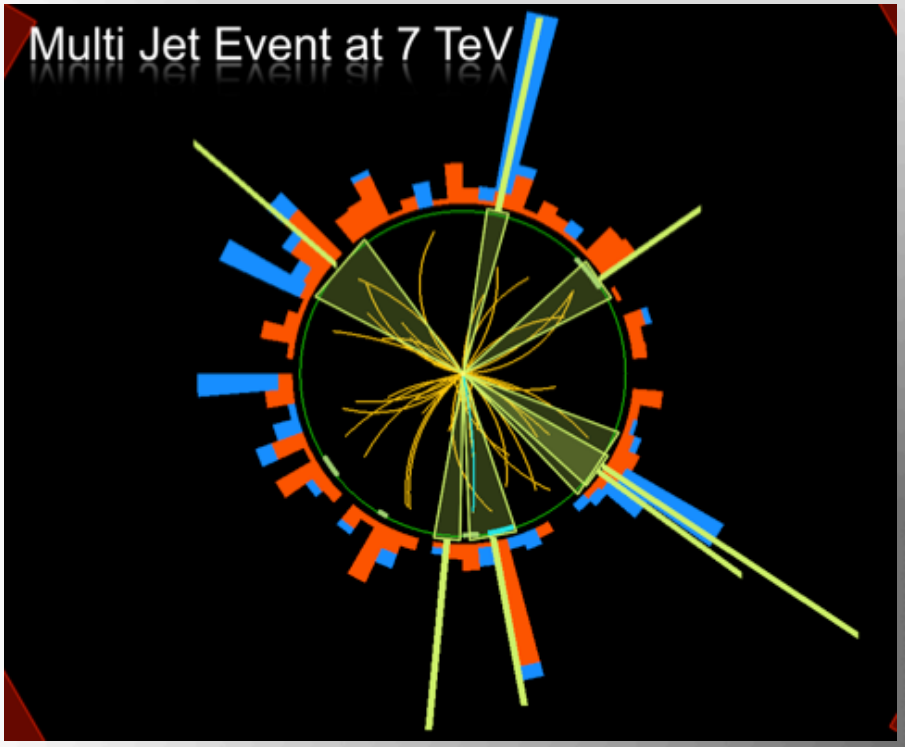
Status of CMS

On behalf of the CMS Collaboration

Albert De Roeck

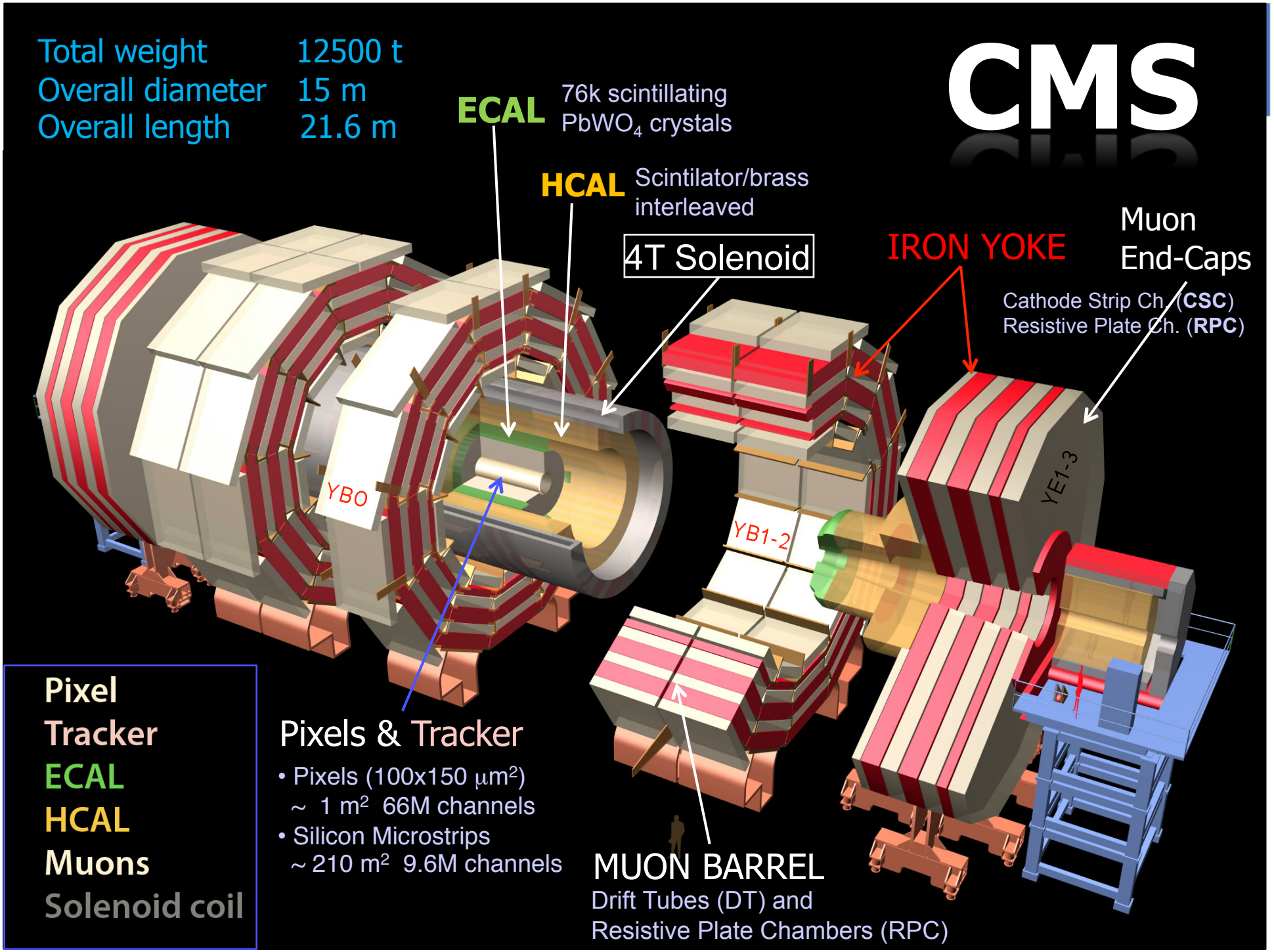
CERN

101st LHCC Meeting - Open Session – May 5, 2010



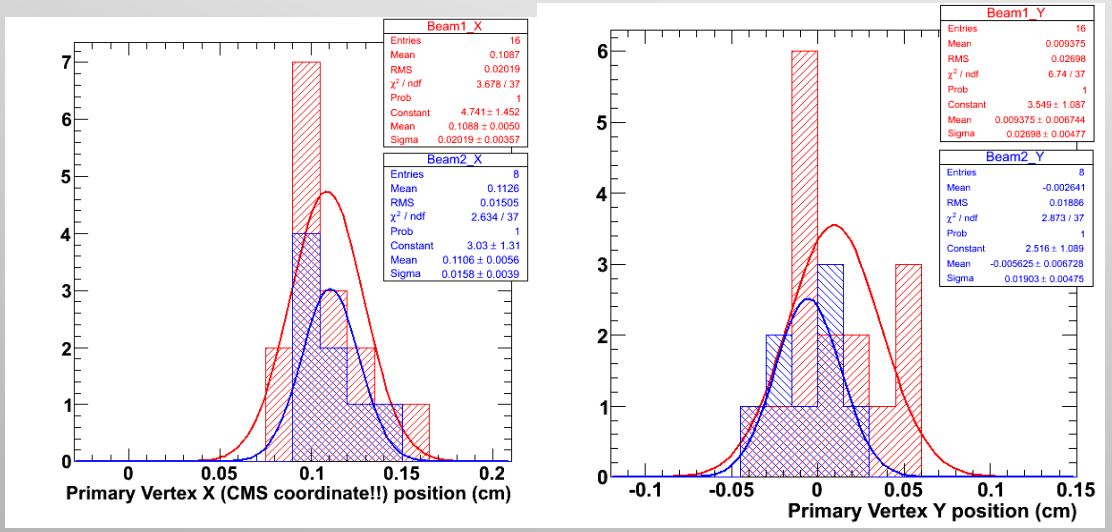
Outline

- Operations @ 7 TeV
- Performance @ 7 TeV
- Physics results at 0.9, 2.36 and 7 TeV
- Summary & outlook


Total weight 12500 t
Overall diameter 15 m
Overall length 21.6 m
CMS
ECAL 76k scintillating PbWO4 crystals
HCAL Scintilator/brass interleaved
4T Solenoid
IRON YOKE
Muon End-Caps
Cathode Strip Ch. (CSC)
Resistive Plate Ch. (RPC)
YBO
YB1-2
YE1-3
Pixel
Tracker
ECAL
HCAL
Muons
Solenoid coil
Pixels & Tracker
• Pixels (100x150 μm²)
~ 1 m² 66M channels
• Silicon Microstrips
~ 210 m² 9.6M channels
MUON BARREL
Drift Tubes (DT) and
Resistive Plate Chambers (RPC)

30/3: 7 TeV Collisions…

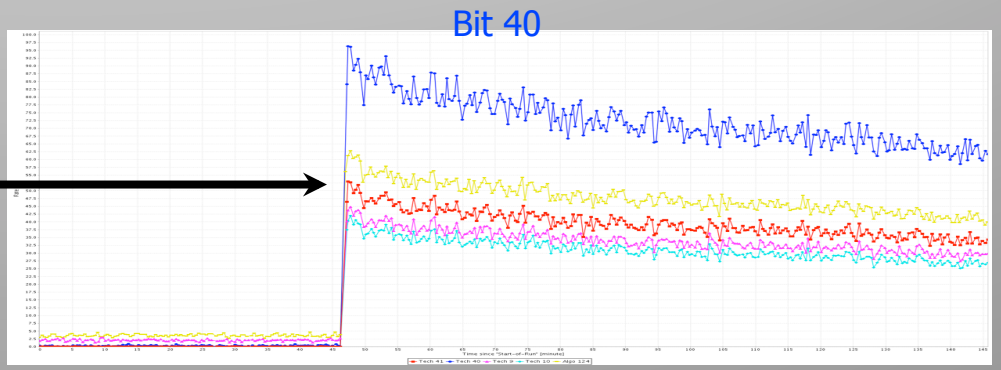
Tuesday March 30, 2 am: study of the position of the beams in IP5 (beams in non-colliding mode) using the interaction with beam gas.



The orbit is ok, beams are in colliding position

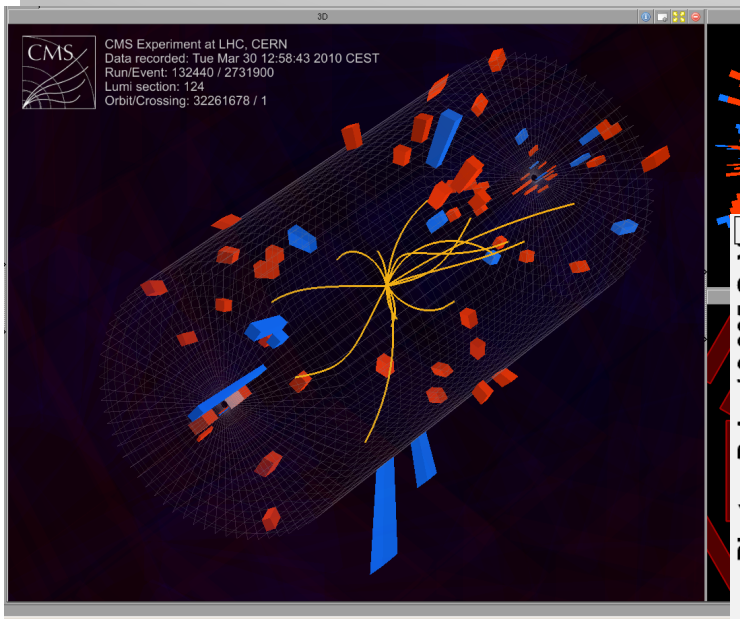
We are go!

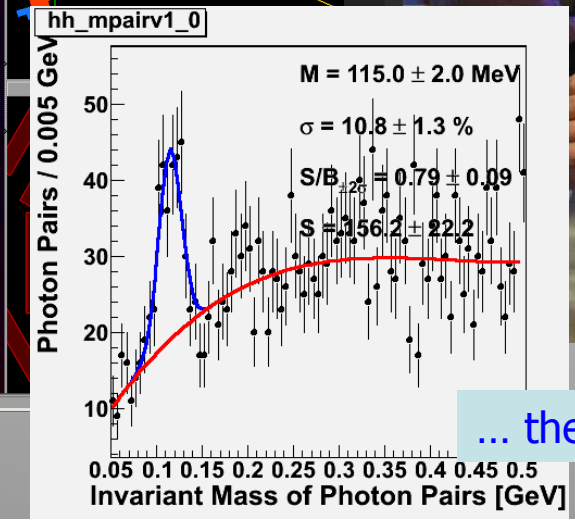
Tuesday March 30, 12.58:
separation bumps collapsed
~60Hz collision rate

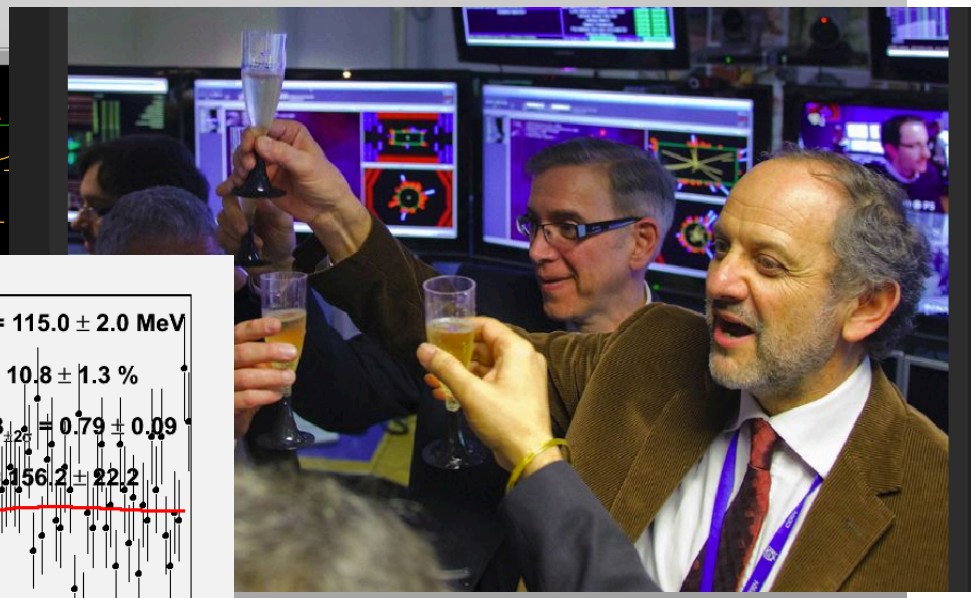


30/3: 7 TeV Collisions…

12:58

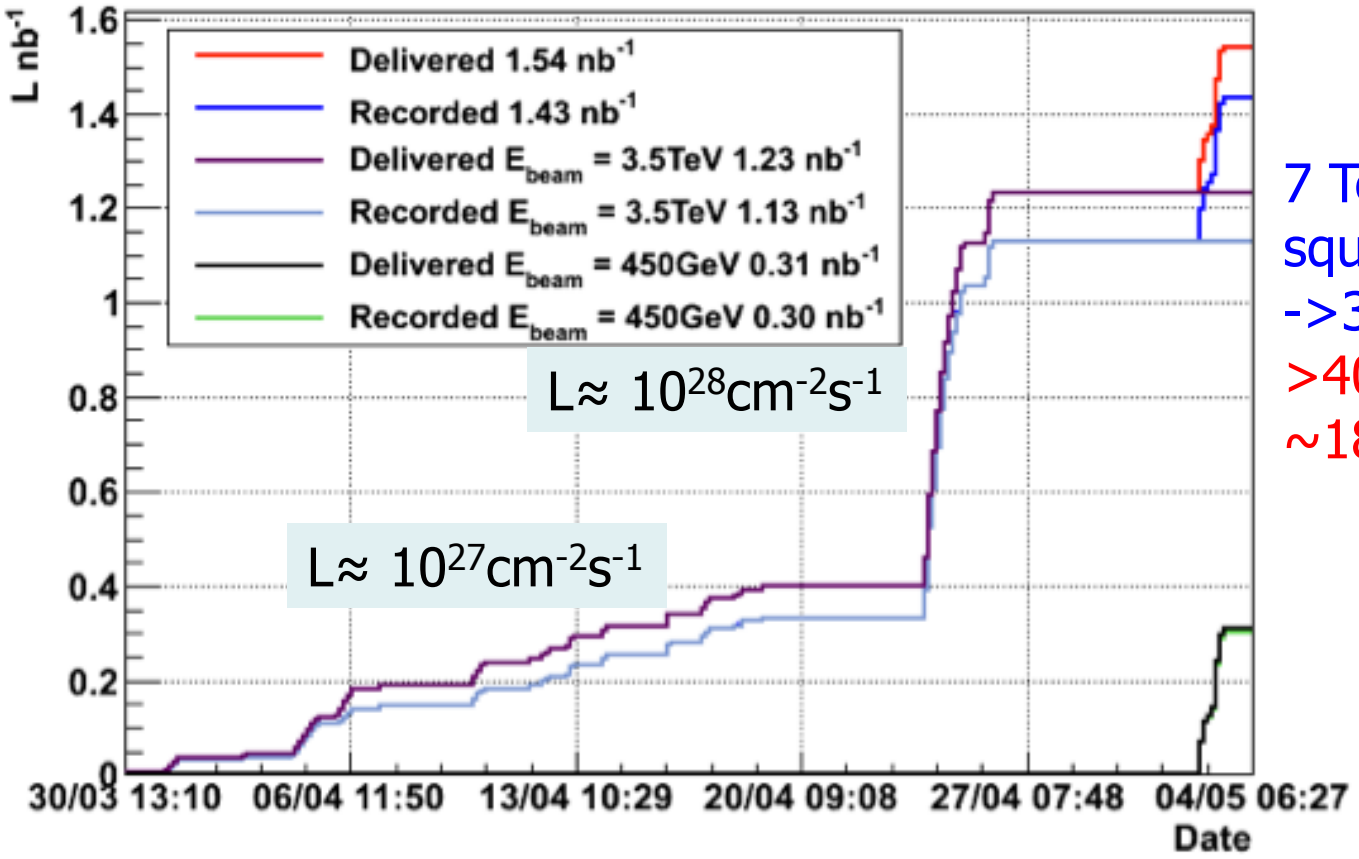






… the first 5 min

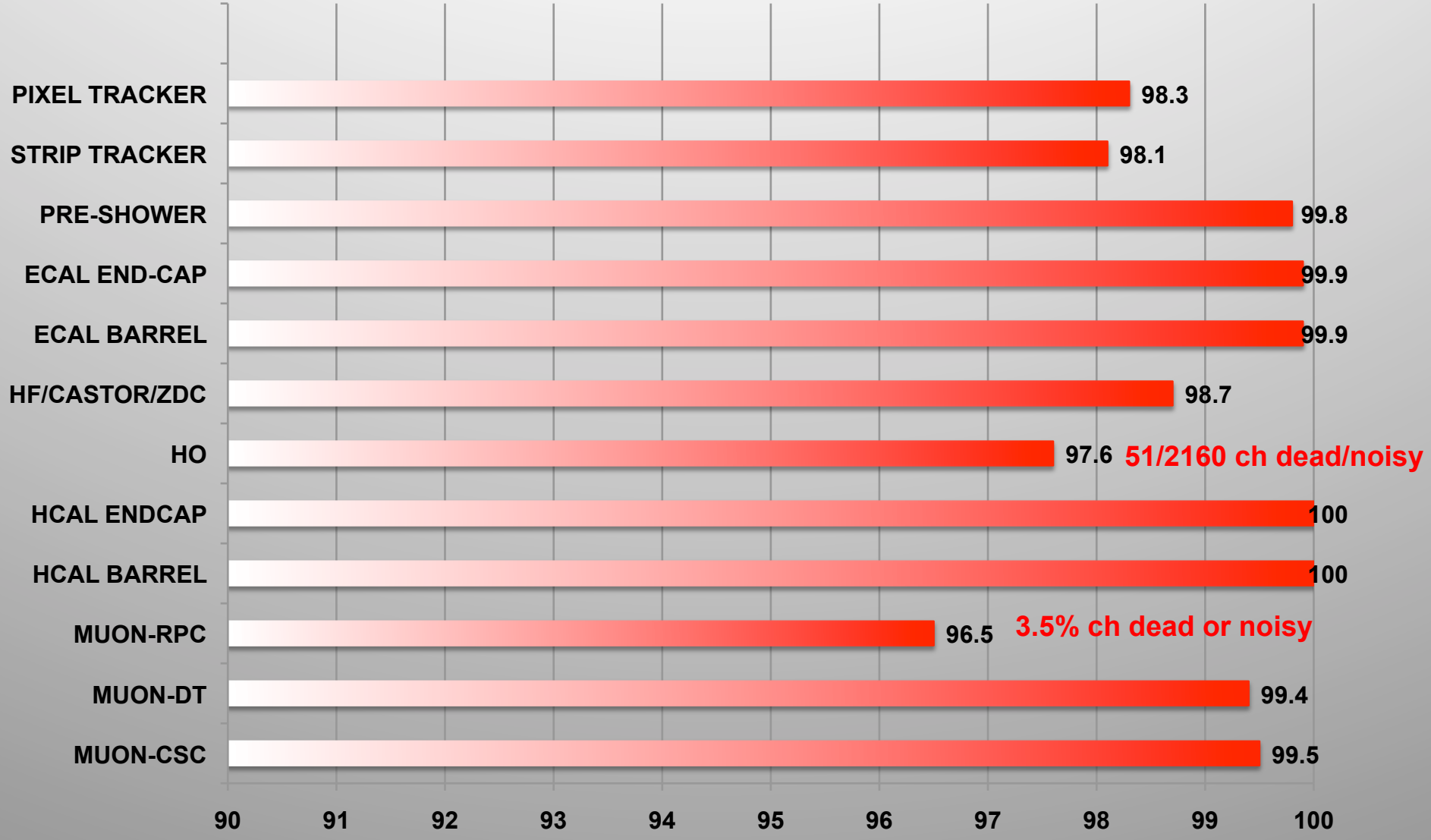
CMS Data Taking



7 TeV DAQ rates with squeezed beams
->300 Hz/ 600 Hz (max)
>40M events @ 7 TeV
~18M events @ 900 GeV
all collisions

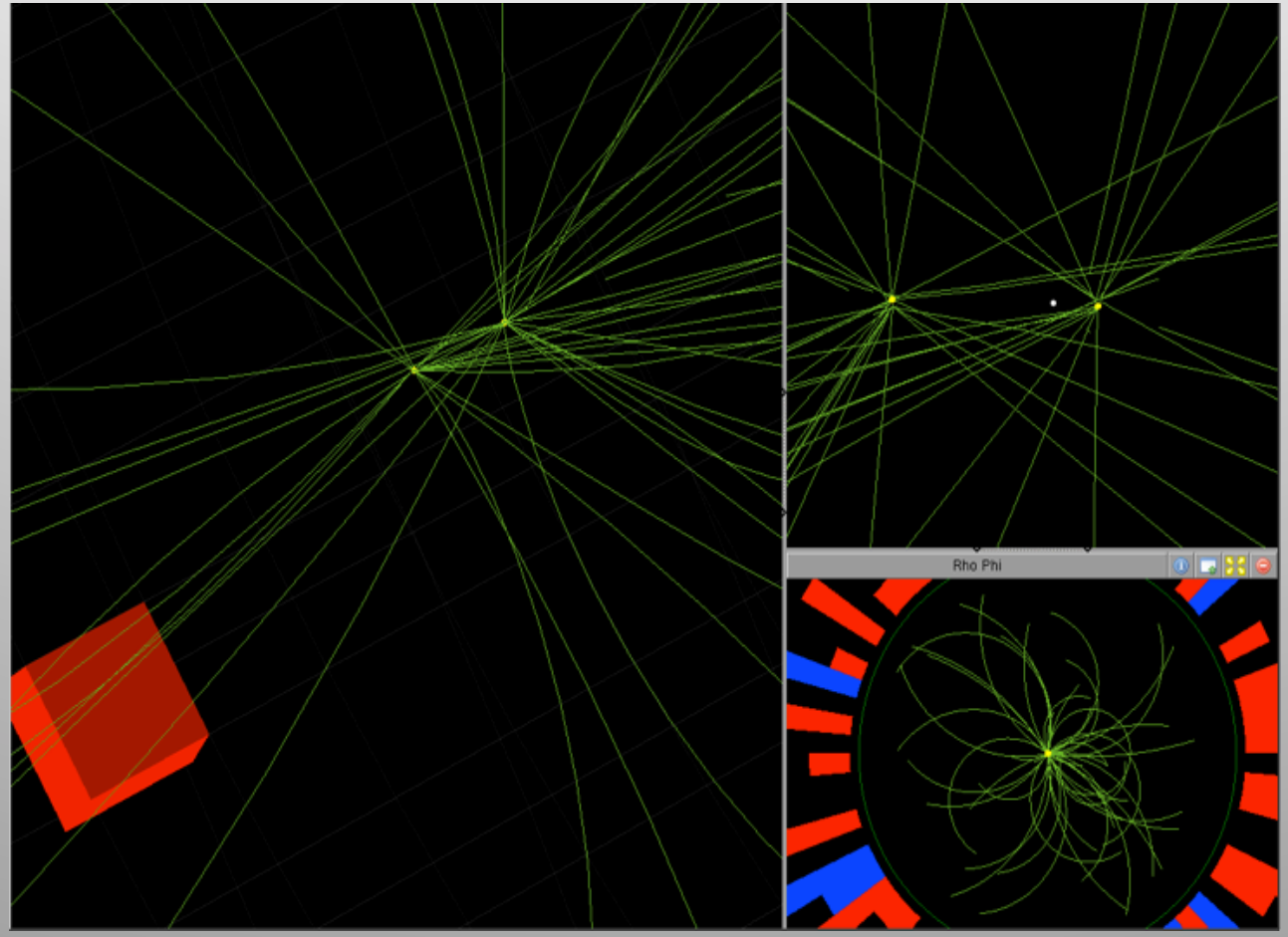
CMS data taking efficiency ~92% this year and ~ 96% in the week before 26/4

CMS Operation at 7 TeV



Low Luminosity but:

Events with two primary vertices

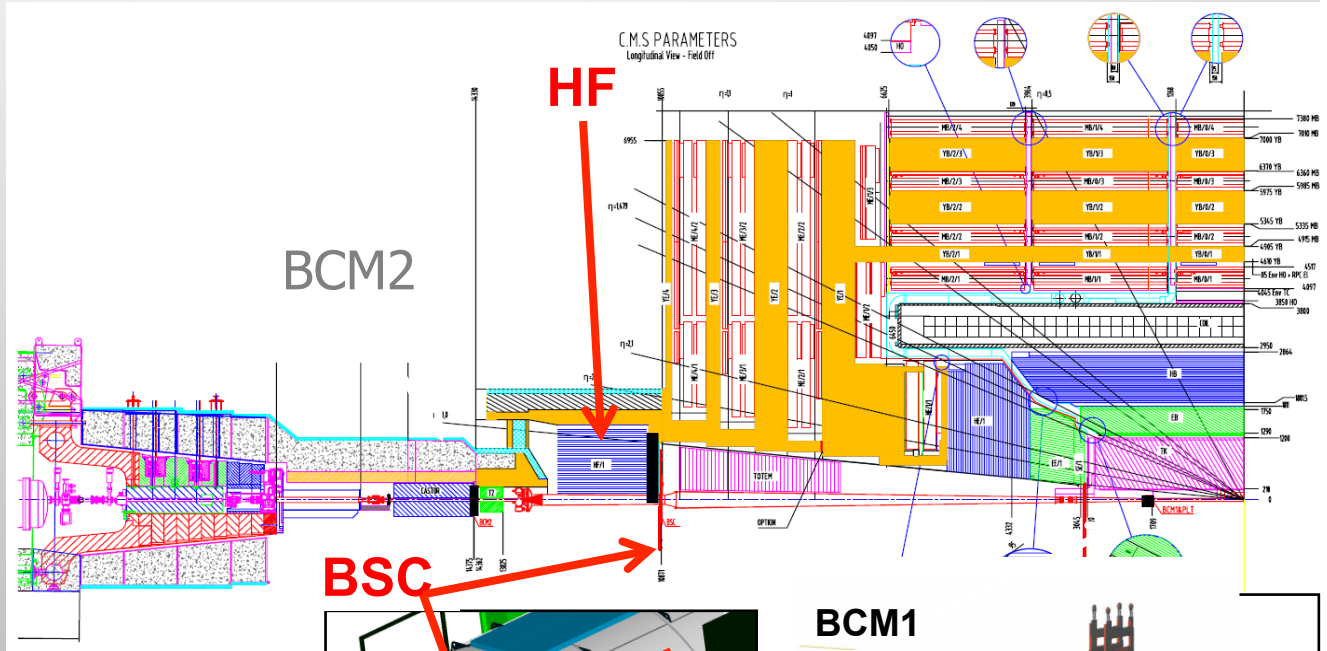


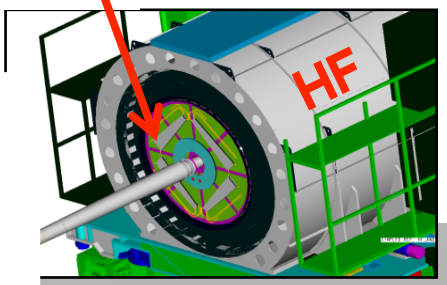
Pile-up still at start (> 0.5 %) but getting more important with squeezed beams and will be an issue for high intensity beams. CMS will be ready for it

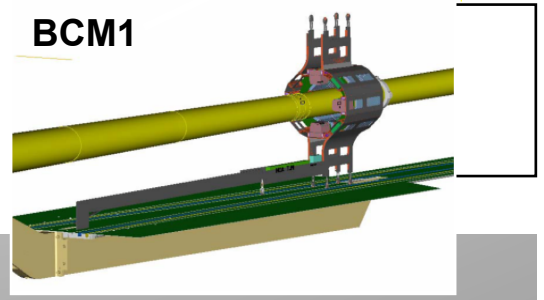
Triggers

7 TeV Start up:
Work horse trigger = minimum bias triggers

- Hadronic Forward
  - HF: 2.5 ≤ |η|≤ 5.
- Beam Scintillator planes
  - BSC: ± 10.5 m from IP
- Beam Pick-up Timing
  - BPTX: ± 175 m from IP
- Trigger: Min Bias & Zero Bias
  - L1 Beam Scintillator Counters
  - L1 Trigger “BPTX” prescaled
- Minimum Bias selection:
  - BSC (OR 2 planes) + vertex: $\epsilon \sim 90\%$
  - HF (E > 3 GeV both sides): $\epsilon \sim 90\%$
    - Combined high ϵfficiency



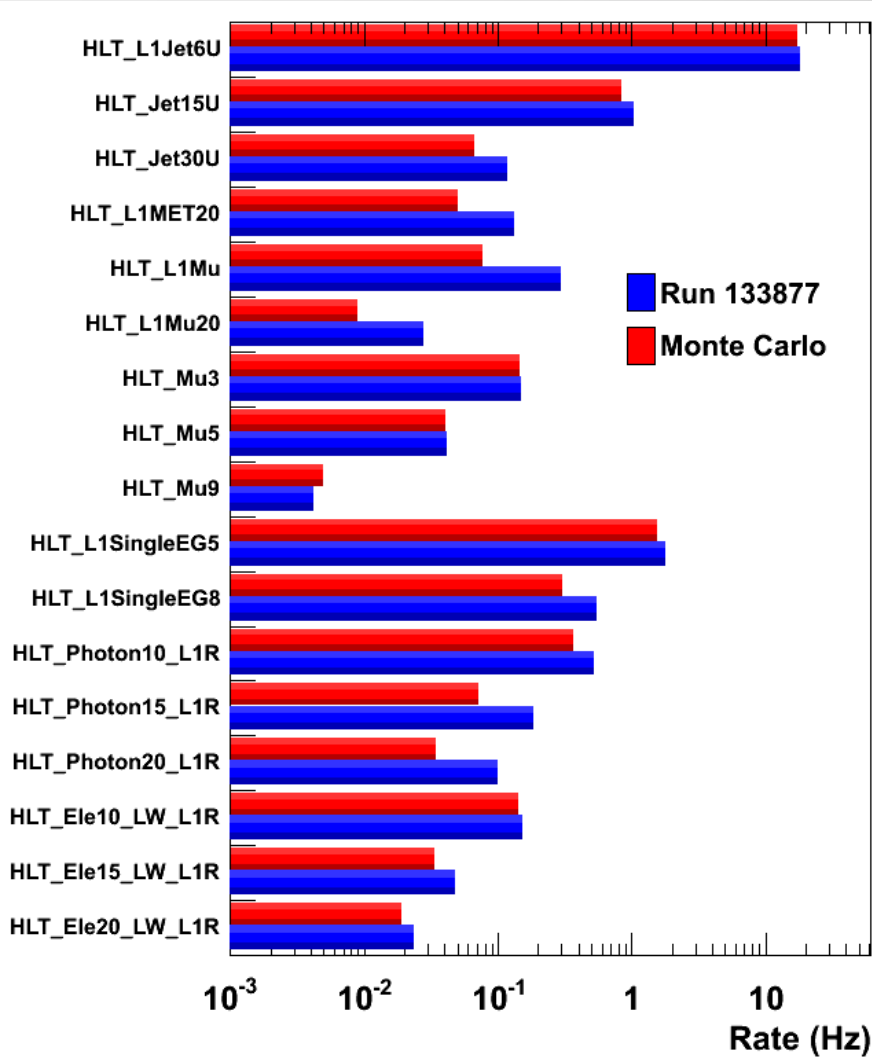




Now with squeezed beams, deploy the full trigger menu

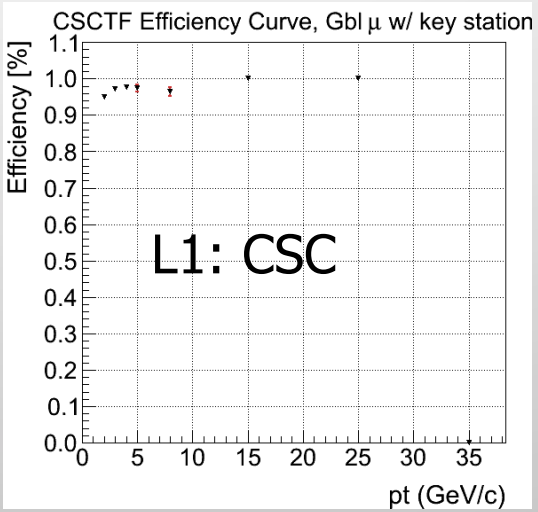
Triggers

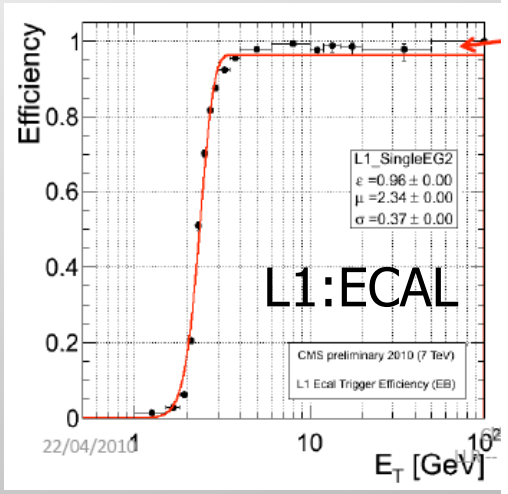
- Developed menus for 10^{27}, 10^{28} and 10^{29}cm^{-2}/s luminosity scenarios
  - Rate predictions based on MC & data
  - Primary datasets for 10^{29}cm^{-2}/s
- Developed menu evolution strategies for higher luminosities:
  - Preparing menu for each ×2 increase
  - Target rate between 200 and 400Hz
- Studies going on to check impact of pile-up on CPU performance & rates
  - Dedicated multiple vertex trigger to capture pile-up events
- Fast validation of the trigger results and efficiencies
- Developing rate predictor tool for the online shifters

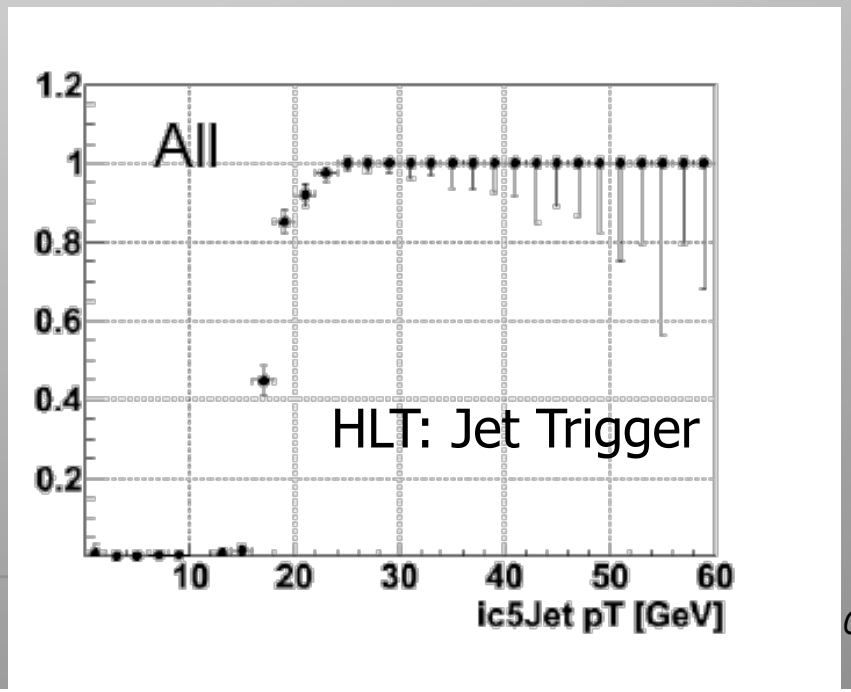


Trigger Performance

- L1:
  - Start of data taking used to improve the relative timing further (time scans)
  - Trigger Efficiencies eg for the Muon and ECAL triggers:
- HLT
  - Farm Capacity~100 msec/evt
    - Average CPU processing time at L1 rate of 50 kHz
  - Presently we spent ~15 ms/ event (min bias dominated)
  - Expect ~ 40 ms/event for a lumi of 10^{30} $cm^{-2}s^{-1}$ on average
- DAQ
  - L1 ~ 1KHz, <500 kB/evt, HLT ~ 2% CPU loaded





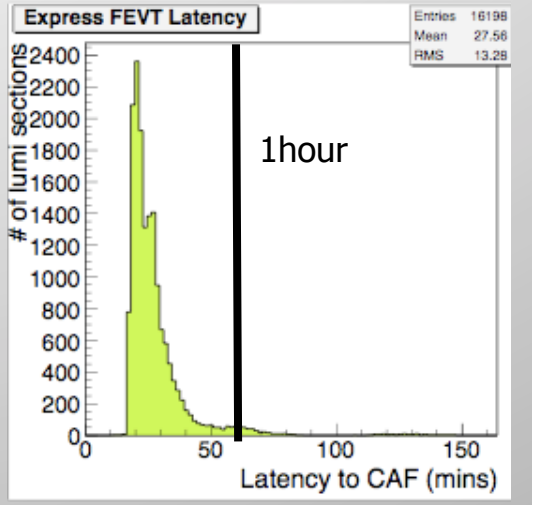


Computing: Processing/Transfer

- Good experience with data processing
  - Tier-0. Software and infrastructure are stable

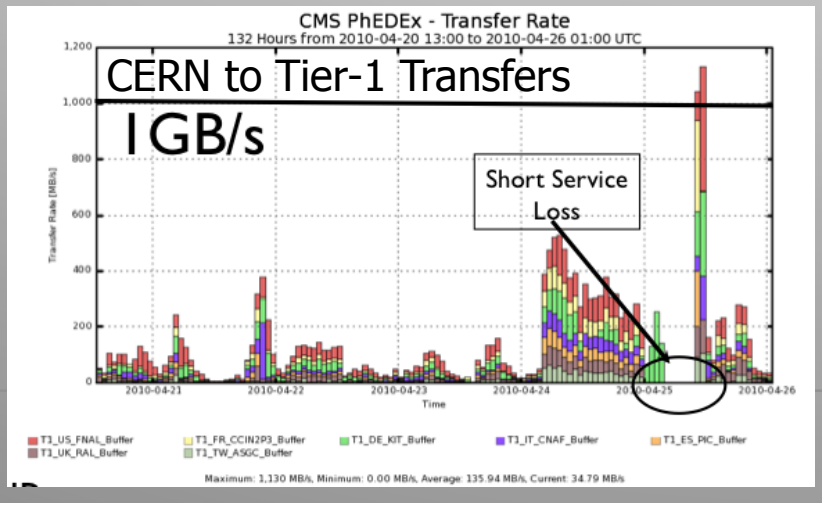
Job Type	Total Jobs	Failures	Success Rate
Express	132314	94	99.93%
Repack	7262	6	99.92%
PromptReco	36538	0	100.00%
AlcaSkim	21336	0	100.00%

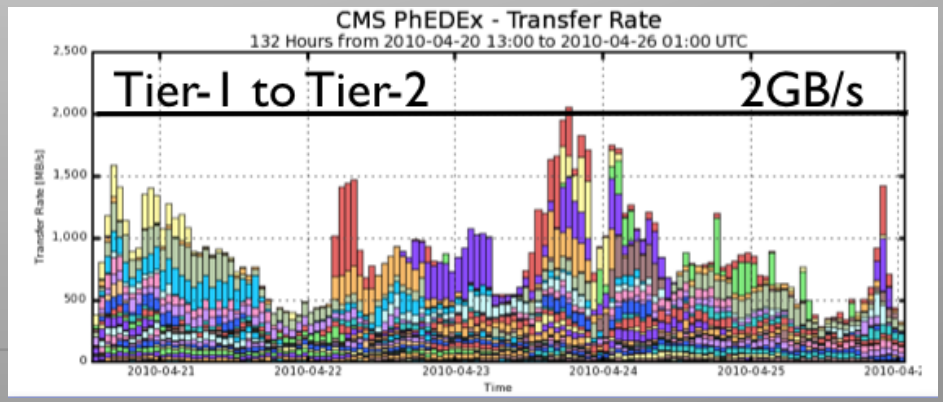
Example from 7TeV Running



(a) Express Latency

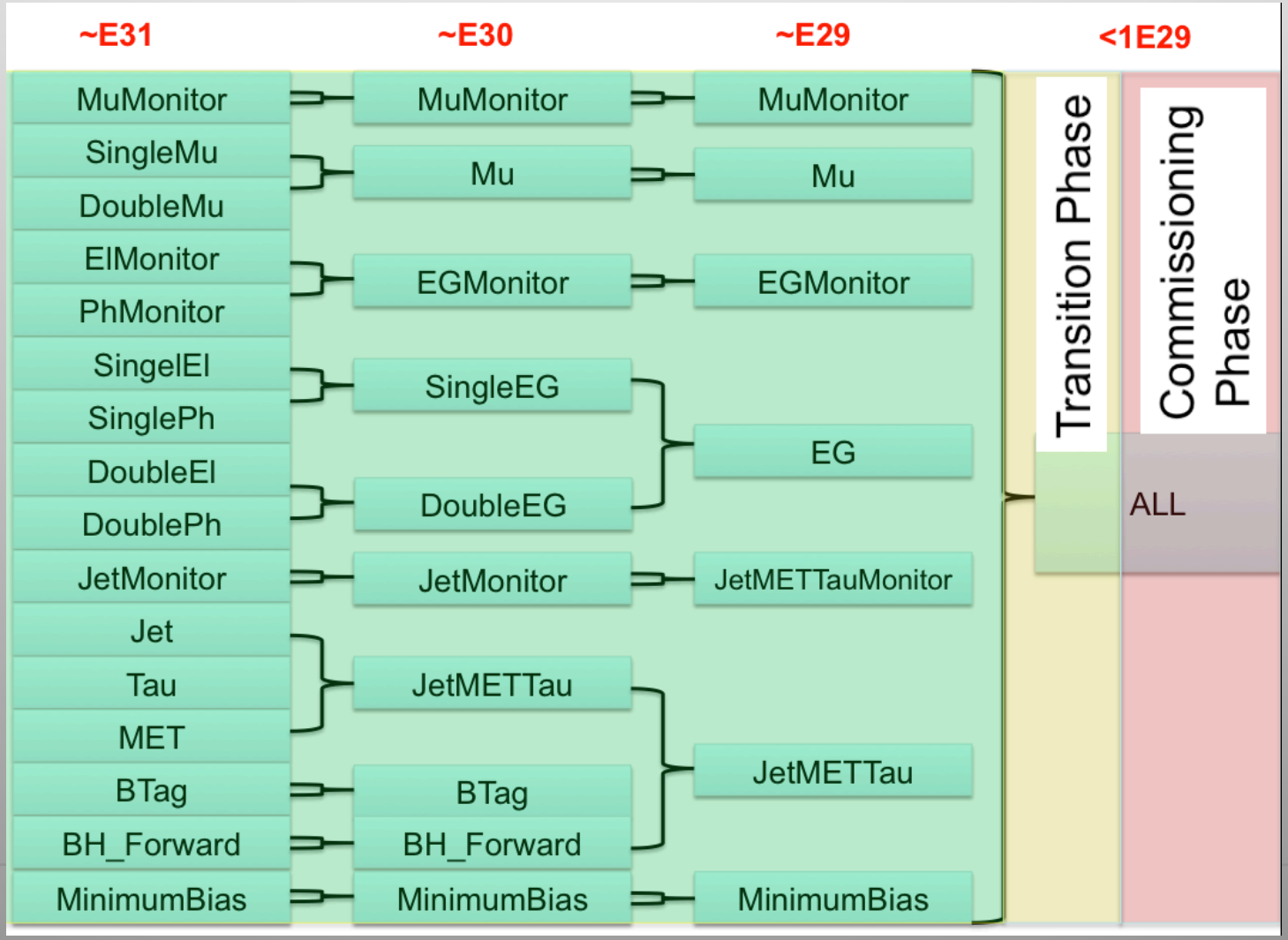
- Tier-1s and Tier-2s making reliable contributions
- 49 Tier-2 institutes receive data
- > 450 users submitting jobs for analyses





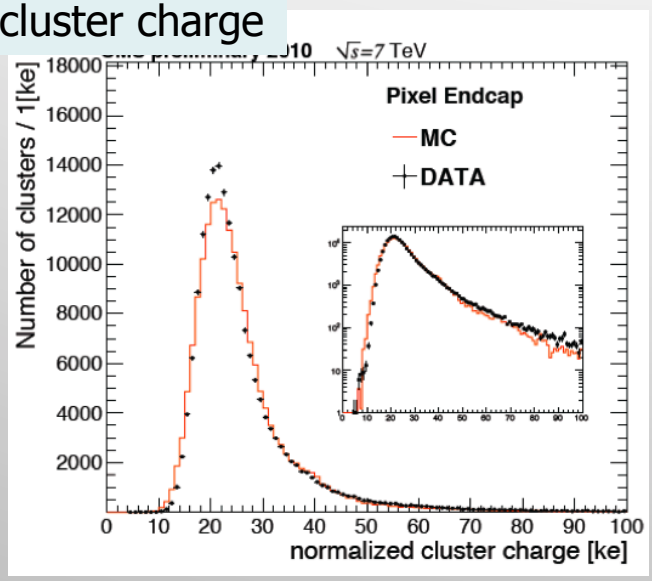
Dataset Evolution with Luminosity

Evolution of primary data sets with increasing luminosity

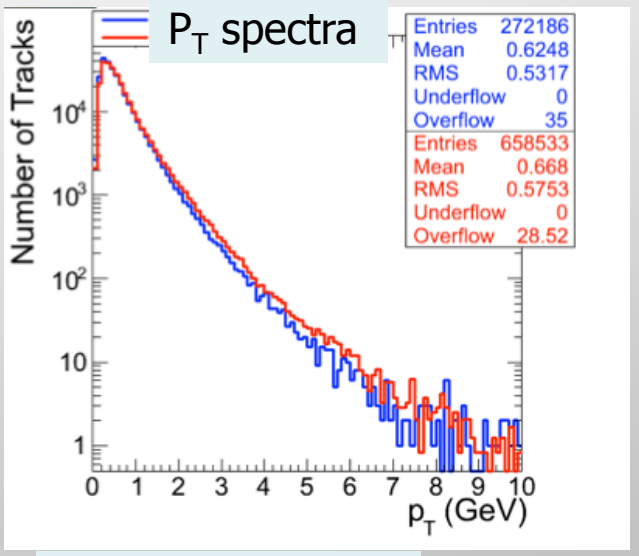


Tracker Performance

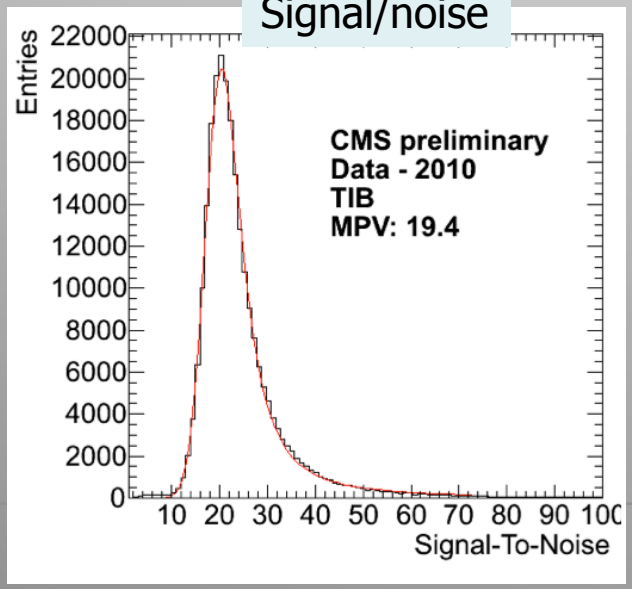
Pixel cluster charge



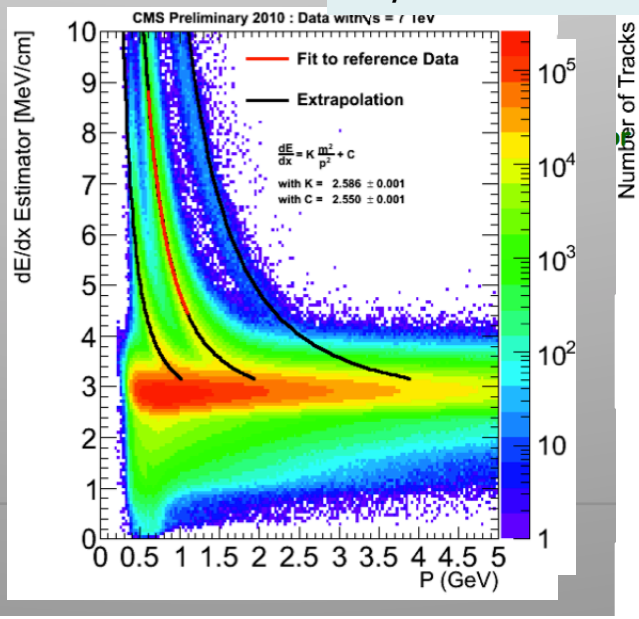
P_T spectra

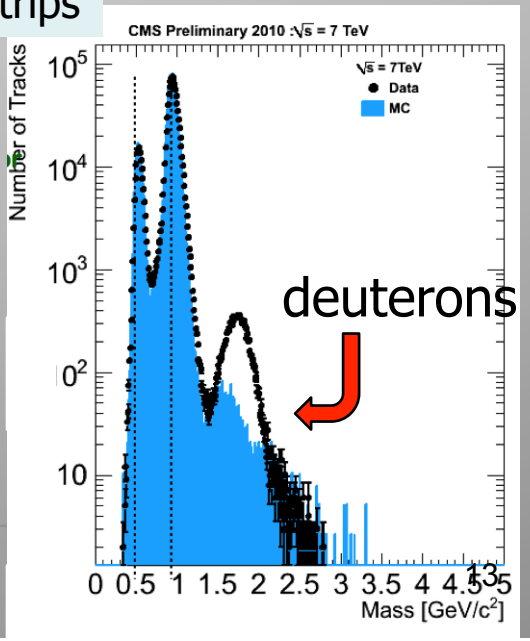


Signal/noise



de/dx in the strips



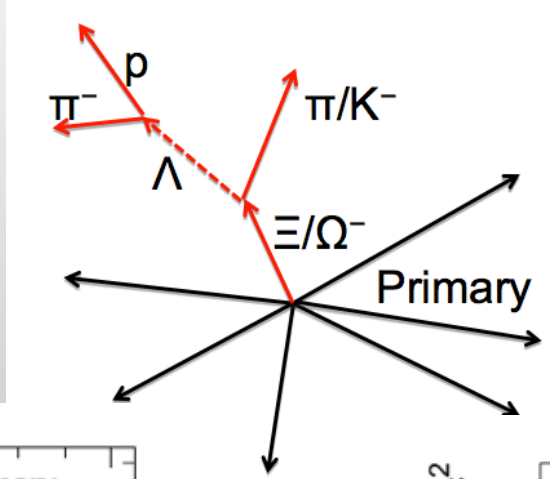


Resonances

$\Omega^{\pm} \longrightarrow \Lambda K^{\pm}$

ΛK^- or anti-ΛK^+ Invariant mass

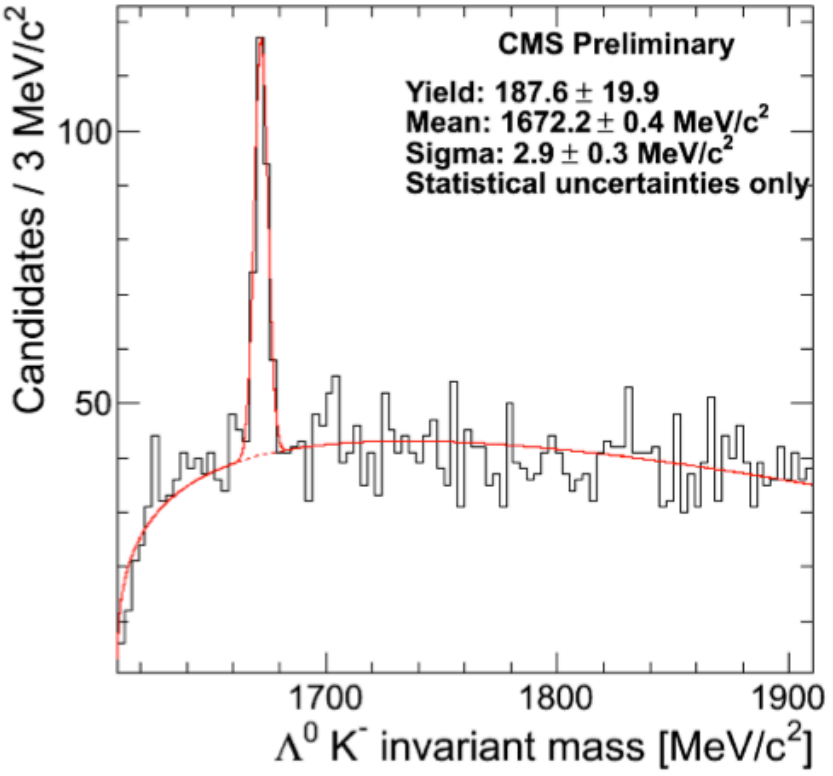
- combinations fit to a common vertex

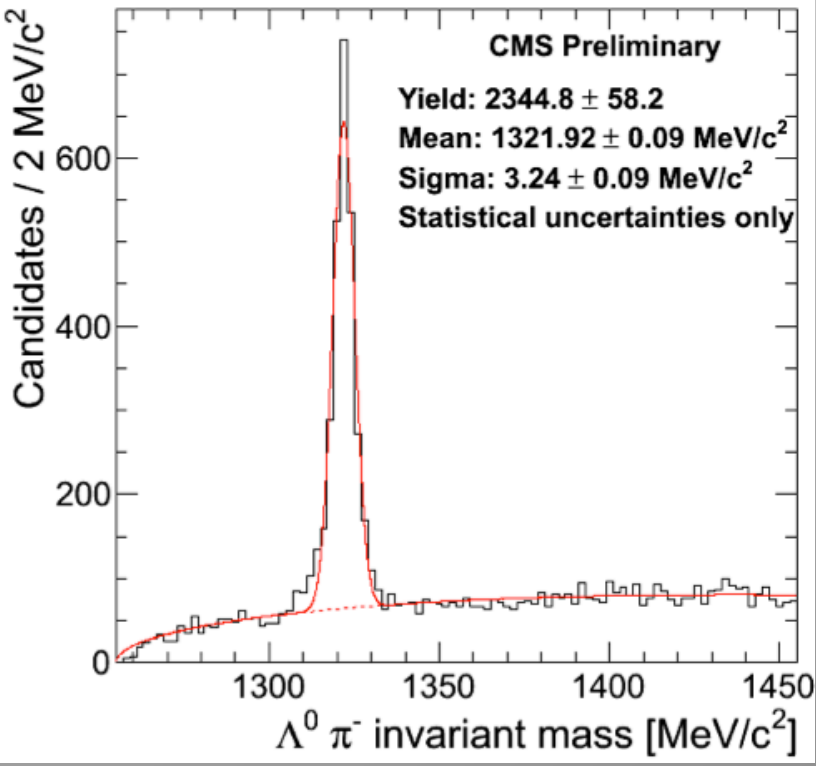


$\Xi^{\pm} \longrightarrow \Lambda\pi^{\pm}$

$\Lambda\pi$ Invariant mass

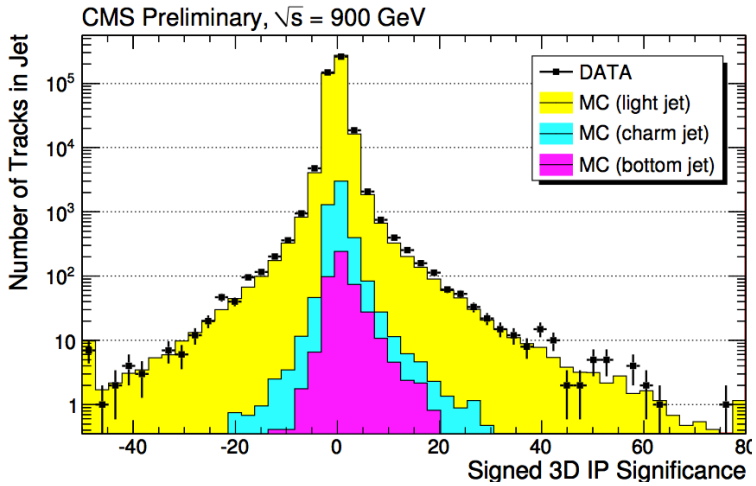
- tracks displaced from primary vertex ($d_{3D} > 3\sigma$)
- Common displaced vertex ($L_{3D} > 10\sigma$)





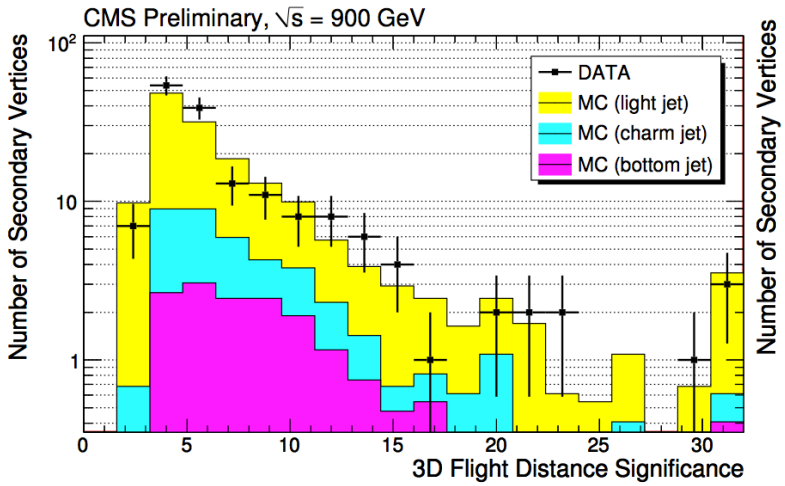
Secondary Vertices (900 GeV)

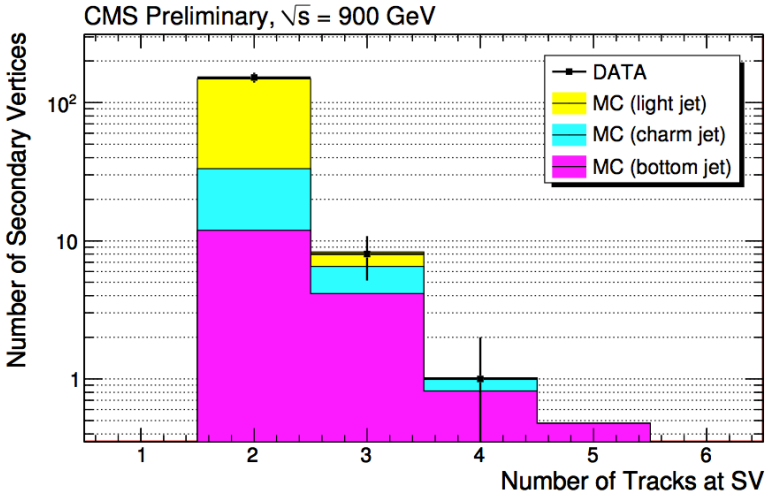
- Observables for B-tagging
- Event sample with Particle Flow jets with a cone of 0.5 and p_T> 3 GeV



Signed 3D impact parameter for tracks, with ≥7 hits, associated to a jet. Impact parameter with respect to primary vertex.

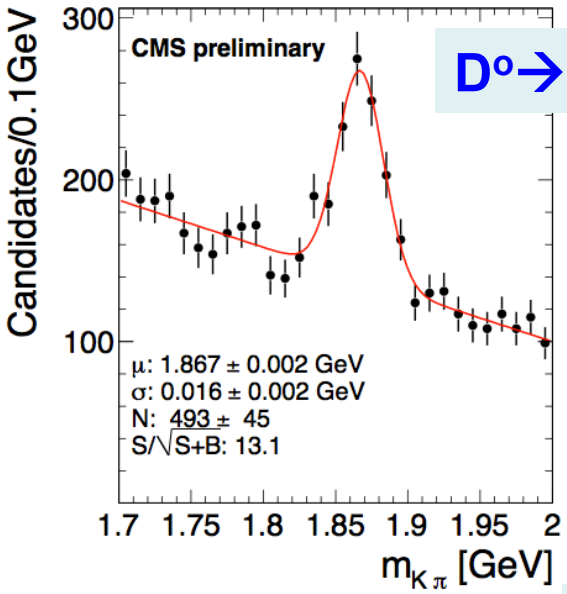
Secondary vertices with above tracks, after K rejection: Lxy< 2.5cm, |Mvtx-MKs|>0.015 GeV



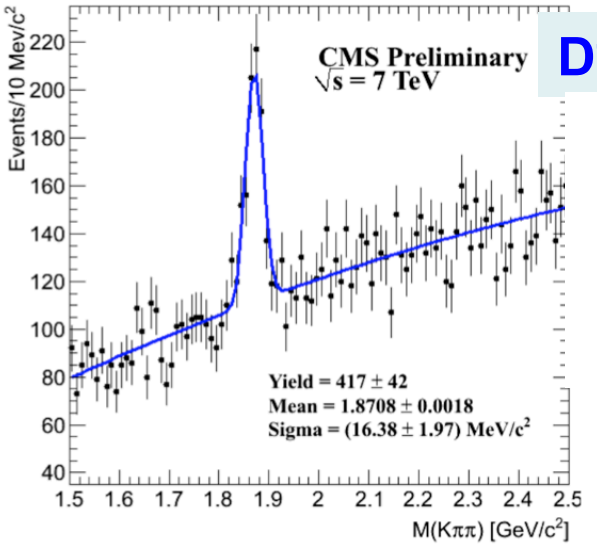


Basic variables relevant for B-tagging are well described by the simulation

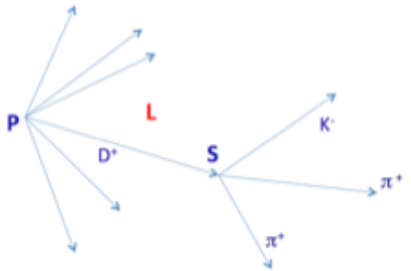
Charm Production



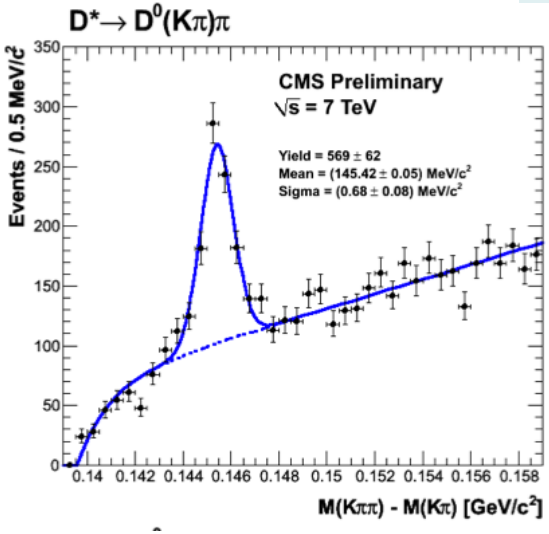
$D^o \rightarrow K^-\pi^+$

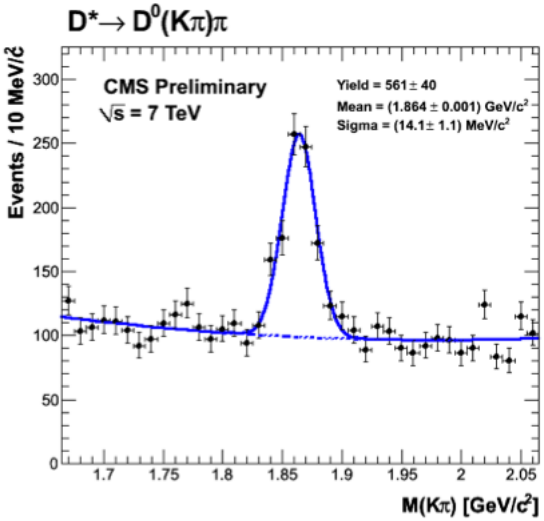


$D^+ \rightarrow K^-\pi^+\pi^+$



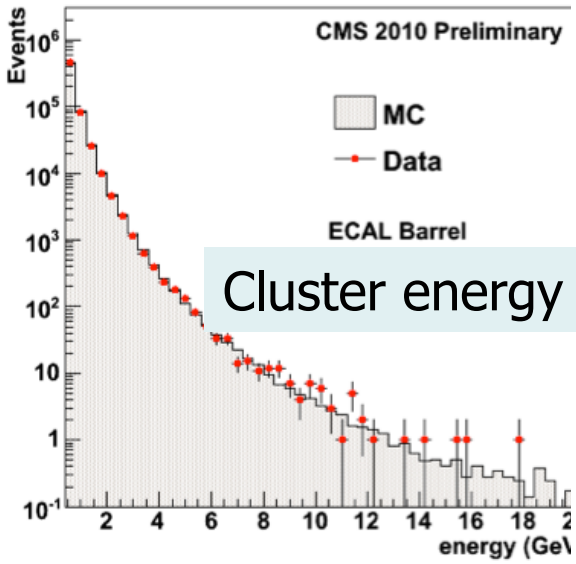
$D^{*+} \rightarrow D^o(K^-\pi^+)\pi^+$



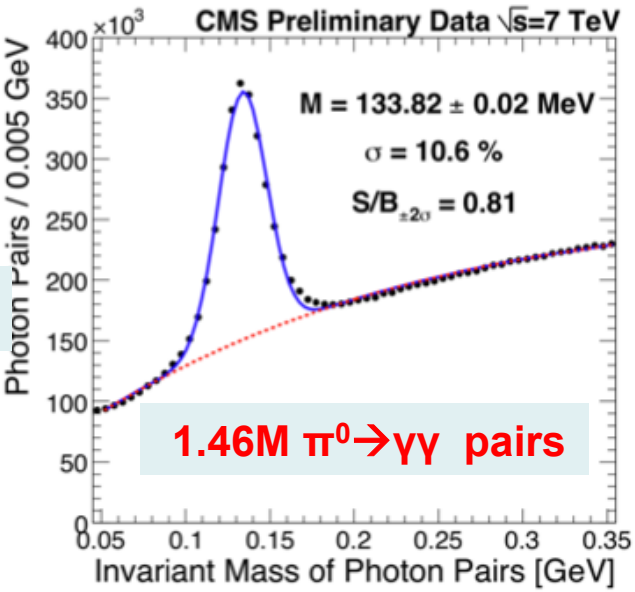


A sign for a well functioning detector…

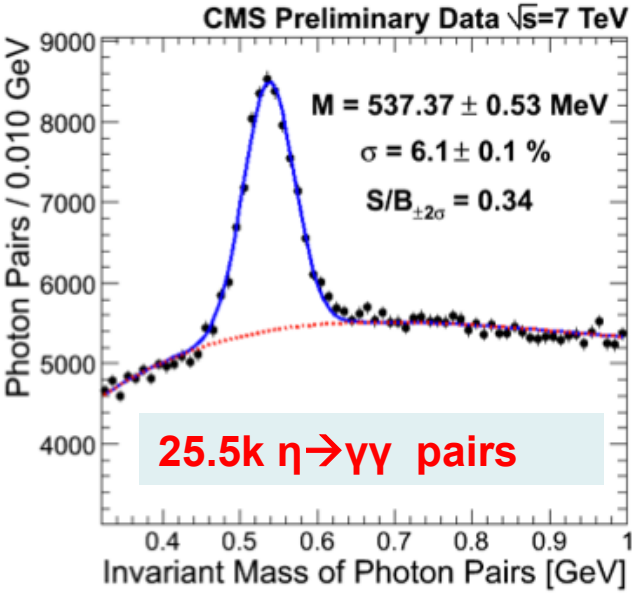
ECAL Performance Examples



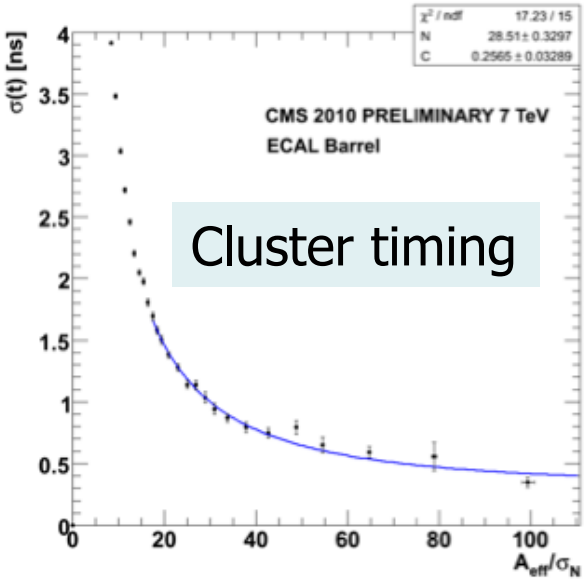
Cluster energy



1.46M $\pi^0 \rightarrow \gamma\gamma$ pairs

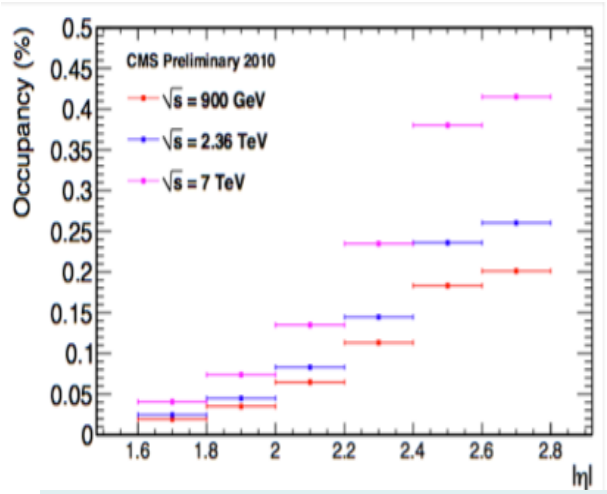


25.5k $\eta \rightarrow \gamma\gamma$ pairs



Cluster timing

Useful for the inter-crystal calibration which can start now

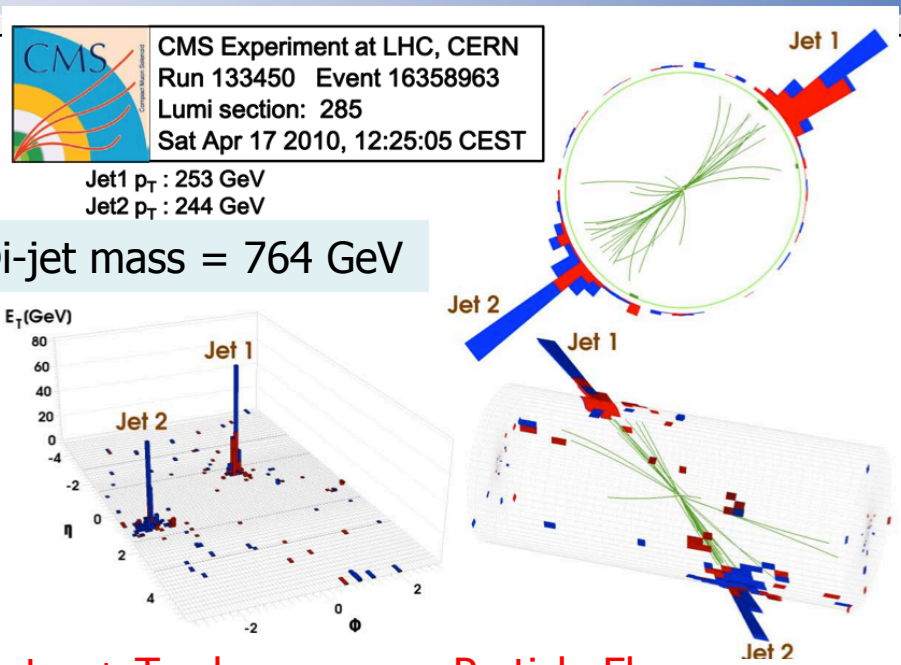


Preshower occupancy

Di-jets Events

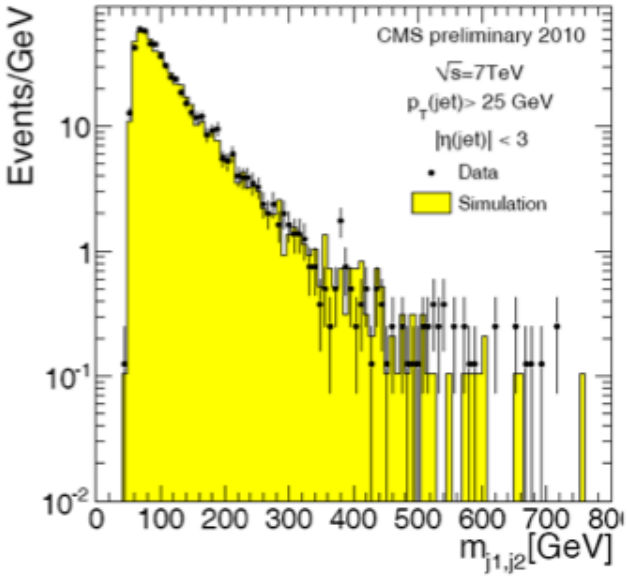
Di-jet selection

- Jet $p_{T1,2}$ > 25 GeV
- $\Delta\Phi$ > 2.1
- $|\eta|$ < 3

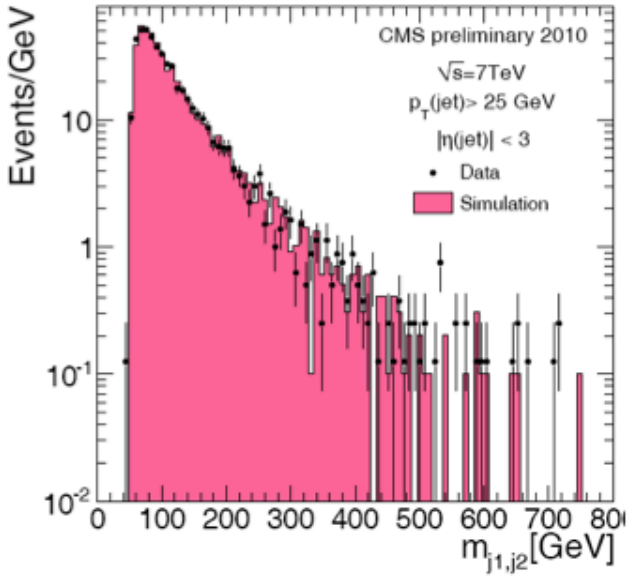


Di-jet mass

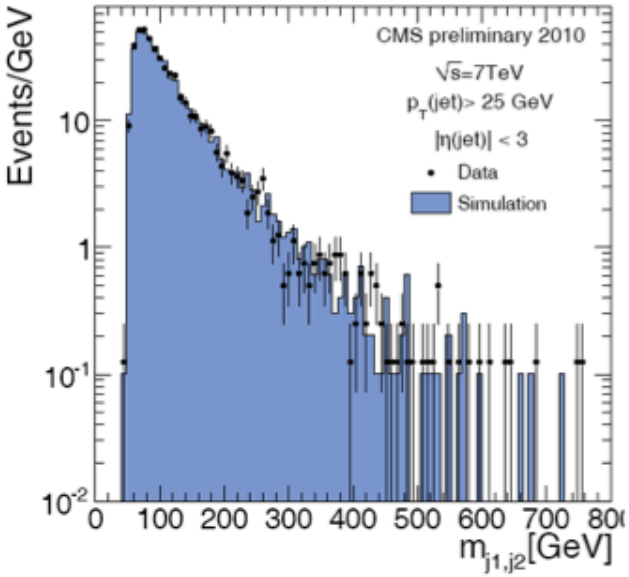
Calorimeter



Calorimeter + Tracks



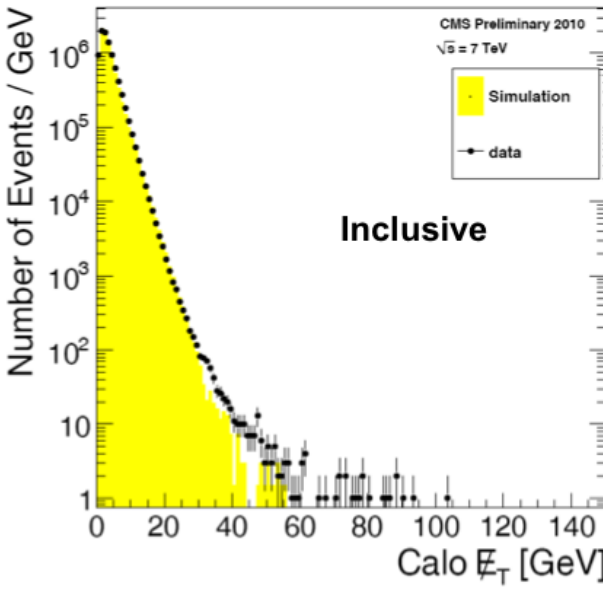
Particle Flow



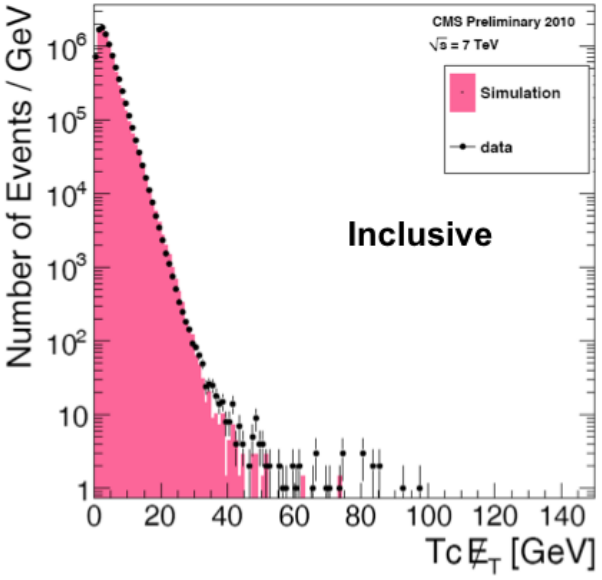
Missing Transverse Energy

3 methods for the calculation of the missing E_T

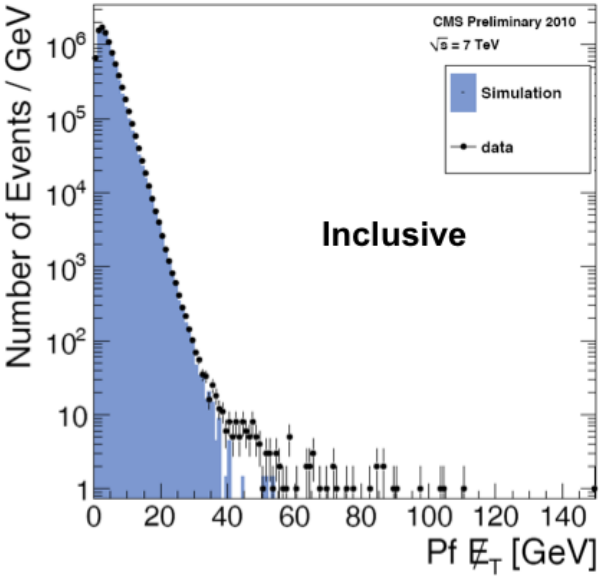
Calorimeter



Calorimeter + Tracks

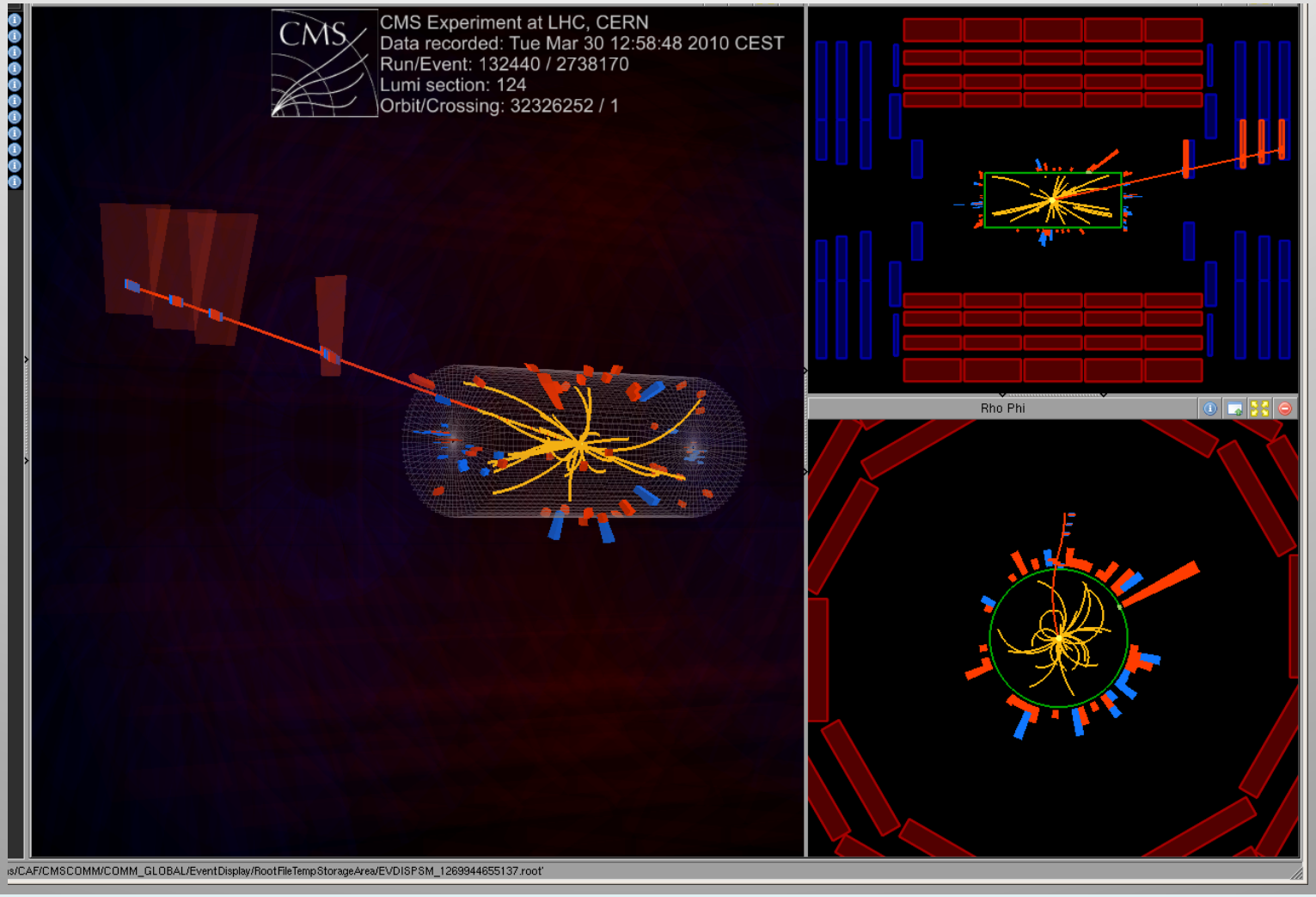


Particle Flow



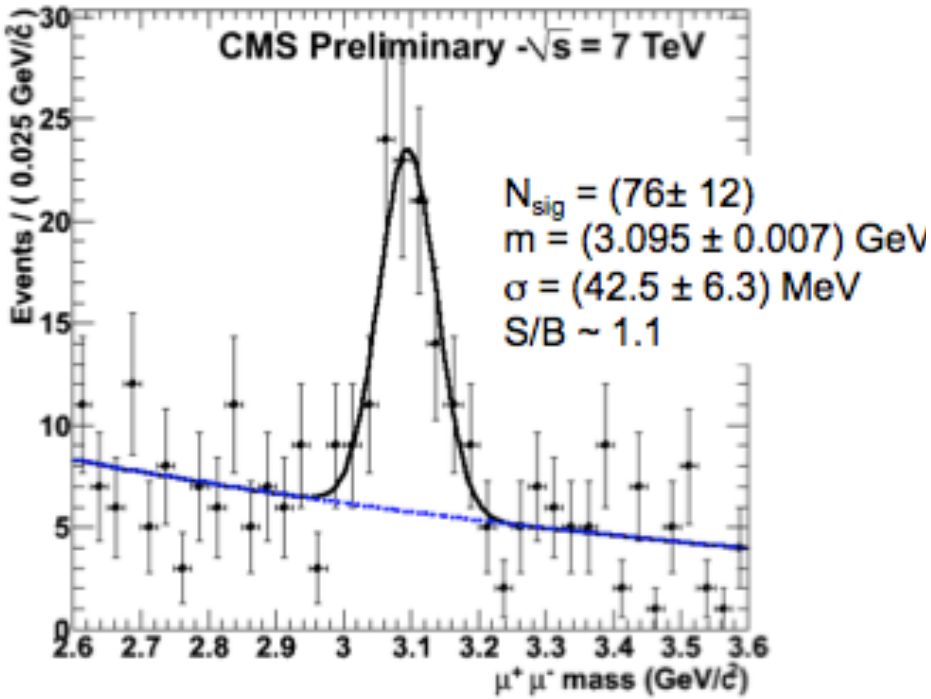
- Monte Carlo (Min Bias) describes the data well over 5 orders of magnitude
- High ET tails subject of ongoing studies, and are found to be dominantly noise. Work in progress.

Muons



Clear muon signals in CMS already on the first minutes at 7 TeV

J/ψs Decaying into Muons



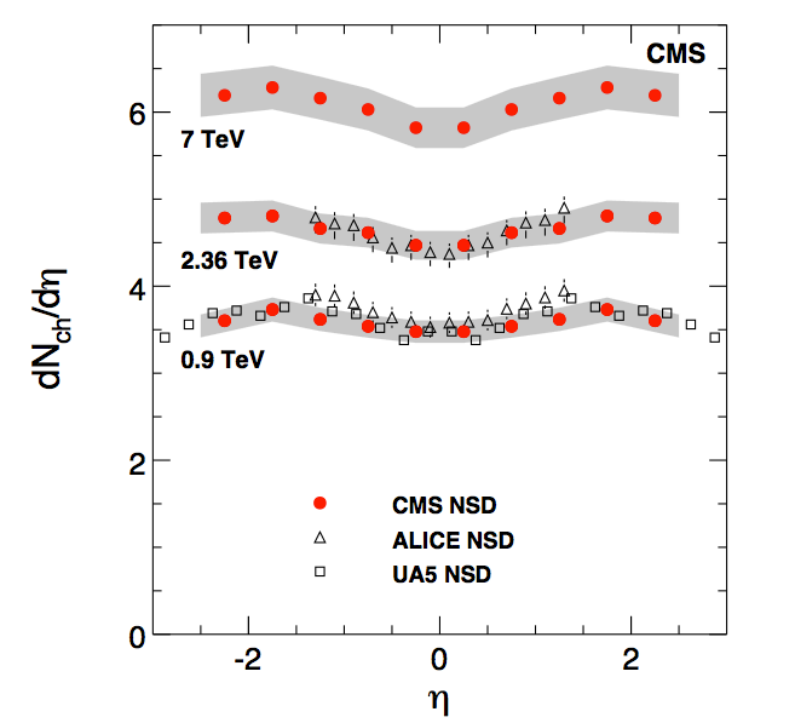
- All muon tracks:
  - Pixel layers with hits > 1
  - Number of pixel+strip hits > 11
  - |d0| < 5 cm, dz < 20 cm
- Global muons:
  - global $\chi^2 < 20$
- Tracker muons:
  - track $\chi^2 < 5$
  - TMLastStationAngTight bit on
- Vertex probability > 0.1%

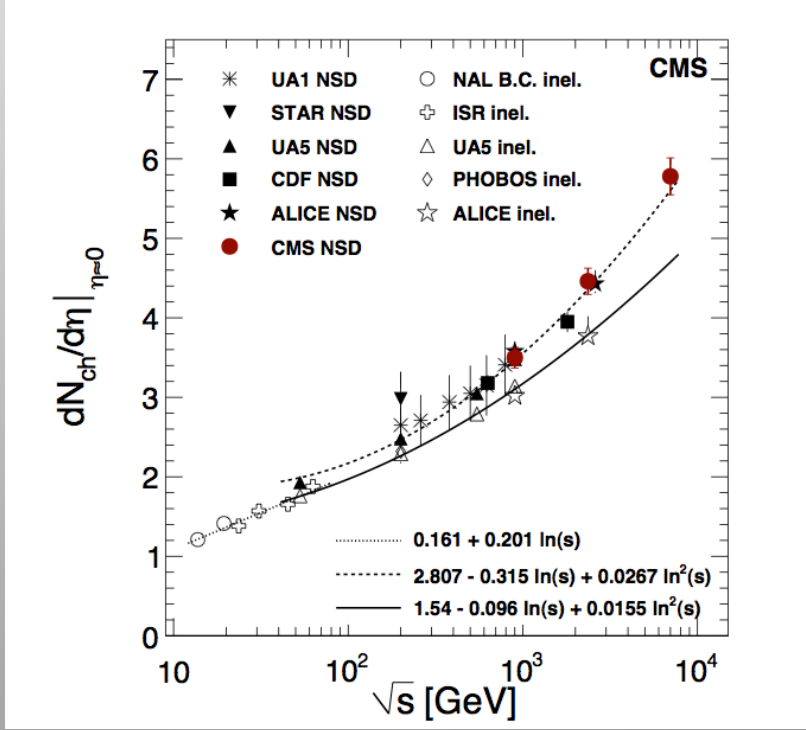
- Clear J/ψ signal in the data
- Upsilon getting within reach (for the next time)

Charged Hadrons

p_T and η distributions of charged hadrons at √s = 7 TeV

- Similar analysis as in the CMS paper JHEP 02 (2010) 041
- Minimum bias selection using BSC trigger.
- Three methods used: tracks, tracklets and pixel clusters
- Results corrected to Non-Single Diffractive cross section.
- Diffraction controlled via forward activity measurements in CMS



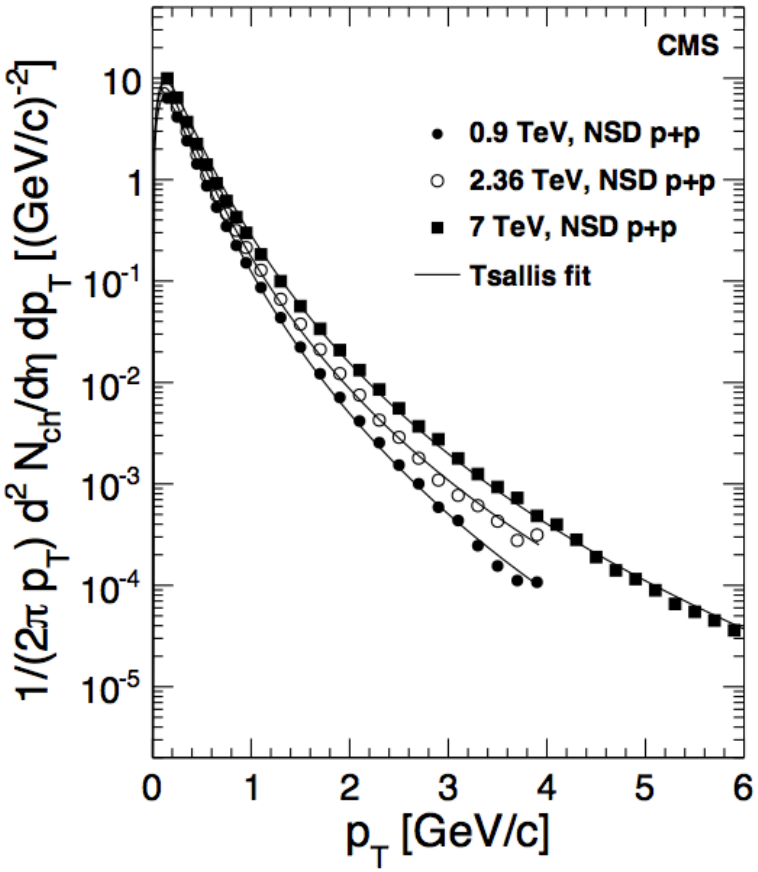


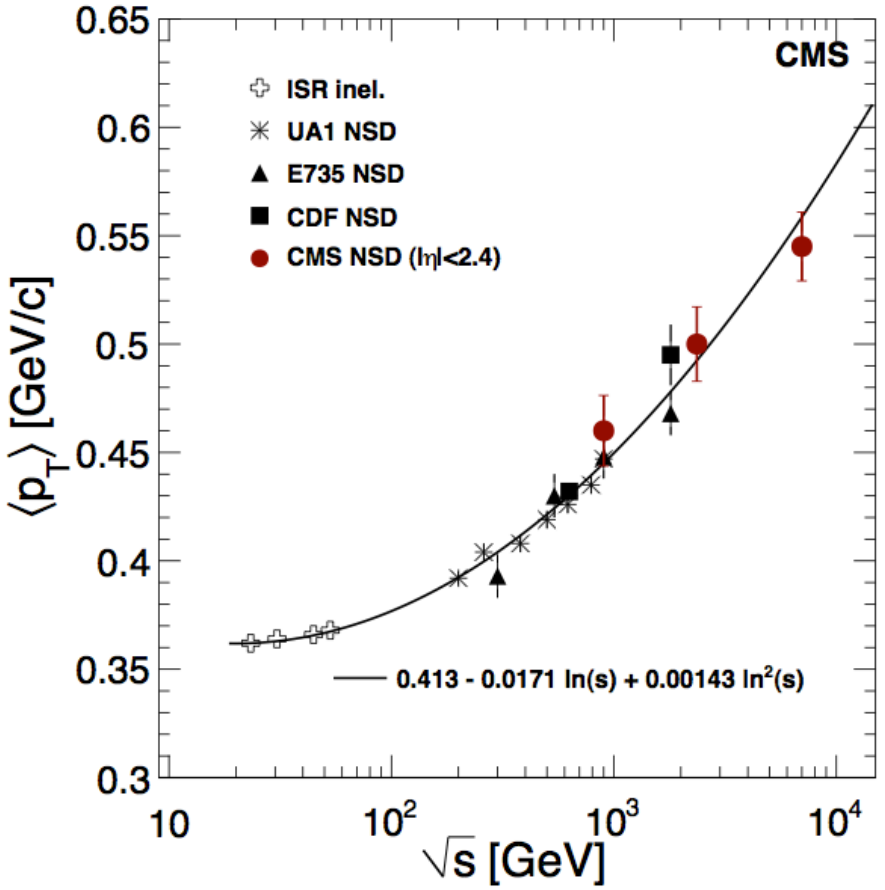
Strong rise of the particle density at 7 TeV

Charged Hadrons

p_T and $\langle p_T \rangle$ distributions of charged hadrons at $\sqrt{s}$ = 7 TeV

P_T measurements down to 100 MeV/c



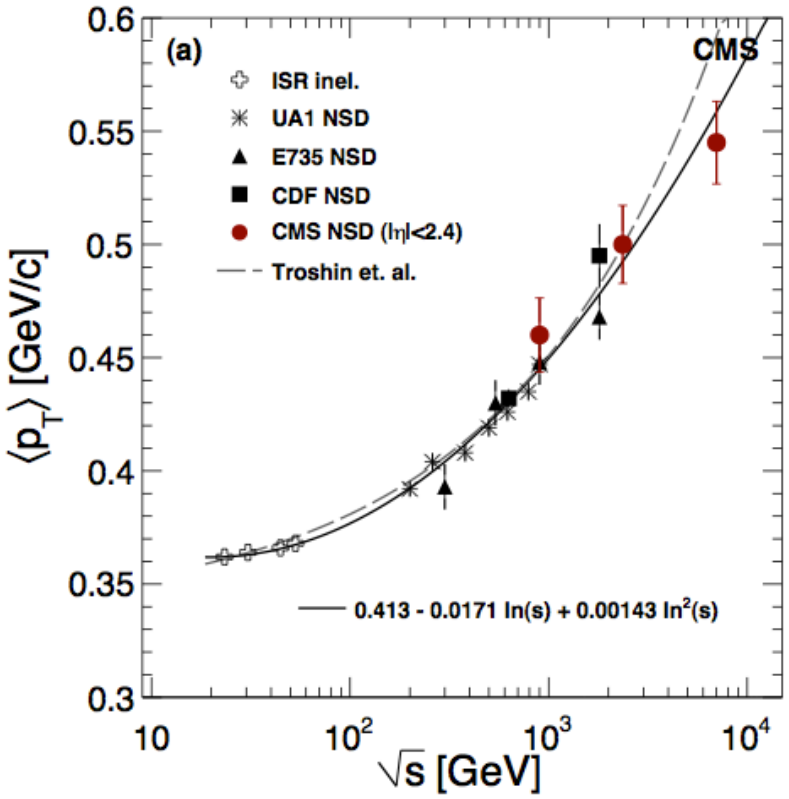


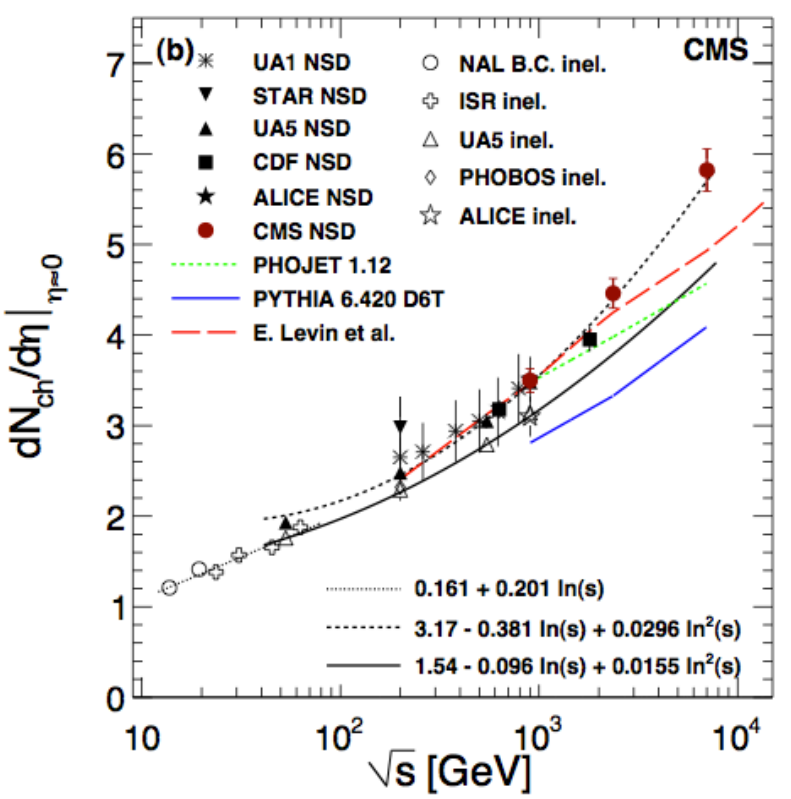
Paper now in final stage of the approval process

Charged Hadrons

$\langle p_T \rangle$ distribution and η density of charged hadrons at √s = 7 TeV

Comparison with recent model predictions



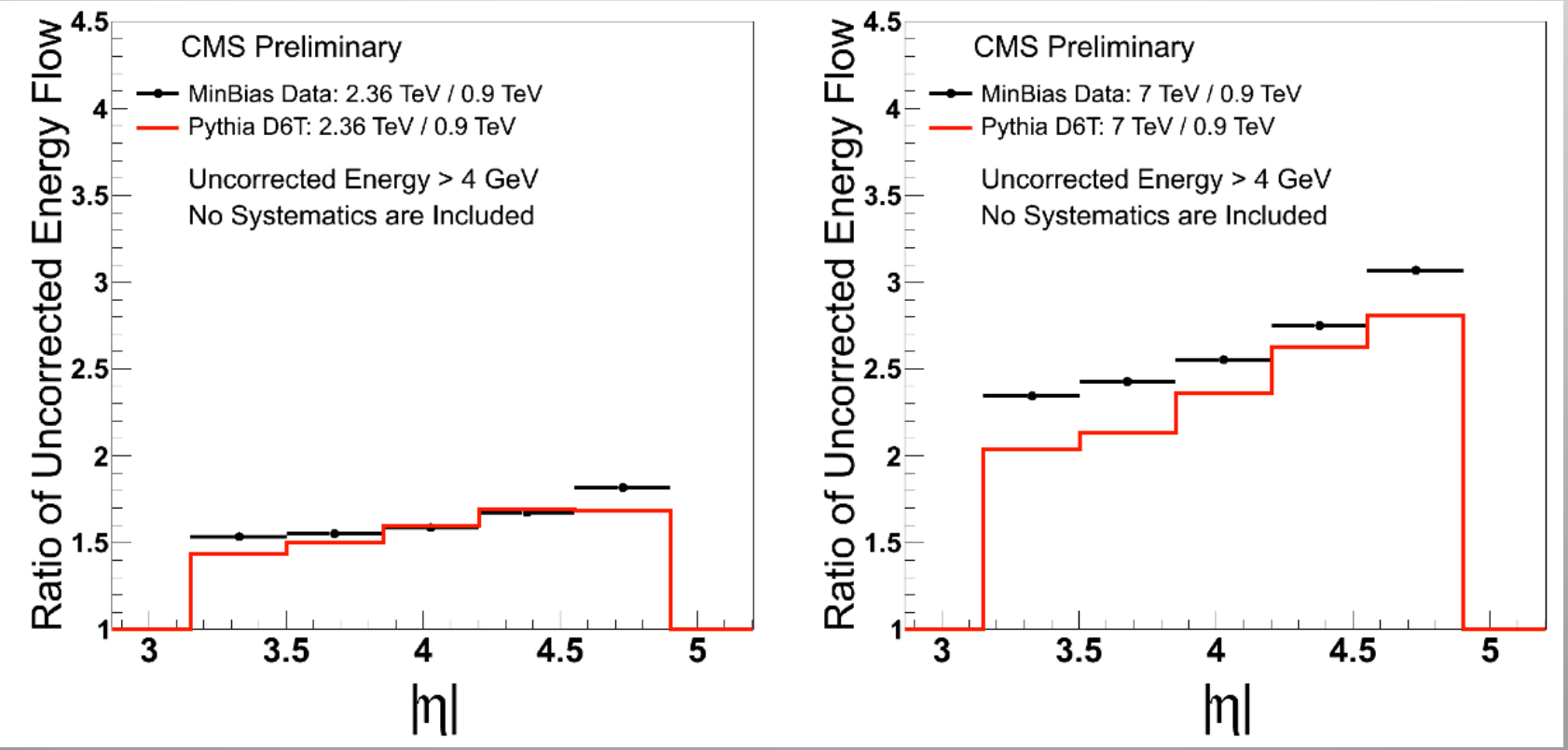


Rise of dN/dη in data stronger than currently used models

Forward Energy Flow

- MinBias event selection
- Ratio of the energy flow at different energies

$$R_{Eflow}^{\sqrt{s}_1,\sqrt{s}_2} = \frac{\frac{1}{N_{\sqrt{s}_1}}\frac{\Delta E_{\sqrt{s}_1}}{\Delta\eta}}{\frac{1}{N_{\sqrt{s}_2}}\frac{\Delta E_{\sqrt{s}_2}}{\Delta\eta}}$$



Similar rise with collision energy as seen in dN/dη analysis

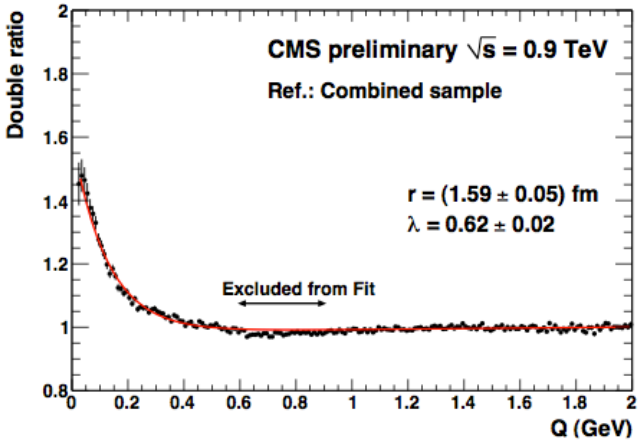
Bose Einstein Correlations

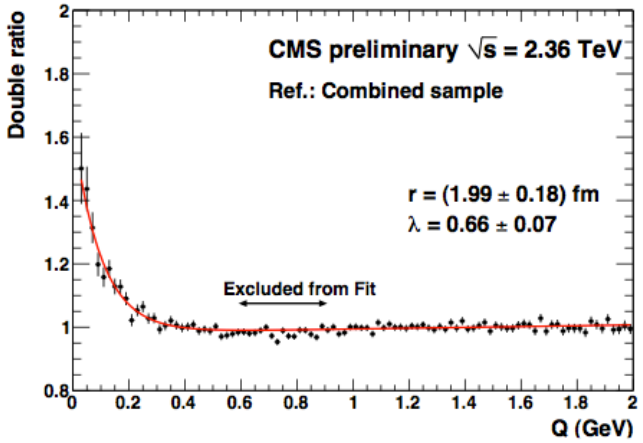
Correlations between identical bosons (pions) √s = 0.9 and 2.36 TeV

$Q^2=-(p1-p2)^2$

- MinBias events
- Use 7 reference samples
- Combination of all ref. samples

$$R(Q) = C\,[1+\lambda\Omega(Qr)]\cdot(1+\delta Q) \qquad \Omega(Qr) = e^{-Qr},$$





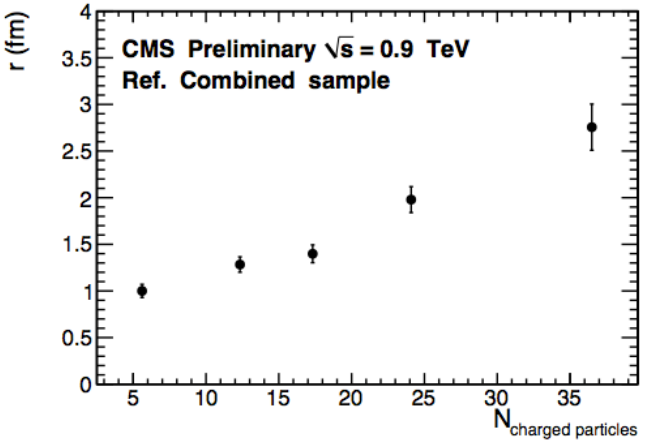
√s = 0.9 TeV $r = 1.59 \pm 0.05\,(\text{stat.}) \pm 0.19\,(\text{syst.})$ fm and $\lambda = 0.625 \pm 0.021\,(\text{stat.}) \pm 0.046\,(\text{syst.})$

√s = 2.36 TeV $r = 1.99 \pm 0.18\,(\text{stat.}) \pm 0.24\,(\text{syst.})$ fm and $\lambda = 0.663 \pm 0.073\,(\text{stat.}) \pm 0.048\,(\text{syst.})$

Multiplicity dependence

Results of fits to 0.9 TeV data

Multiplicity range	P-value	C	λ	r (fm)
2 - 9	9.7×10^{-1}	0.90 ± 0.01	0.89 ± 0.05	1.00 ± 0.07 (stat.)± 0.05 (syst.)
10 - 14	3.8×10^{-1}	0.97 ± 0.01	0.64 ± 0.04	1.28 ± 0.08 (stat.)± 0.09 (syst.)
15 - 19	2.7×10^{-1}	0.96 ± 0.01	0.60 ± 0.04	1.40 ± 0.10 (stat.)± 0.05 (syst.)
20 - 29	2.4×10^{-1}	0.99 ± 0.01	0.59 ± 0.05	1.98 ± 0.14 (stat.)± 0.45 (syst.)
30 - 79	2.8×10^{-1}	1.00 ± 0.01	0.69 ± 0.09	2.76 ± 0.25 (stat.)± 0.44 (syst.)

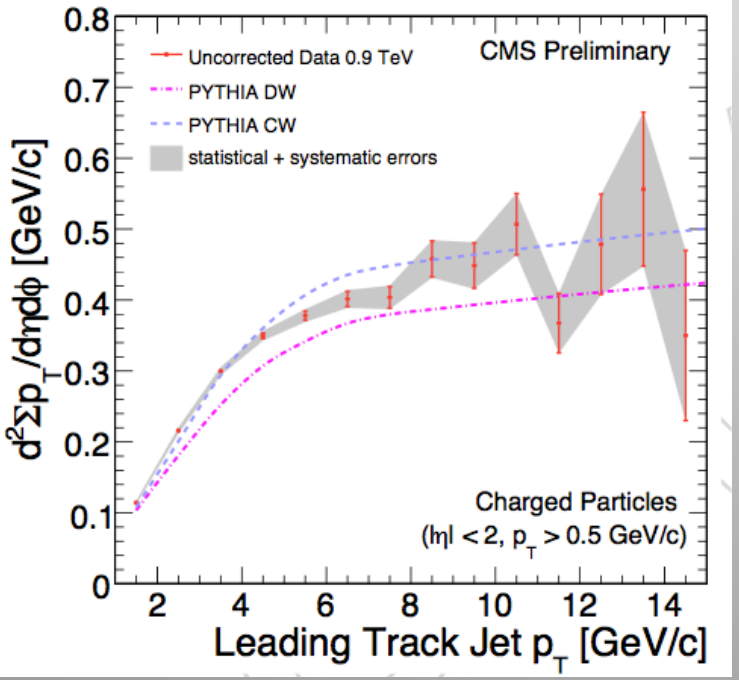


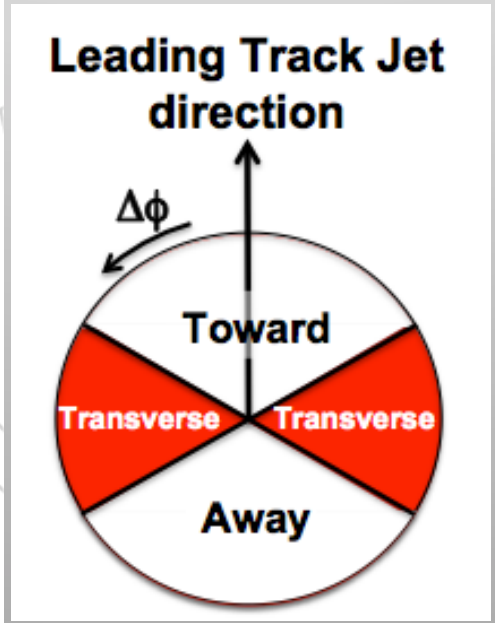
Paper now in final stage of the approval process

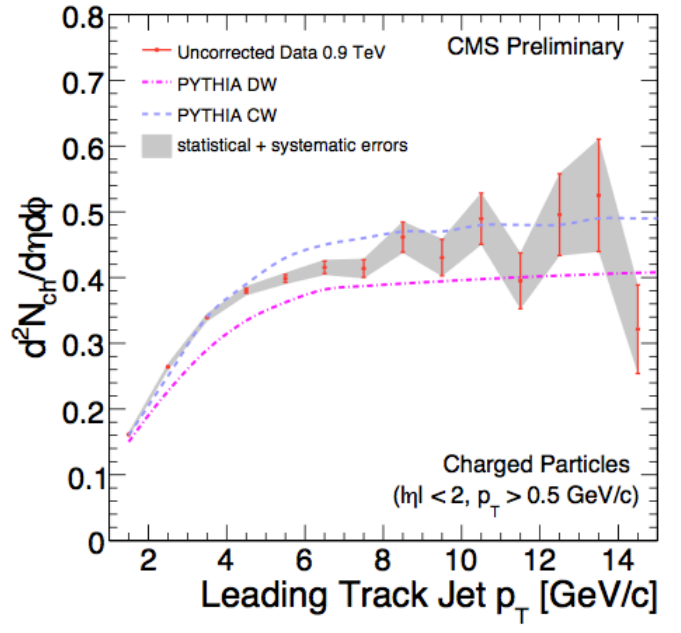
Underlying Event Studies

Underlying event activity at √s = 0.9

- MinBias event selection, with additional requirement of a 'hard' scattering via a track jet with p_T > 3 GeV
- Study the particle density and scalar p_T sum in the transverse region, for particles with $|\eta| < 2$ and $p_T > 0.5$ GeV (uncorrected data)





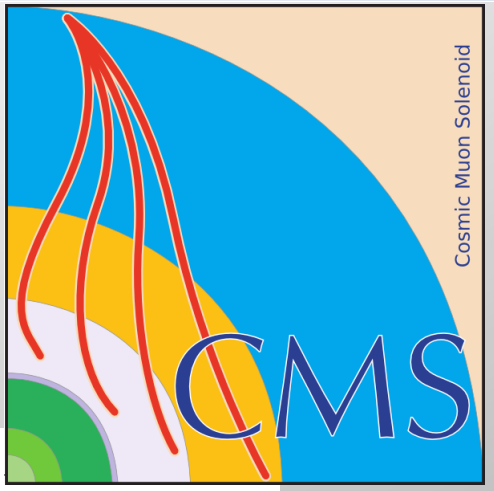


Model Comparison: DW = Standard Tune CW = New Tune (p_{T0}= 1.8 GeV, ε= 0.3)

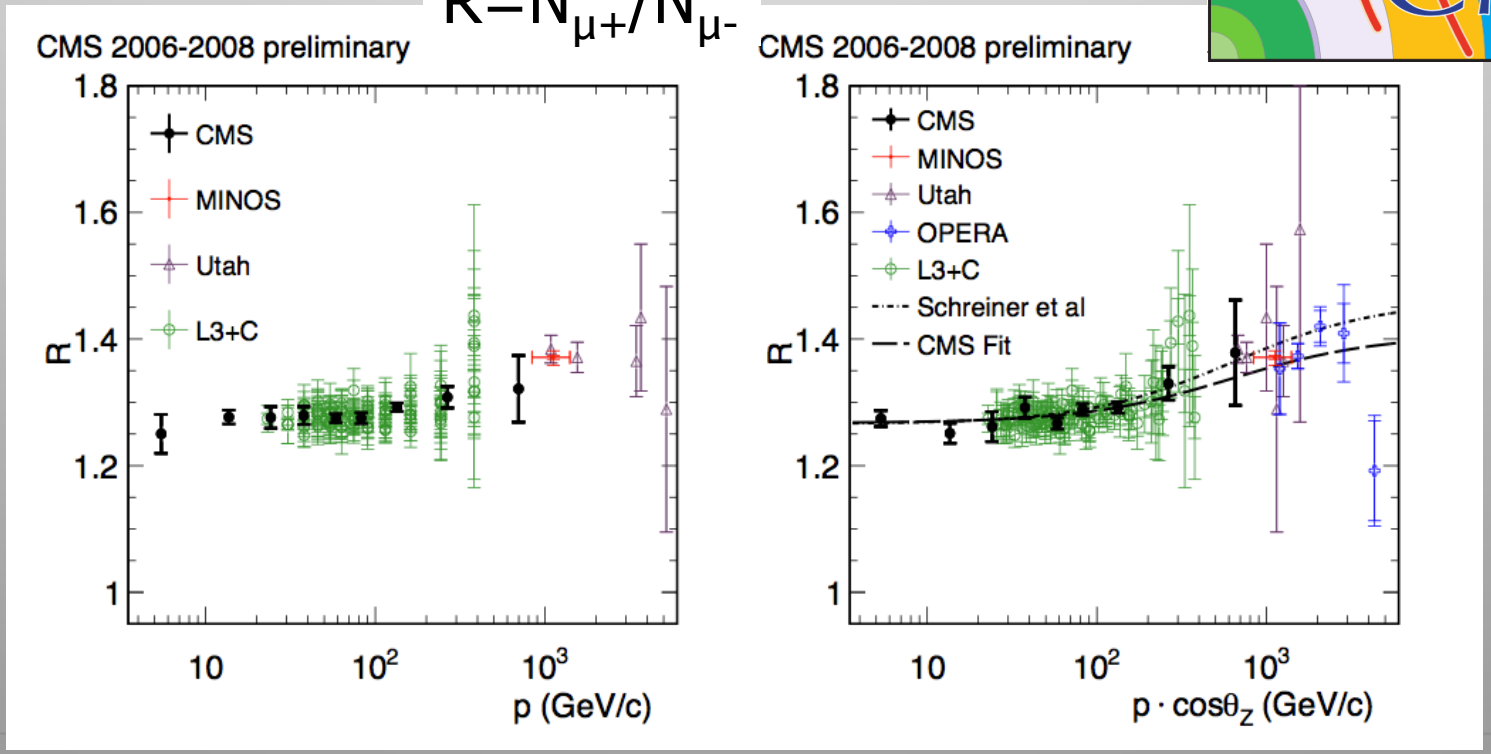
More food for MC model tuning…

Muon Charge Asymmetry

- High energy cosmic muons measured during the 2008/2009 cosmic data runs, and from the 2006 on surface MTCC test
- Good understanding of the alignment is critical



$R = N_{\mu+}/N_{\mu-}$

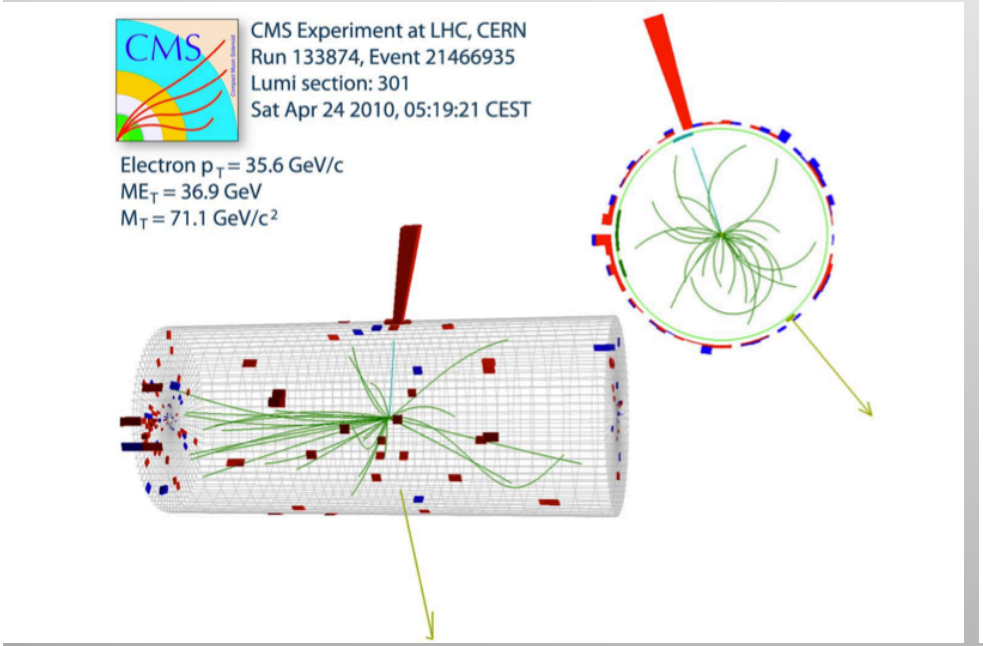


Paper now in final stage of the approval process

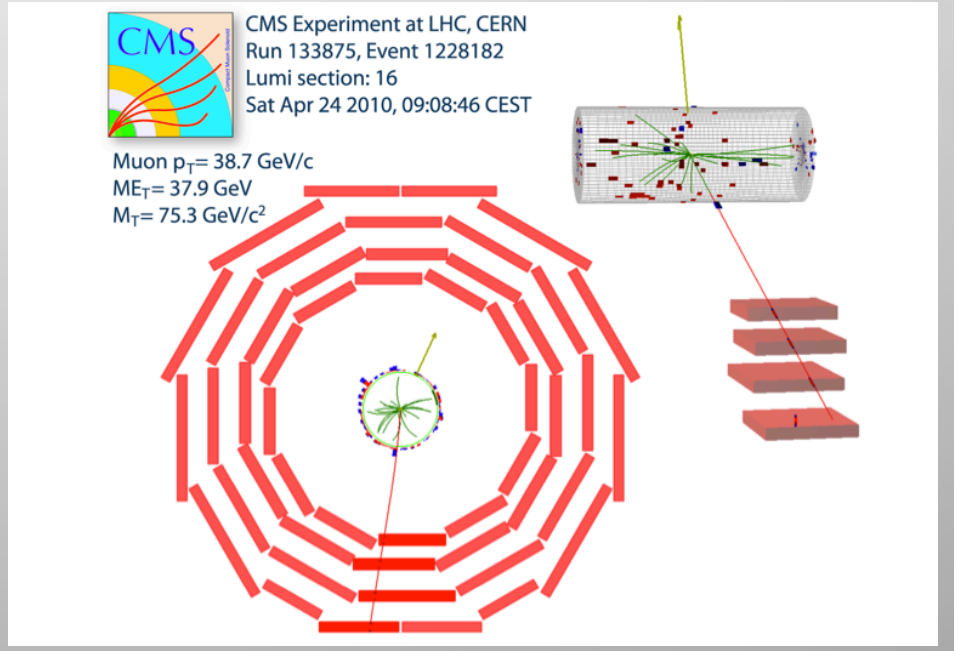
W and Z Bosons

For 1 nb^{-1}, after acceptance, expect 8 W candidates and 0.8 Z candidates

W➔ev: three candidates found



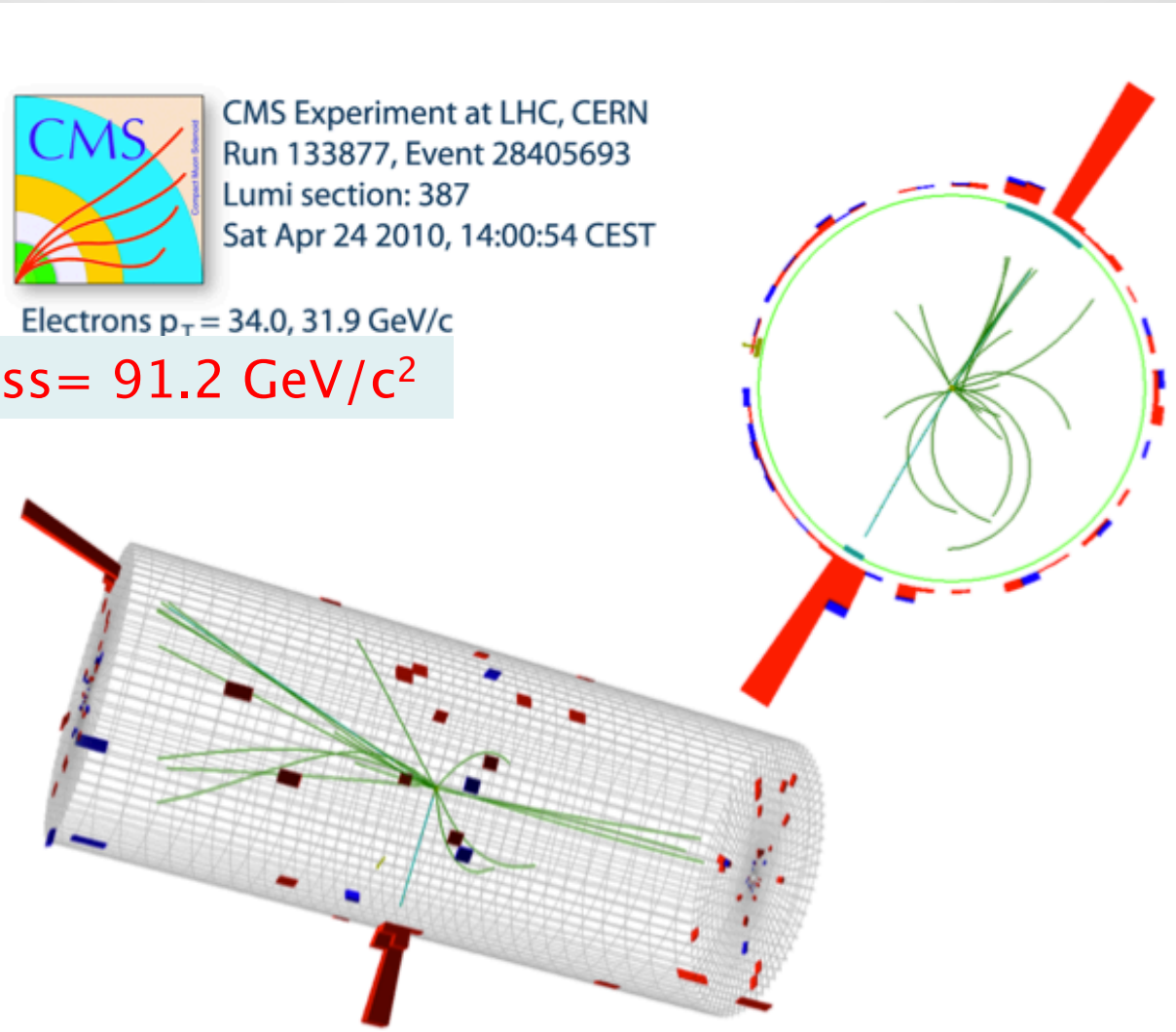
W➔μν: three candidates found



- Apply lepton ID criteria established in advance from MC studies
- Apply loose kinematic cuts on lepton ET and MET (or MT)
  - Lepton ET > 20 GeV, some MET > 20 GeV (or MT >50 GeV)
  - Looser 10 GeV cuts for Z hunting.

W and Z Bosons

Z➔ee: one candidate found



Mass= 91.2 GeV/c^2

Summary

- CMS is very well advanced with the detector commissioning and calibration
- CMS records physics data, following a well defined scheme, evolving with luminosity, for triggers and datasets and data distribution. We'll reach luminosities soon that will allow real stress tests of the system.
- Physics papers being completed on the low energy and 7 TeV collisions. Next Stop ICHEP2010, where CMS prepares for many analyses, luminosity permitting. Retuning of the Monte Carlos is ongoing.
- CMS would like to thank the LHC team for their extraordinary efforts and looks forward to forthcoming high luminosity running

BACKUP