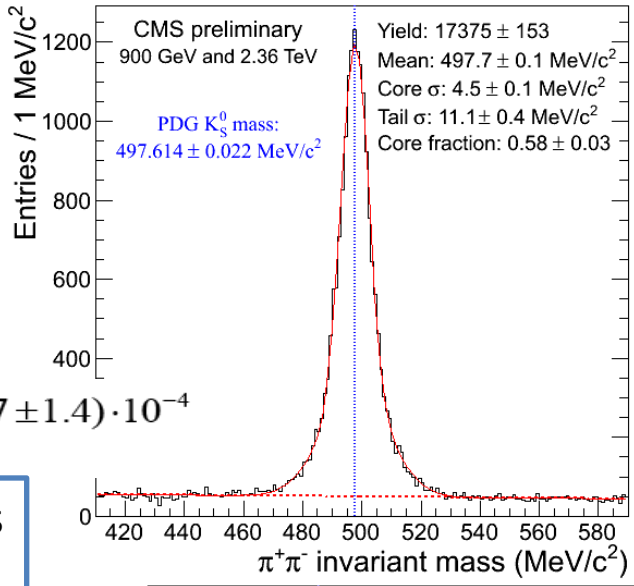
DATA



MC



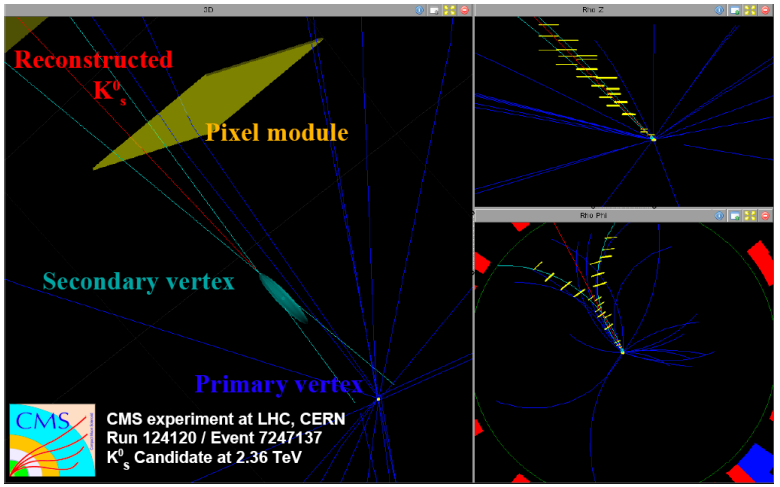
K^o_s , Λ^o, $\Xi^{\pm}$ Reconstruction

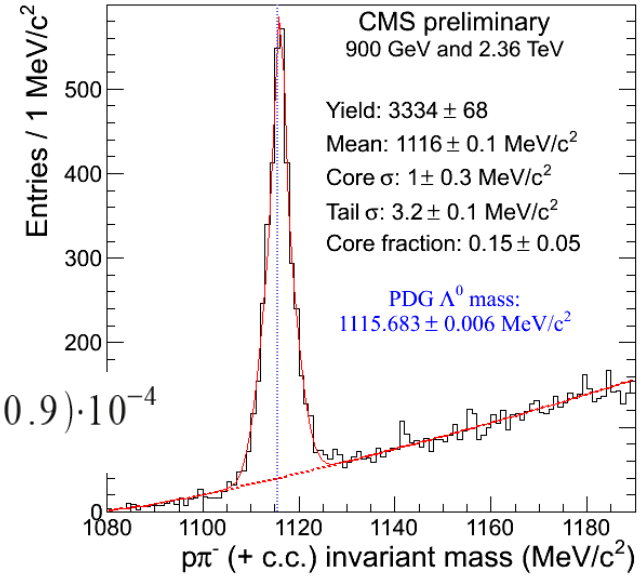


$$\frac{m}{m_{PDG}} = 1-(0.7\pm1.4)\cdot10^{-4}$$

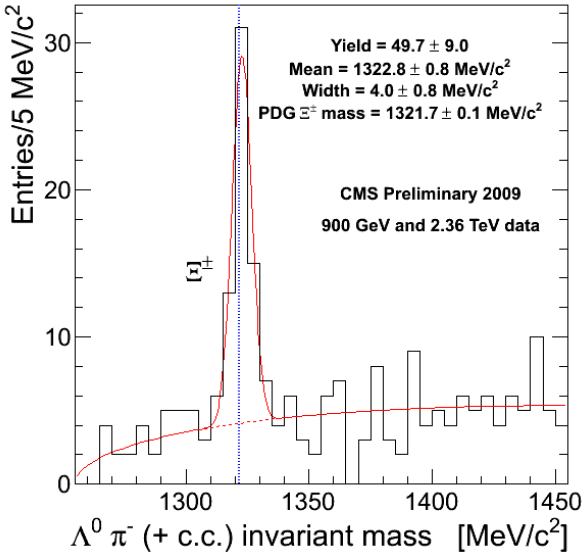
For lifetimes see backup slides

K^0_s candidate event at 2.36 TeV

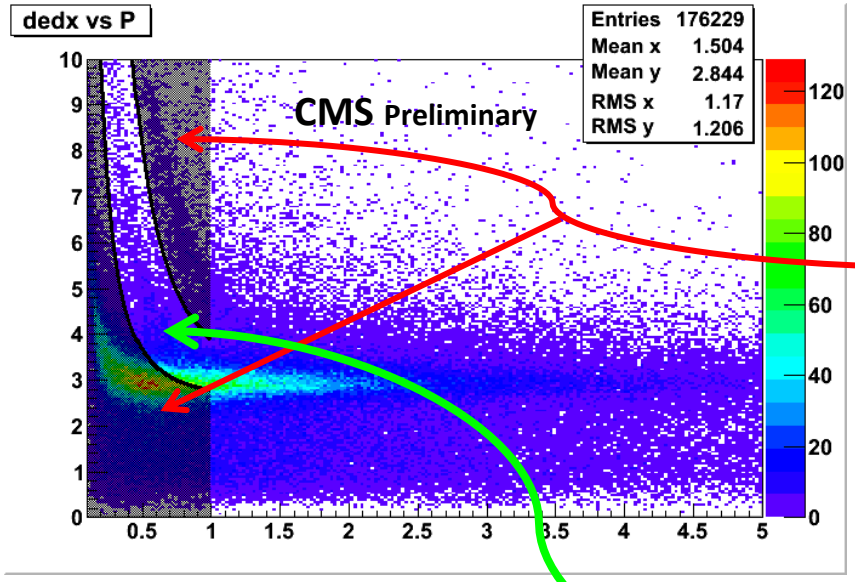


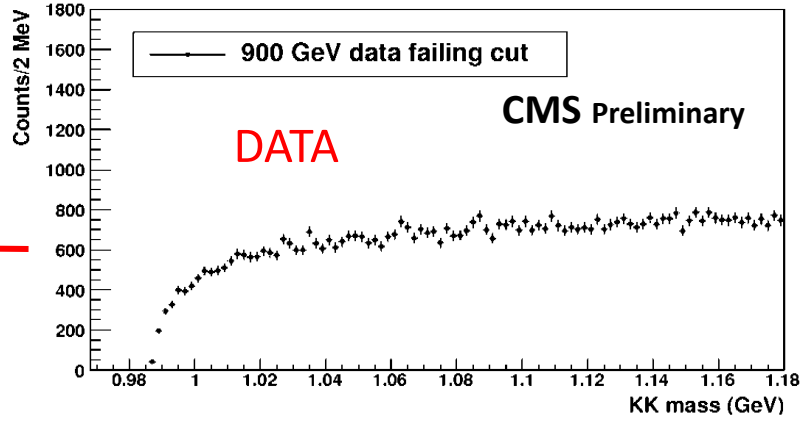


$$\frac{m}{m_{PDG}} = 1+(1.9\pm0.9)\cdot10^{-4}$$

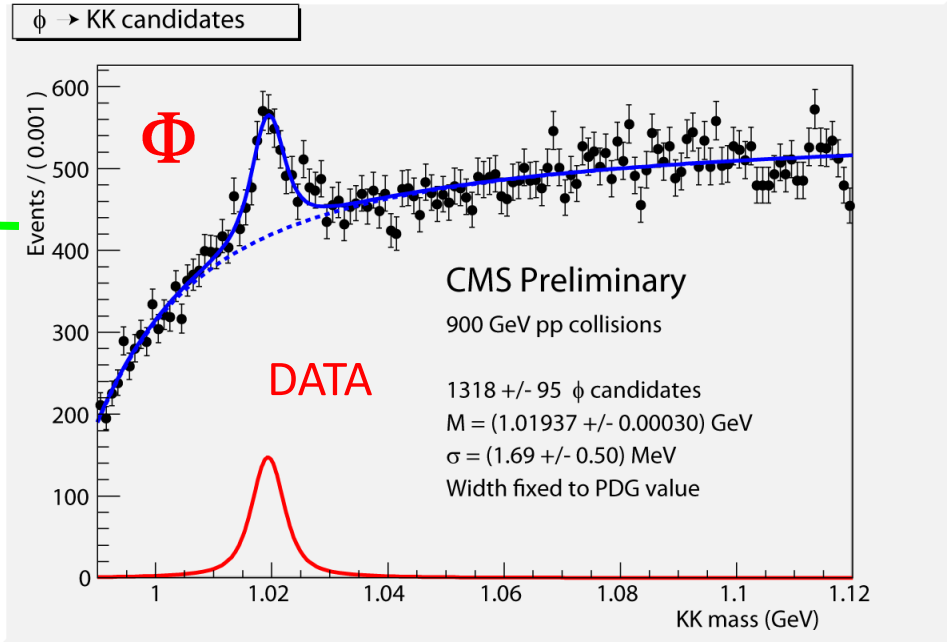


$\Phi \rightarrow K^+K^-$ using dE/dx





- Event selection.
- Rejection of low P tracks (< 1GeV) with dE/dX incompatible with the hypothesis of a charged K (light band).
- Invariant mass reconstruction in the two regions

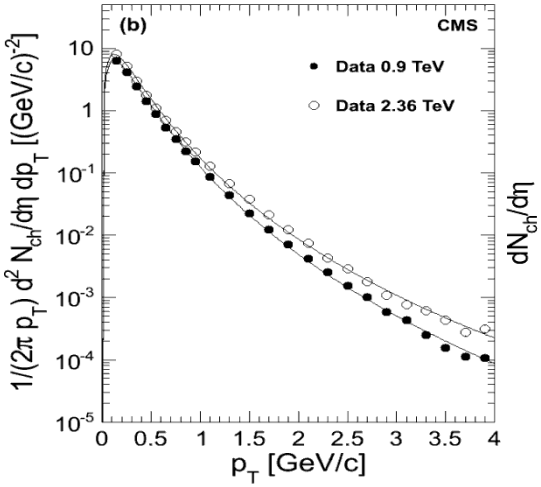


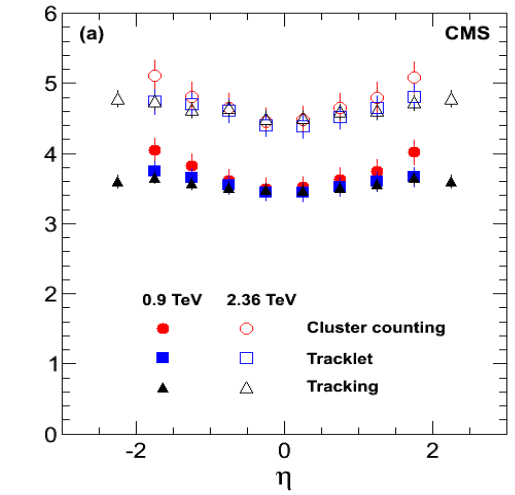
and the first CMS paper on LHC data

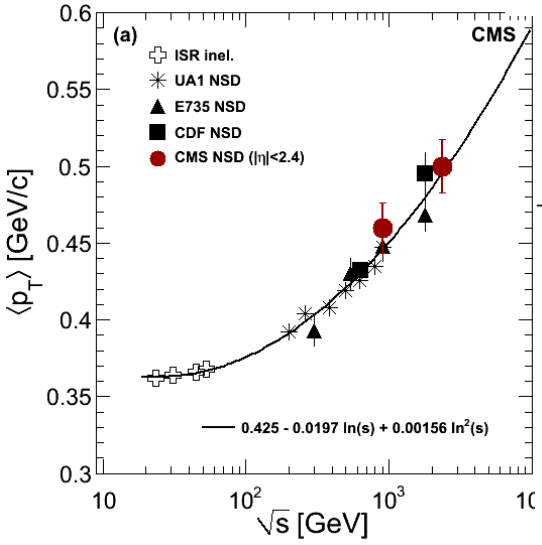
Transverse momentum and pseudorapidity distributions of charged hadrons at √s =900 and 2360GeV

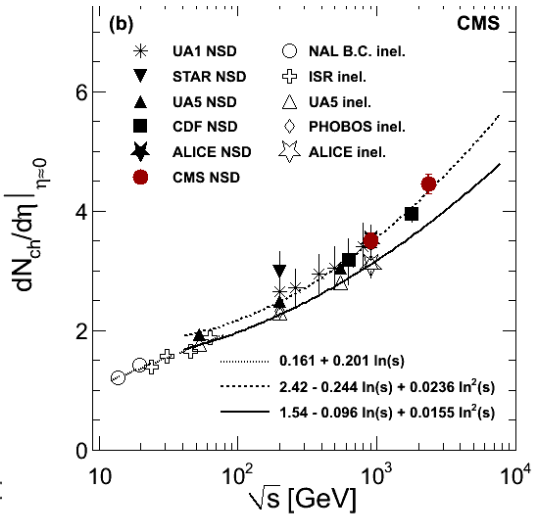
submitted to JHEP on February 3-rd, accepted for publication on February 7-th

*http://dx.doi.org/10.1007/JHEP02%282010%29041





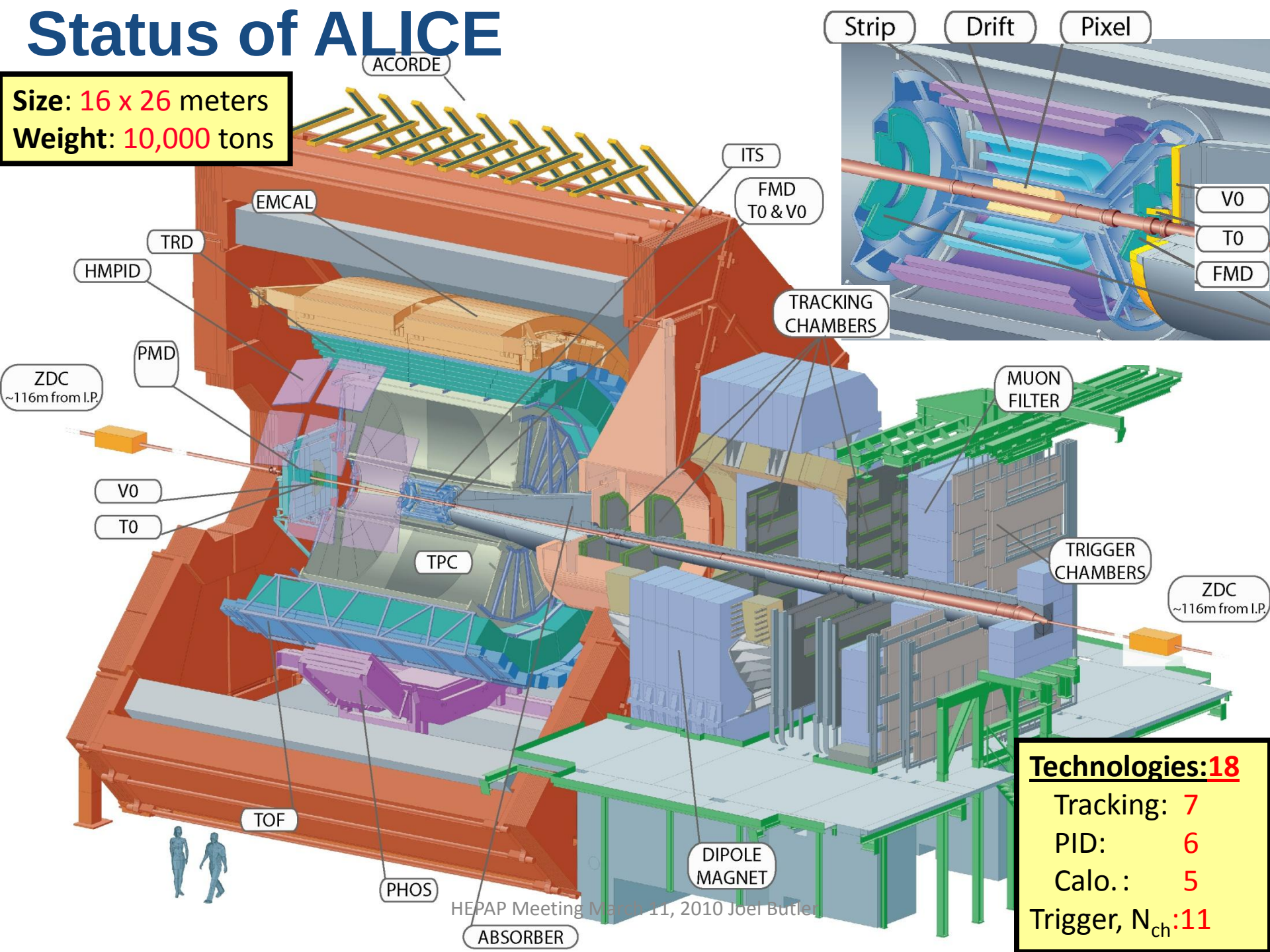




- Complete analysis with three different methods to control better systematics.
- Another confirmation of the excellent tracker performance and good MC description of pixel and strips.
- Important test of our capability to produce high quality physics results in a timely manner.
- First detailed look at minimum bias and underlying event to prepare for high luminosity and HI running.

Status of ALICE

Size: 16 x 26 meters
Weight: 10,000 tons

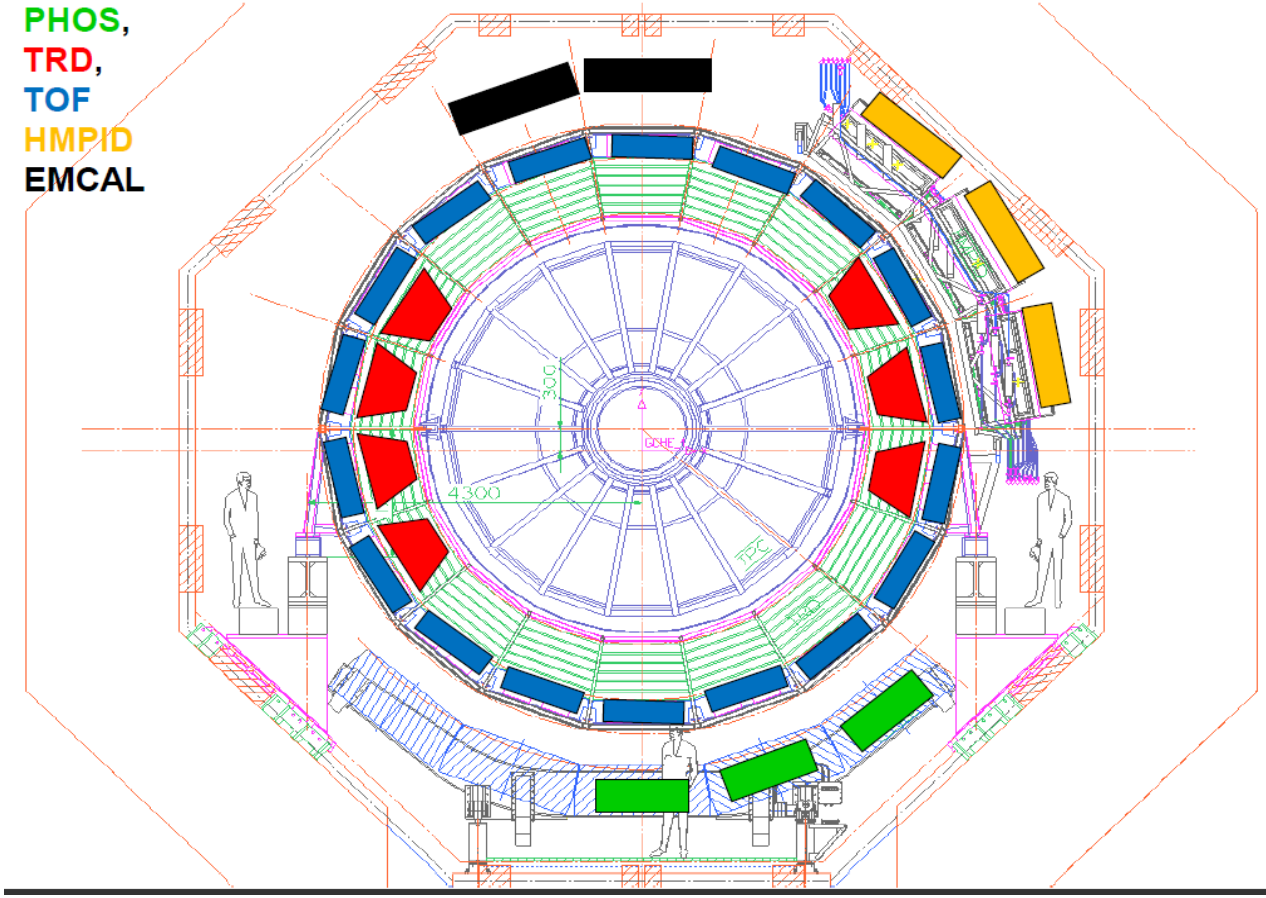


Technologies:18

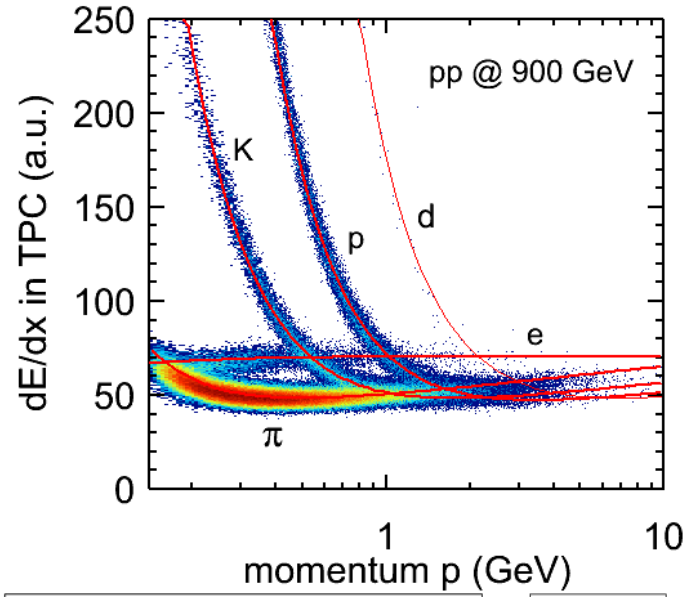
Tracking:	7
PID:	6
Calo.:	5
Trigger, N_{ch}:	11

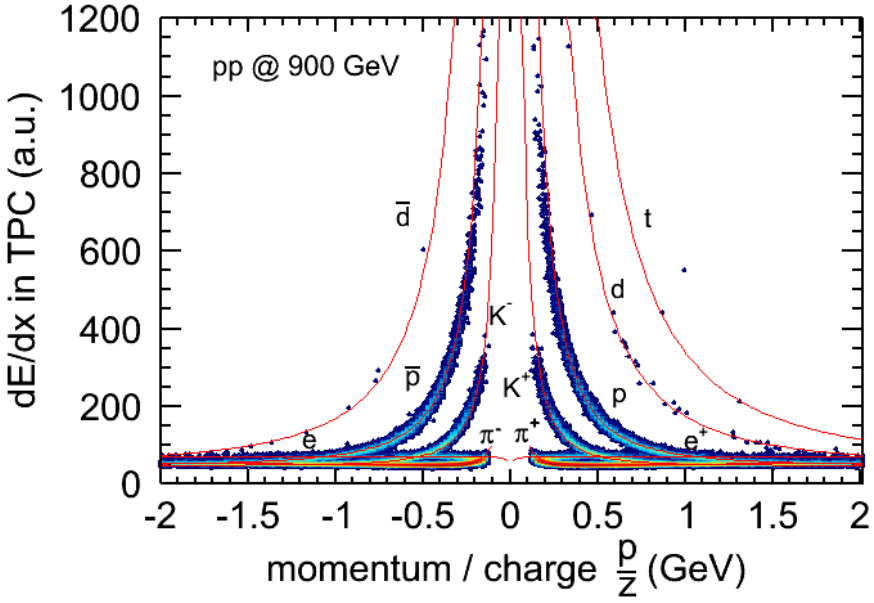
Completion Status

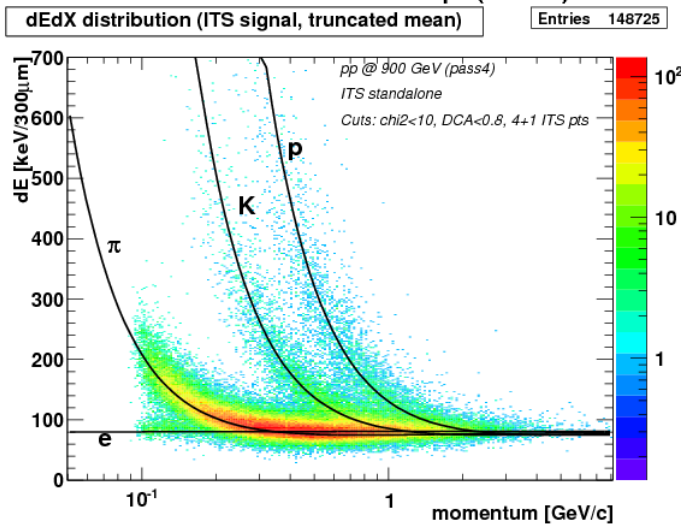
Complete: ITS, TPC, TOF, HMPID, Muon, Vo, To, FMD, PMD, ZDC
Partial: TRD (7/18), EMCAL(4/12), PHOS (3/5), HLT (60%)

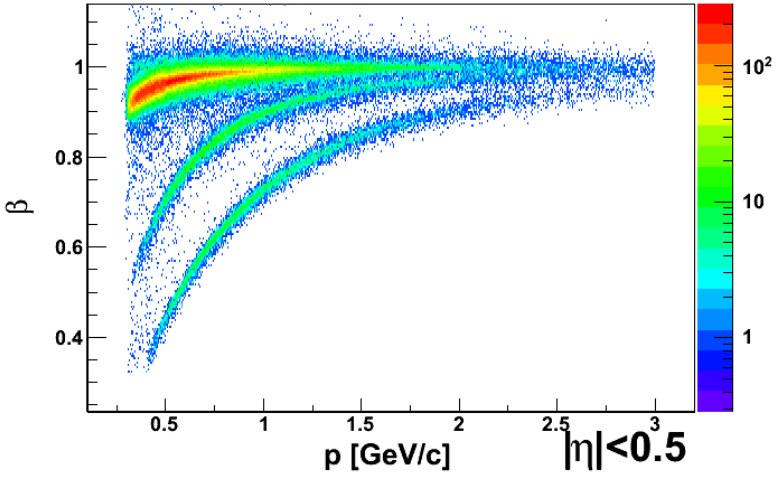


Particle Identification

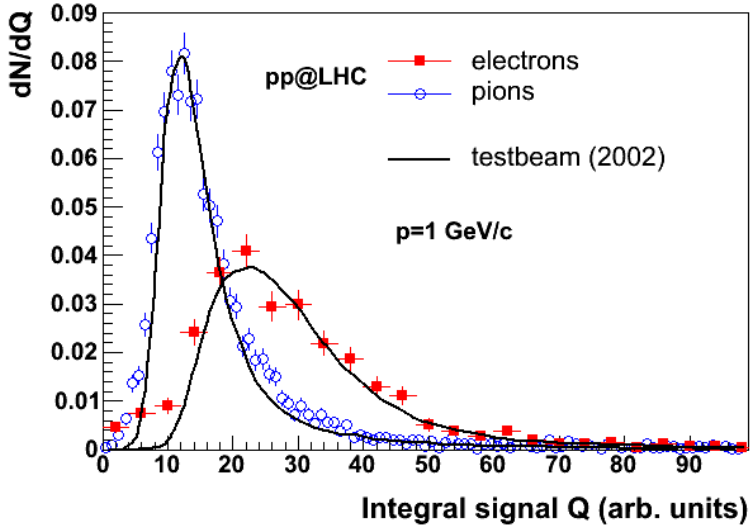


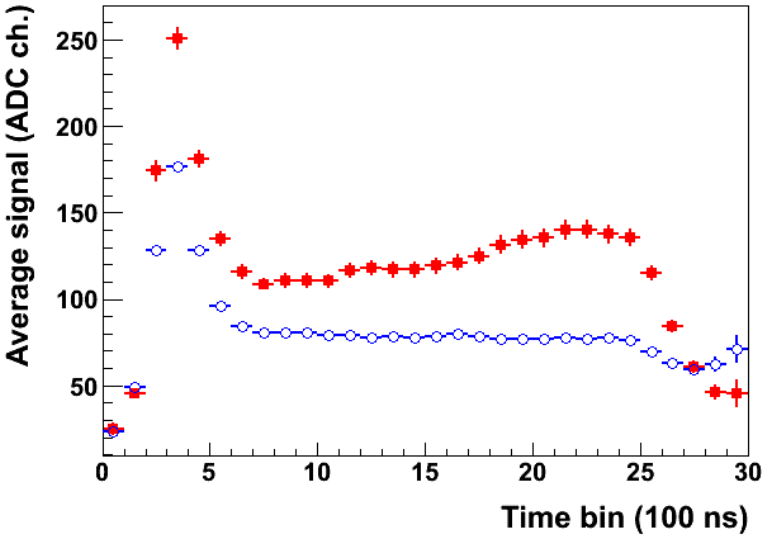


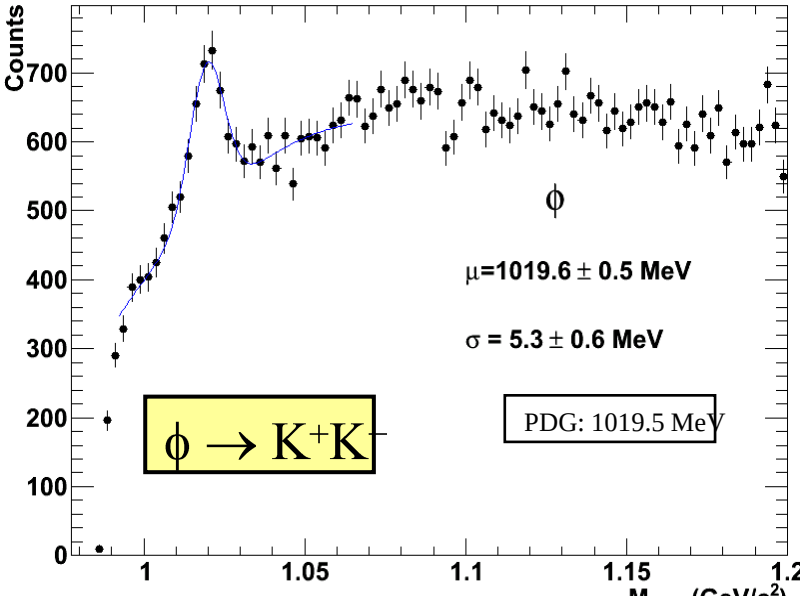




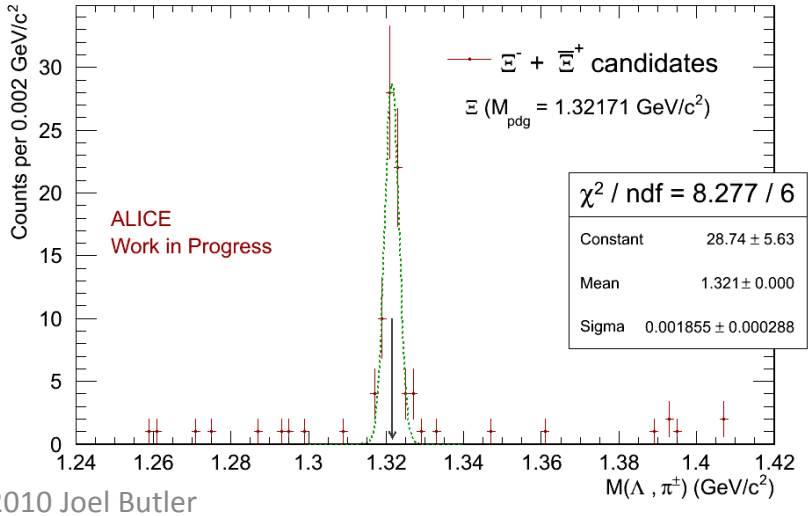
Transition Radiator and Tracking



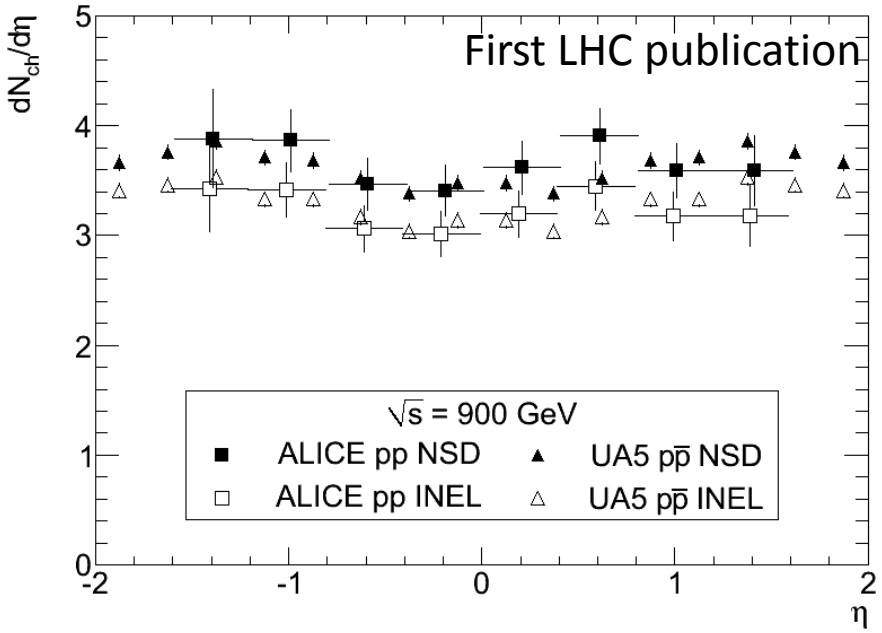


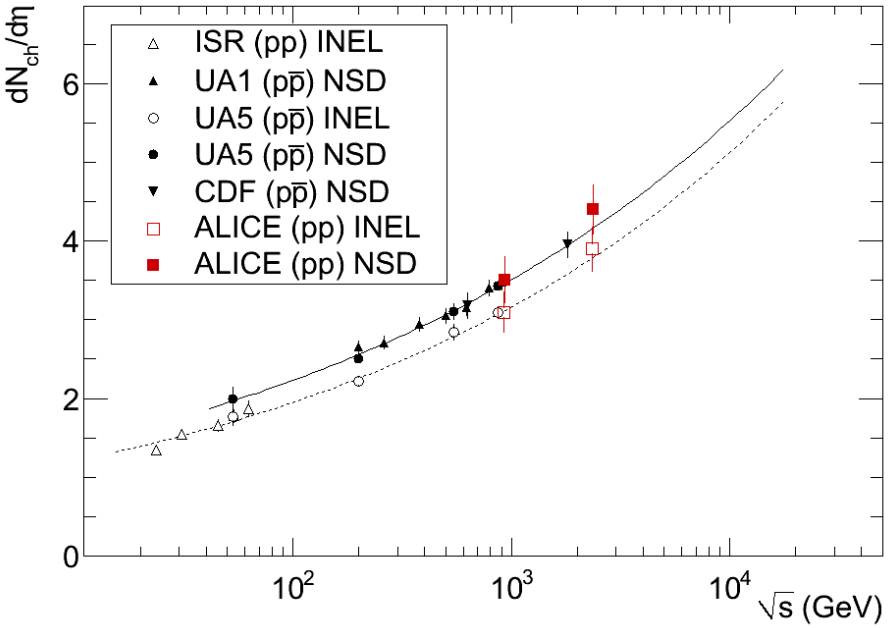


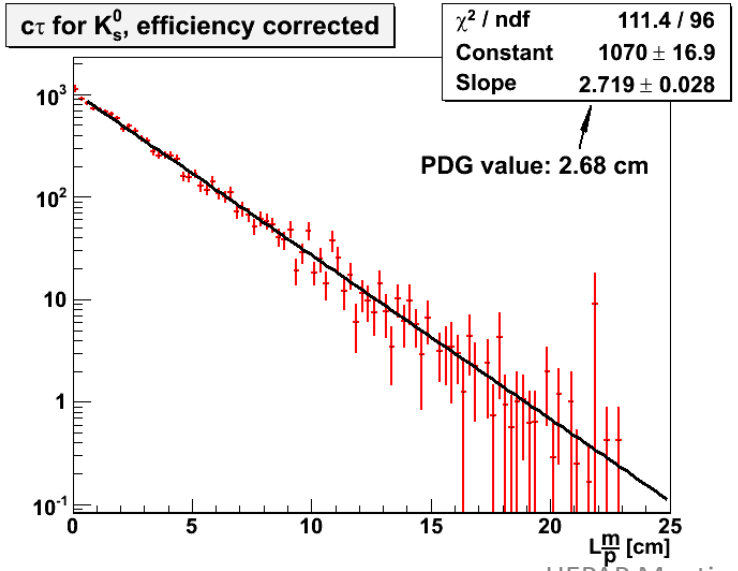
ALICE data, p-p at 900 GeV

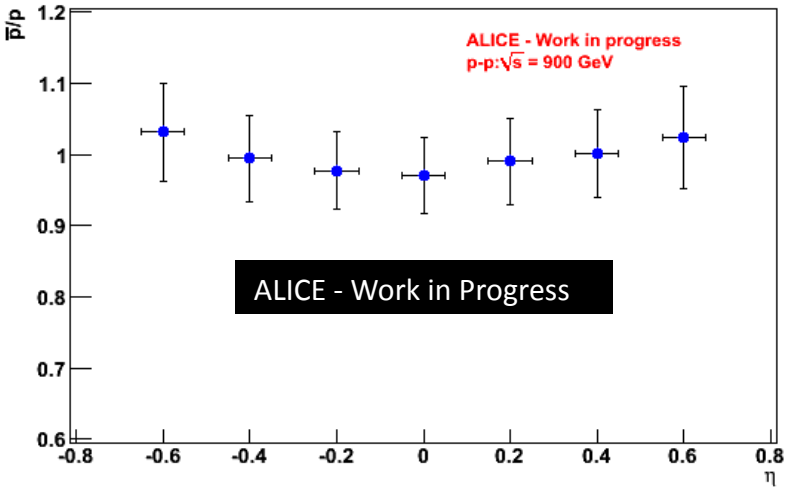


Some ALICE Physics Results

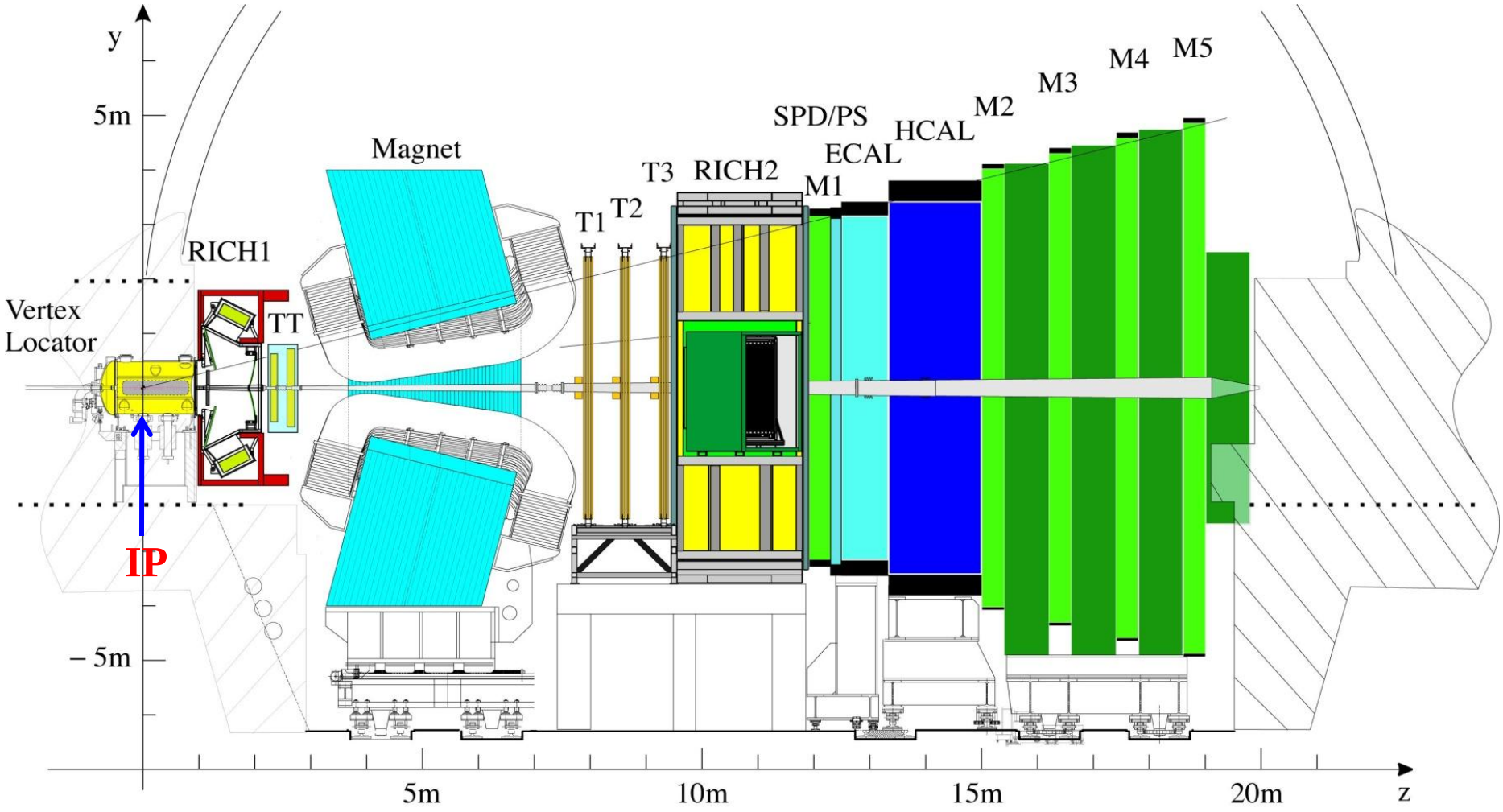




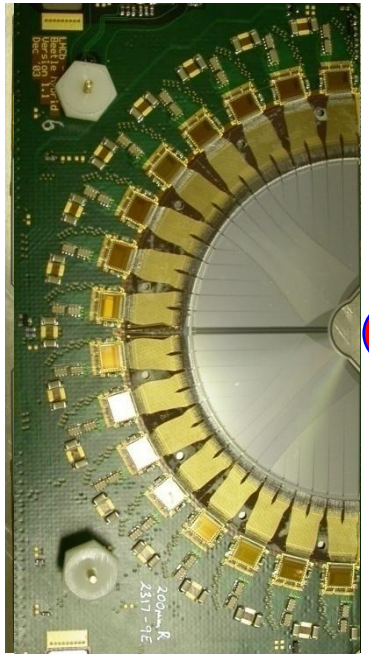


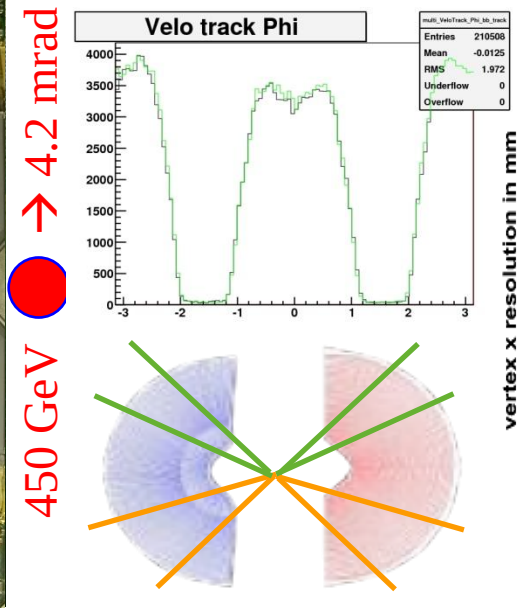


Status of LHCb

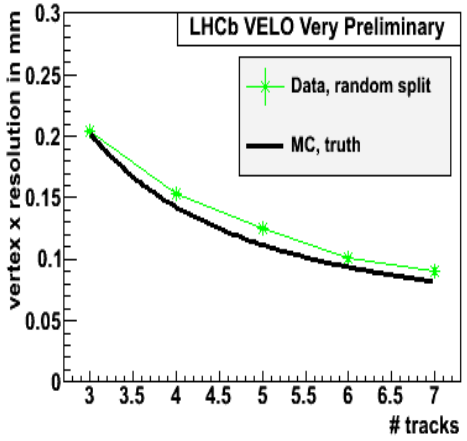


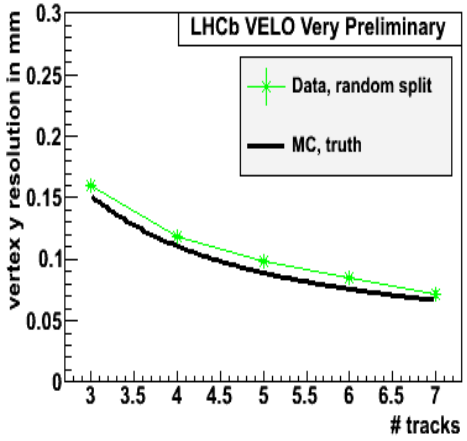
Tracking, K_s and Λ masses



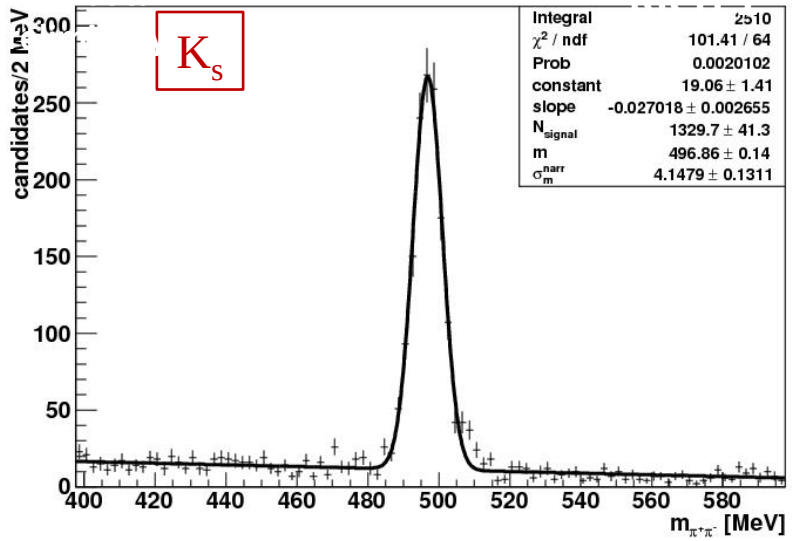


VELO stays partially open to protect it from beam incident at this early stage

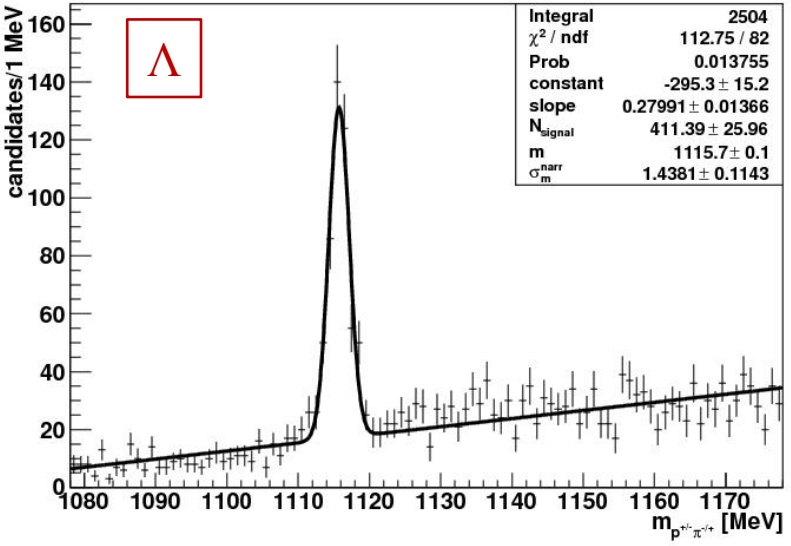




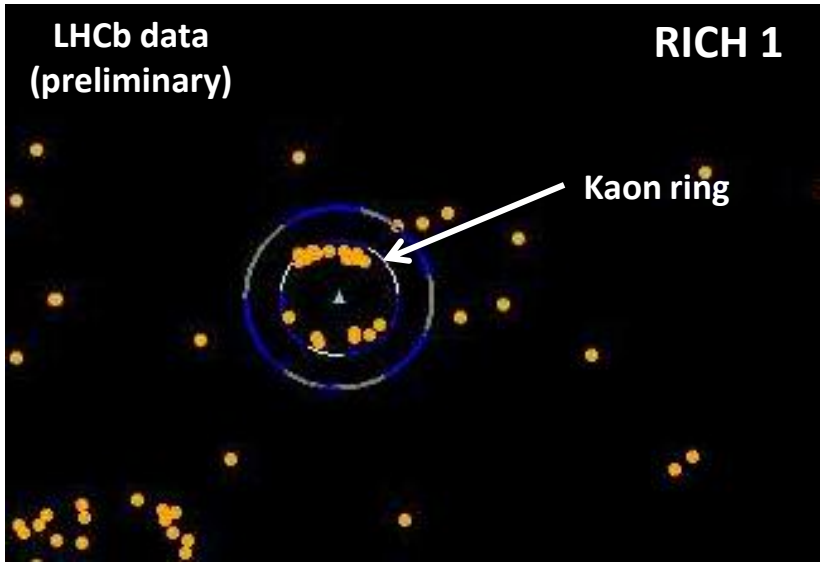
$m_{\pi^+\pi^-}$ (LHCb 2009 data, preliminary)

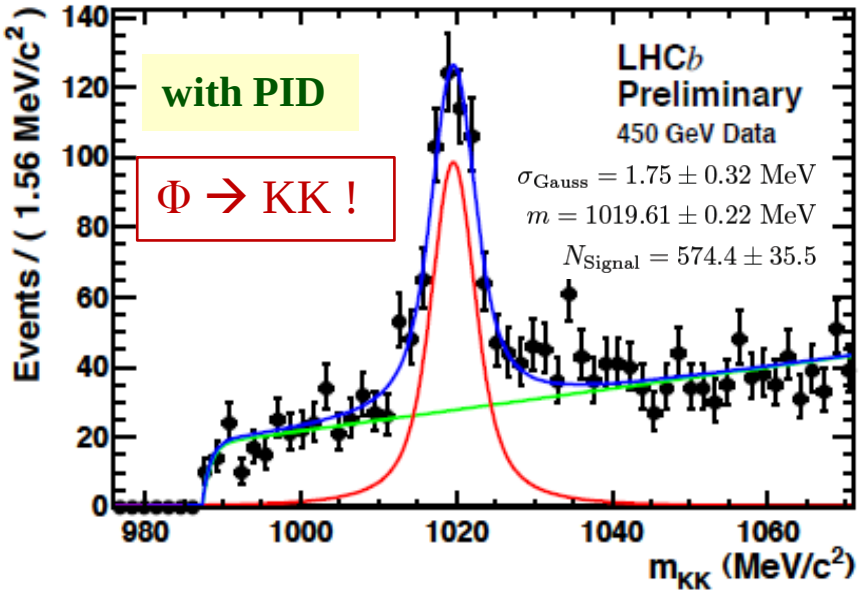


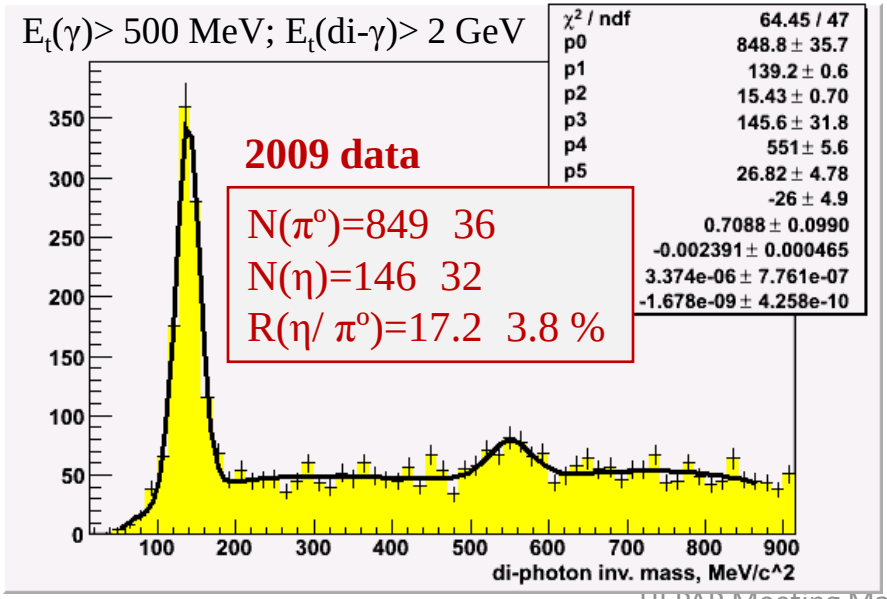
$m_{p^{+/-}\pi^{-/+}}$ (LHCb 2009 data, preliminary)

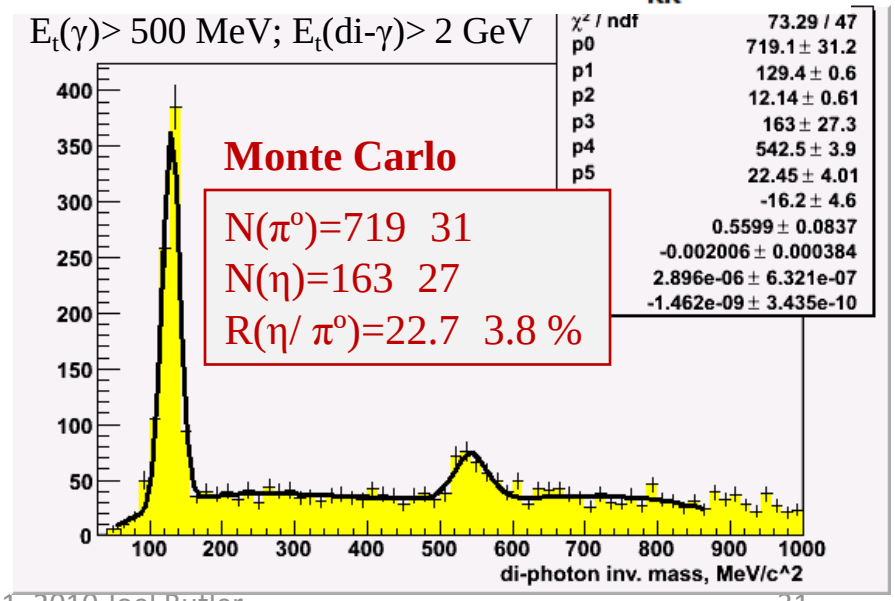


RICH and Calorimeter performance



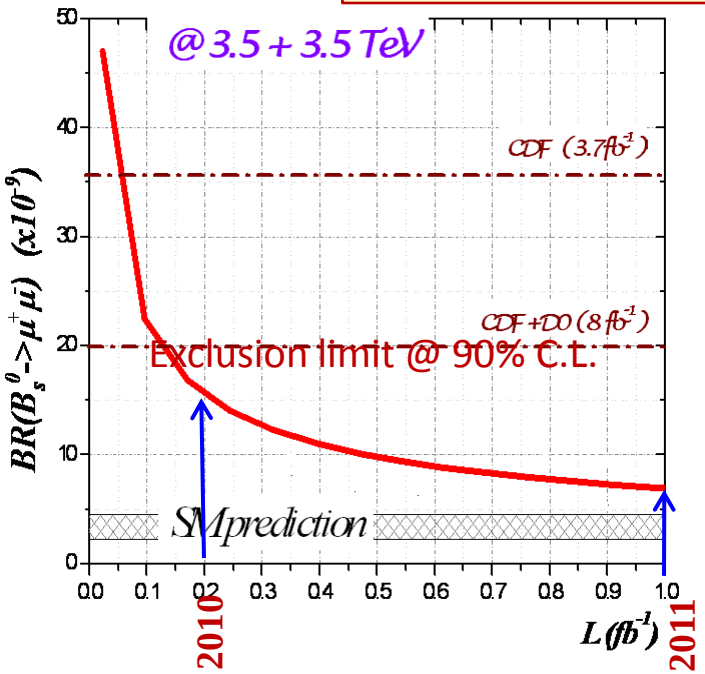


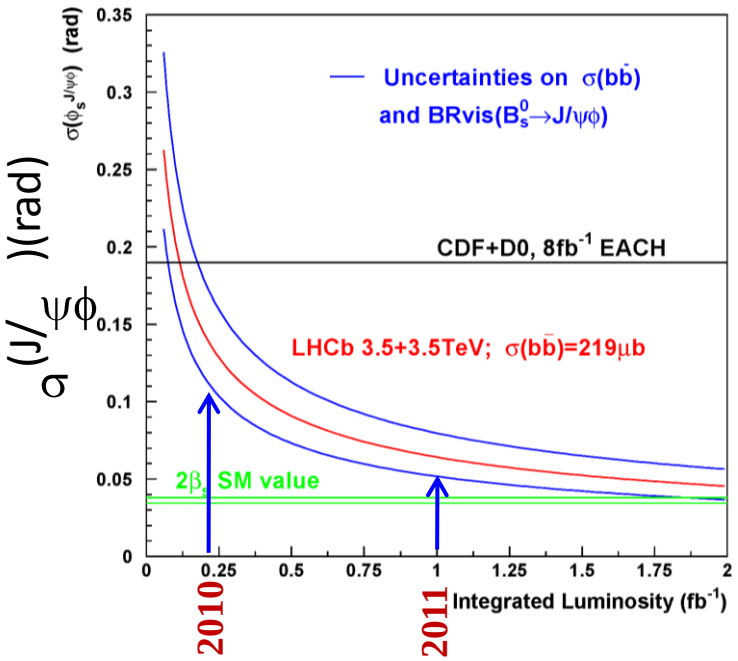




B and Charm Physics: 2010-2011

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





Sensitive probe for MSSM with large tanβ:

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

Large (non-SM) phase (D0 and CDF) :

Φ_s [−1.47 ; −0.29] ∪ [−2.85 ; −1.65]
(90% CL range)

Charm: Expect ~4x10^6 $D^{*+} \to D^0(K^-K^+)\pi^+$ (100 pb^{-1}):

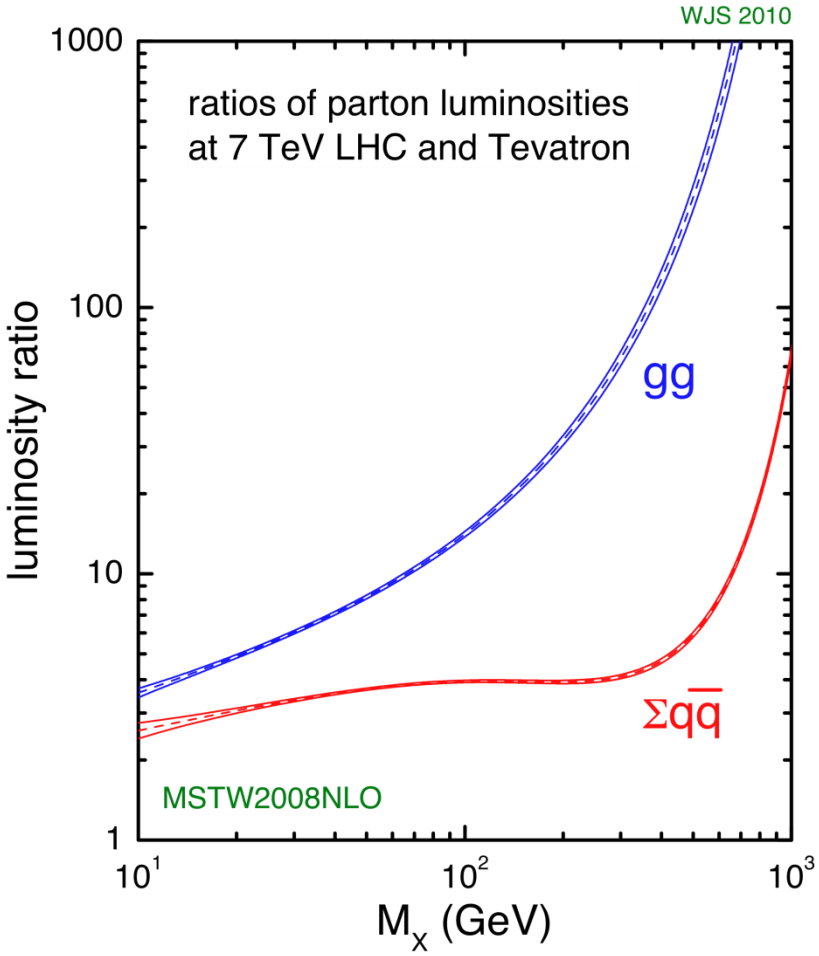
- Measurements of D^0 mixing
- Studies of CP violation in charm decays
- Searches for rare decays, such as $D^0 \to \mu\mu$

Prospects for Upcoming Run ATLAS and CMS

ATLAS

At 7 TeV for	200 pb^{-1}	1 fb^{-1}
# *Z→ee*	*51,000*	*260,000*
# *Top → l+jets*	*1,200*	*5,900*
# *Top → llbb*	*500*	*2,500*
SUSY limit; m_{squark} 5σ	~500 GeV	~700-750 GeV
# W' (mW' = 1.5 TeV)	~4	~20
# Z' (mZ' = 1.5 TeV)	~1	~4
SM $H_{m=160}$→WW	~1.9σ	3-4 σ

CMS: Great physics is within reach
(just to give you an idea)
1.SUSY (squarks and neutralinos) up to ~ 800GeV
2.W' up to ~ 2 TeV; Z' up to ~ 1.5 TeV
3.SM Higgs exclusion in range ~165 ± 10 GeV/c^2



Conclusions

- All 4 detectors have their equipment for the run in place and working and are ready to take data and to analyze it expeditiously
- Every opportunity to use particles from cosmics and the LHC has been exploited
  - Cosmic rays, beam splash events, beam halo events, collisions
  - Not all issues have yet been addressed because of the low integrated luminosity – especially muons, triggers
- Pushing the early collision data through to publication has created a discipline that has advanced our capabilities
- The luminosity that we expect to get over the next two years will allow us to address the remainder detector issues and offer **the opportunity for new physics if we are lucky. This run has the potential for a new discovery!**

Bring on the COLLISIONS!

Acknowledgement

- Thanks to the spokespersons and their designees in all four collaborations who provided material for this talk.