Highlights from CMS

the path to discovery...

Prof. Robin D. Erbacher -- U.C. Davis

Brookhaven Forum -- "A Space-Time Odyssey" -- May 26, 2010

Data through last year...

- CRAFT '08/'09 + other ~ 1B cosmic events
  ➡ 23 performance papers to JINST

- 900 GeV (Nov 2009) -- 300k events
  ➡ first physics paper, lots of calibrations

- 2.36 TeV (Dec 2009) -- 20k events
  ➡ first peek at high energies

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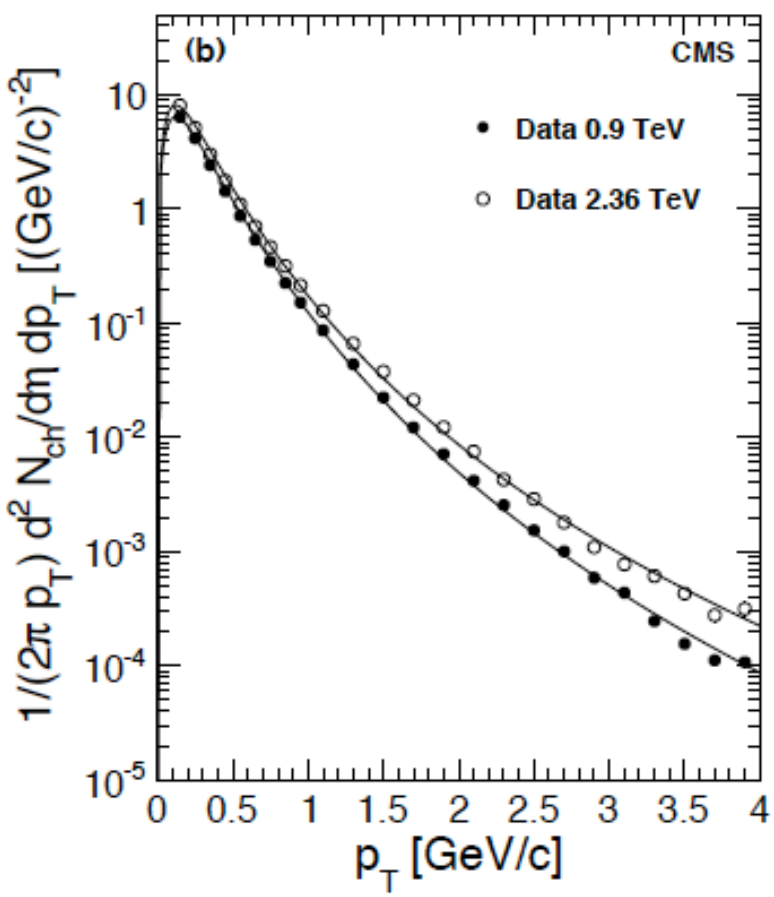
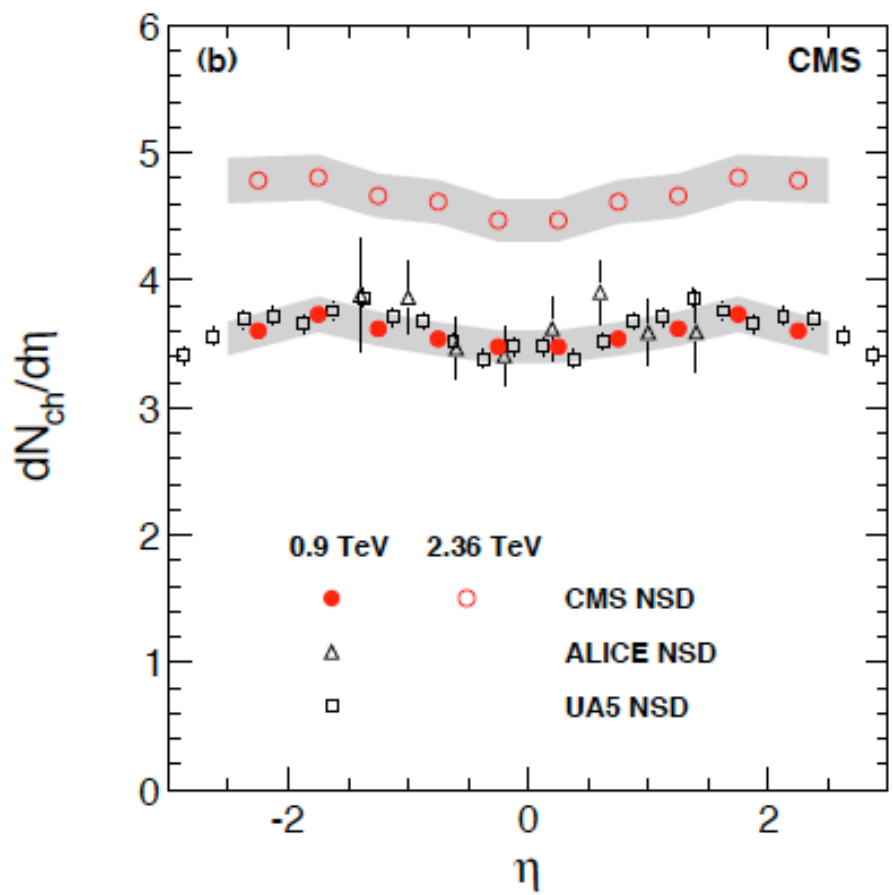
First Publication from CMS!

Inclusive particle p_T, and pseudorapidity at 900 GeV and 2.36 TeV





JHEP 02 (2010) 041

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Ramping up for high energy collisions...

- CRAFT (end 2008) -- 600k events
  - ➡ 23 performance papers to JINST
- 900 GeV (Nov 2009) -- 300k events
  - ➡ first physics paper, lots of calibrations
- 2.36 TeV (Dec 2009) -- 20k events
  - ➡ first peek at high energies

The big event: March 30, 2010 -- 7 TeV collisions!

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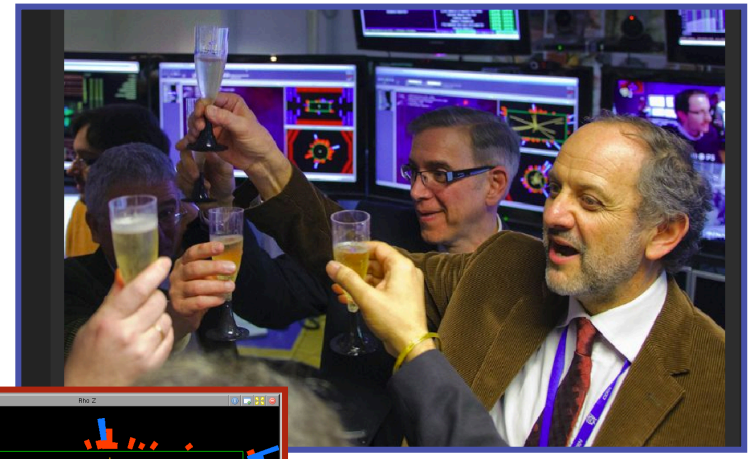
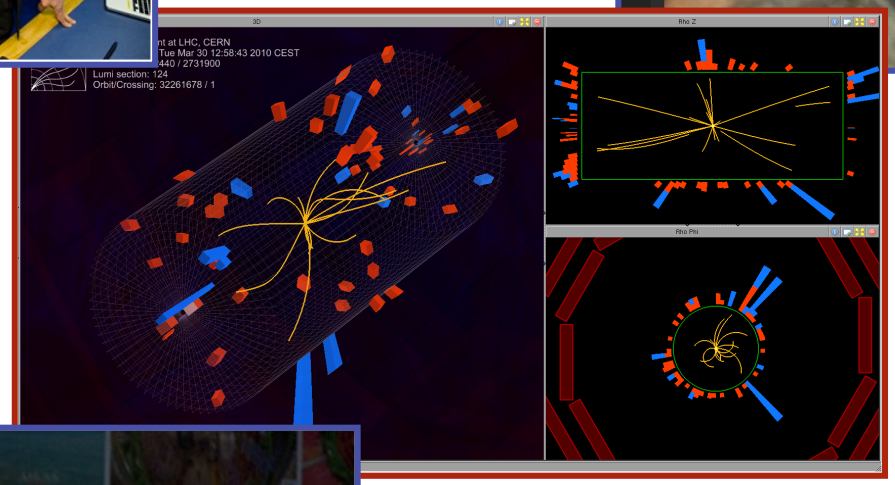
First 7 TeV Collisions

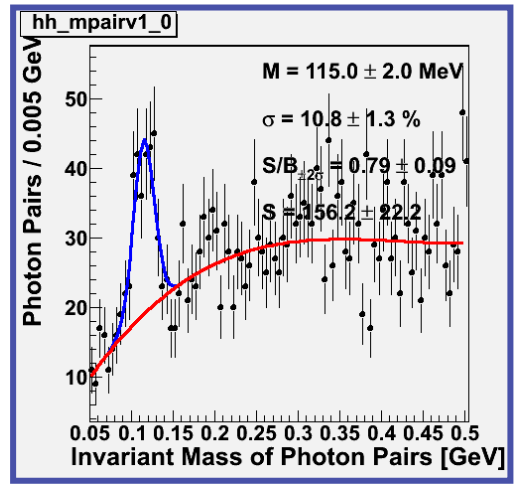
Point 5 Control Room - March 30, 2010

Success!

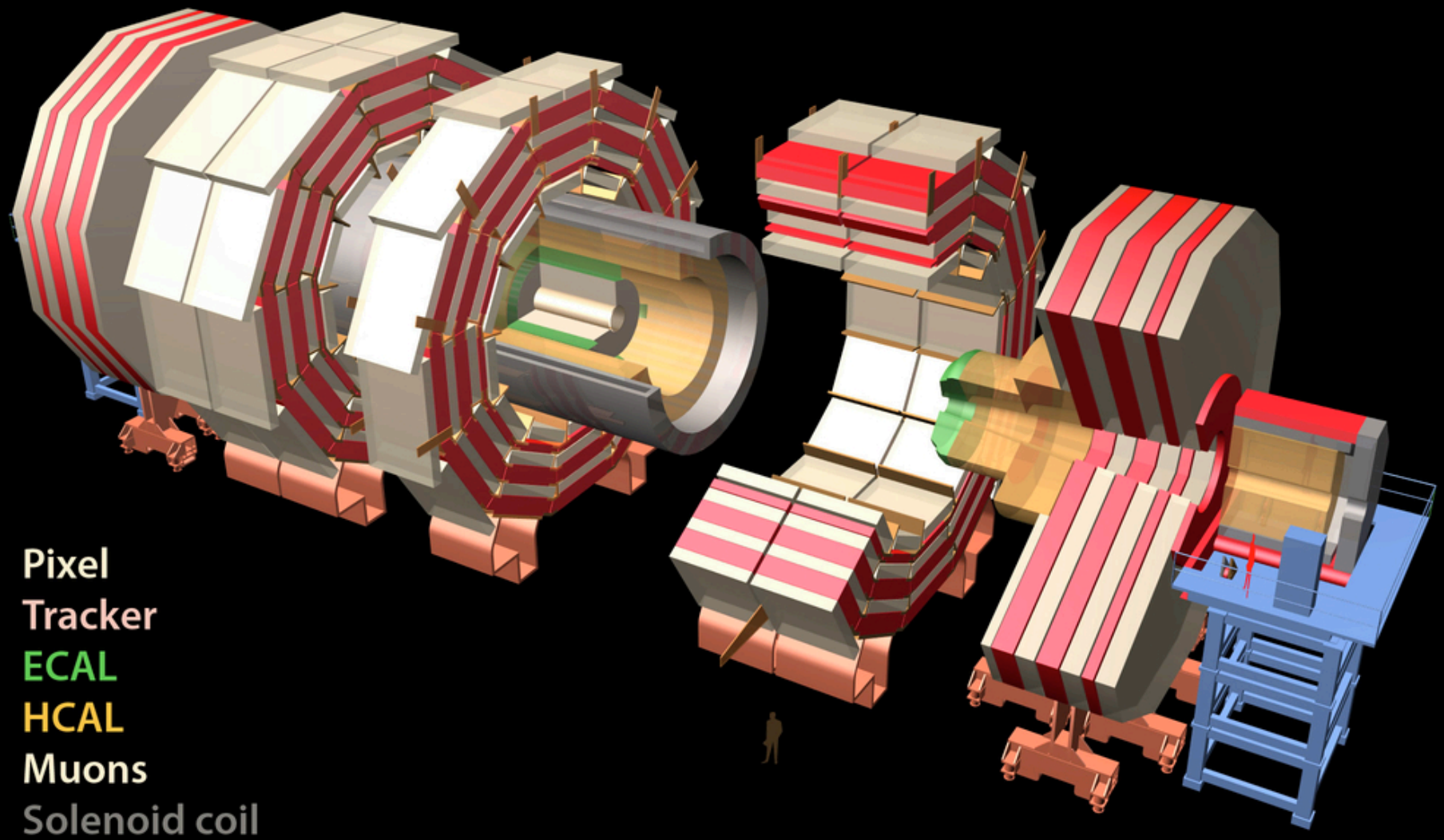




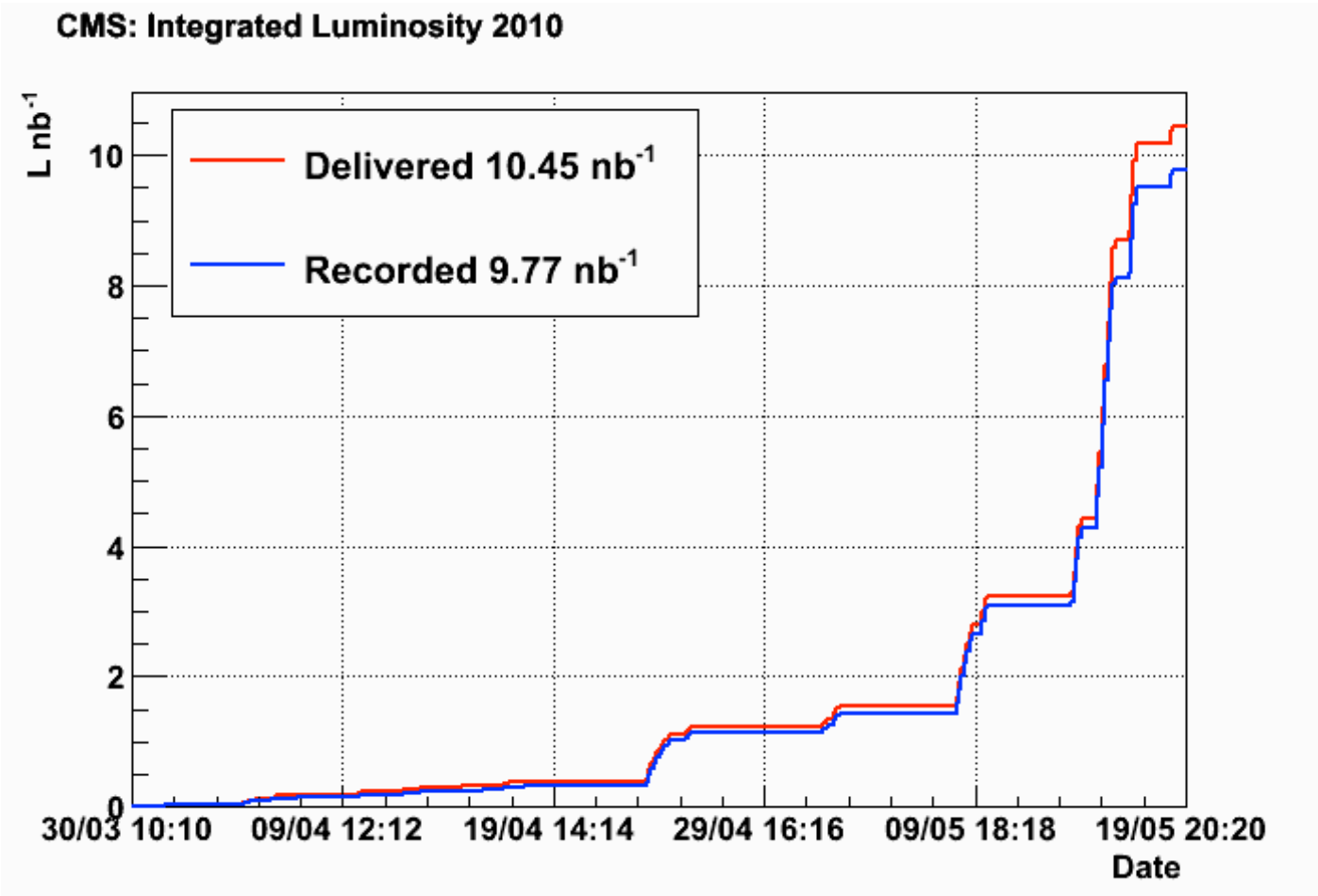
within 5 minutes...



The LHC experiments are at last collecting high energy data!



Luminosity profile since March



Data-taking efficiency quite good even at start

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Theorists v. Experimentalists

- Theorists want to know...
  - Now that we have collisions, how will we know if the new physics is SUSY?
  - How will we determine the full spectrum and mass scale? The Lagrangian?
- Experimentalists are thinking...
  - Now that we have collisions: Is there a leak? Does the trigger work?
  - How much noise is there?
  - What is the actual size of the QCD backgrounds?
  - How will we know whether its new physics, or SM plus mistakes on the tails of the distributions?

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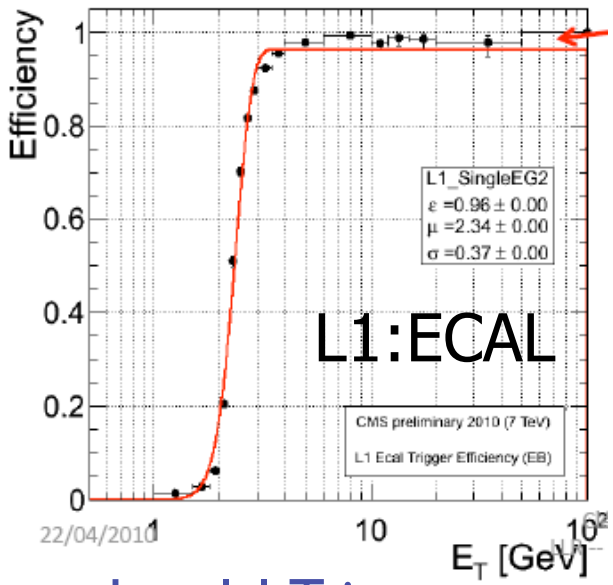
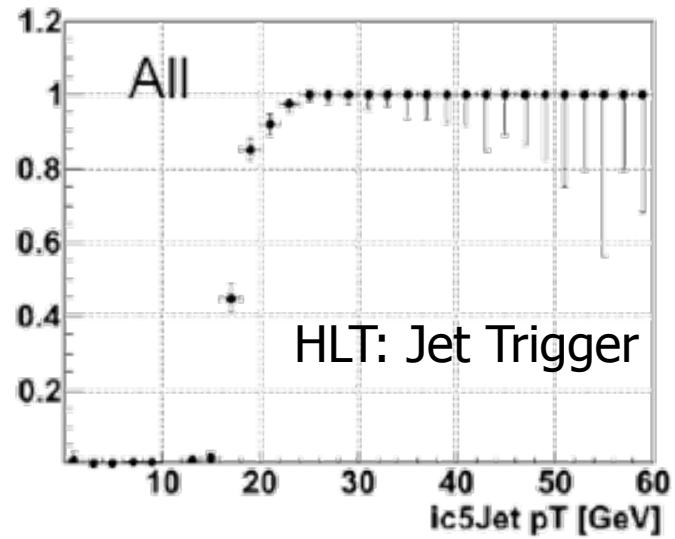
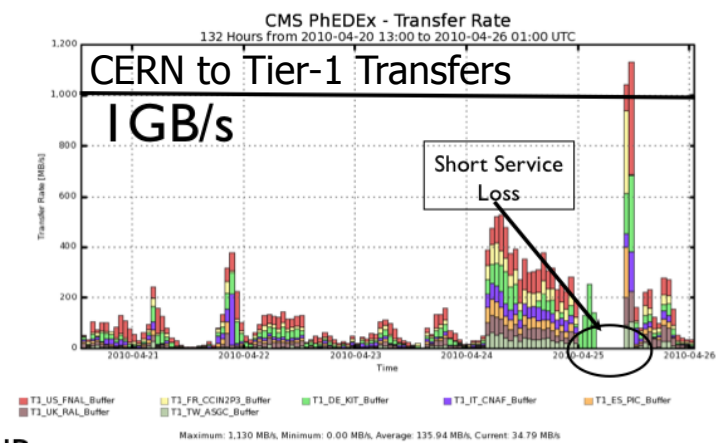
Triggers and Computing

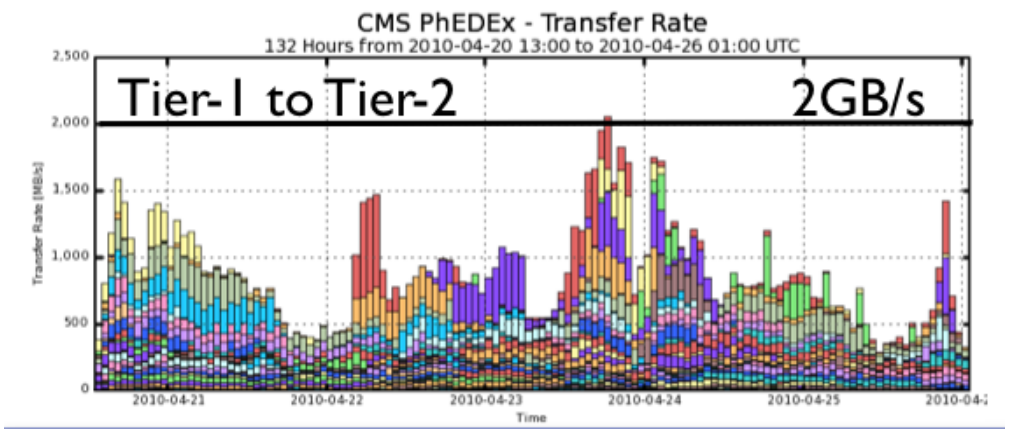


Level 1 Triggers quite efficient



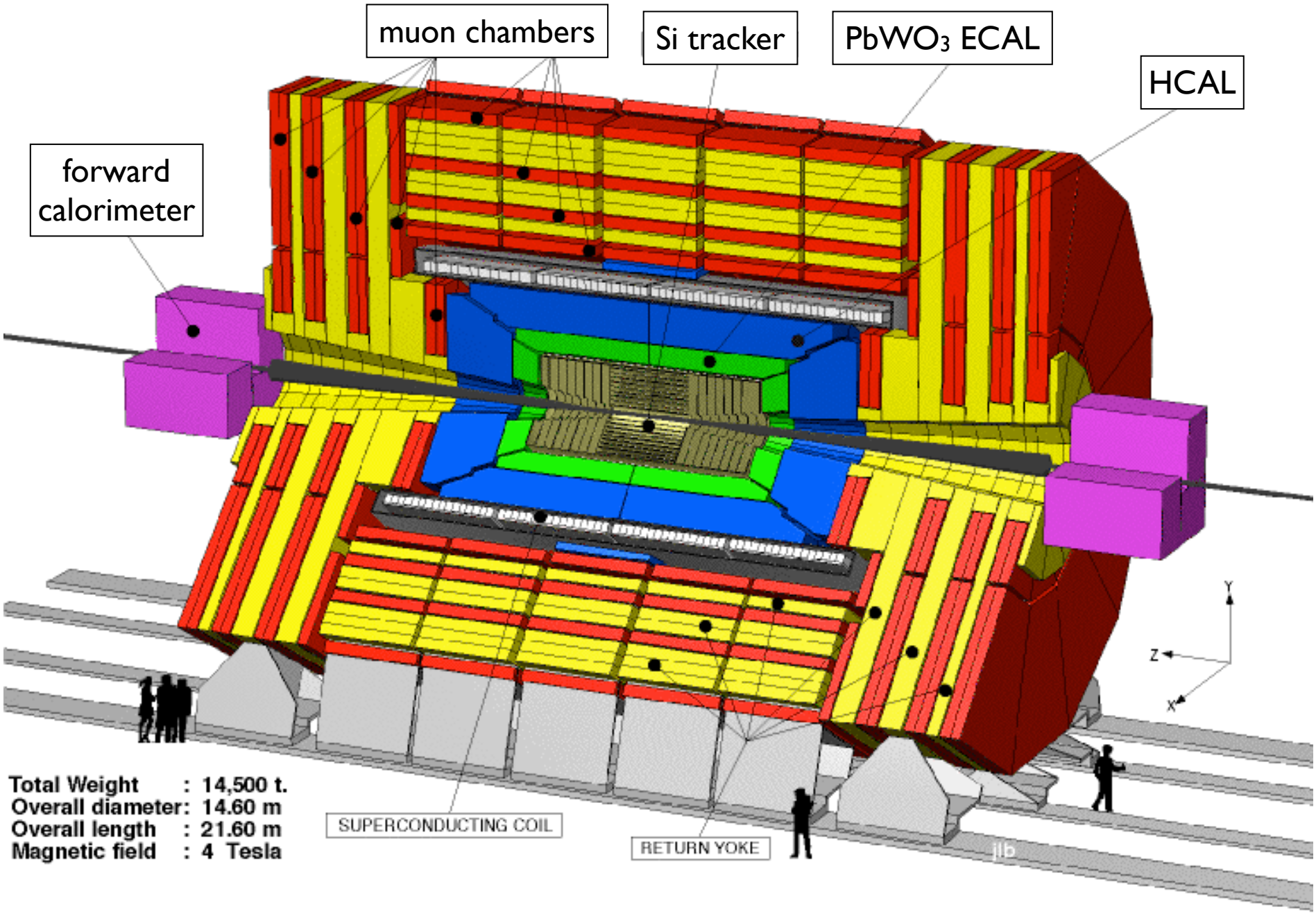
High Level Trigger menus performing well



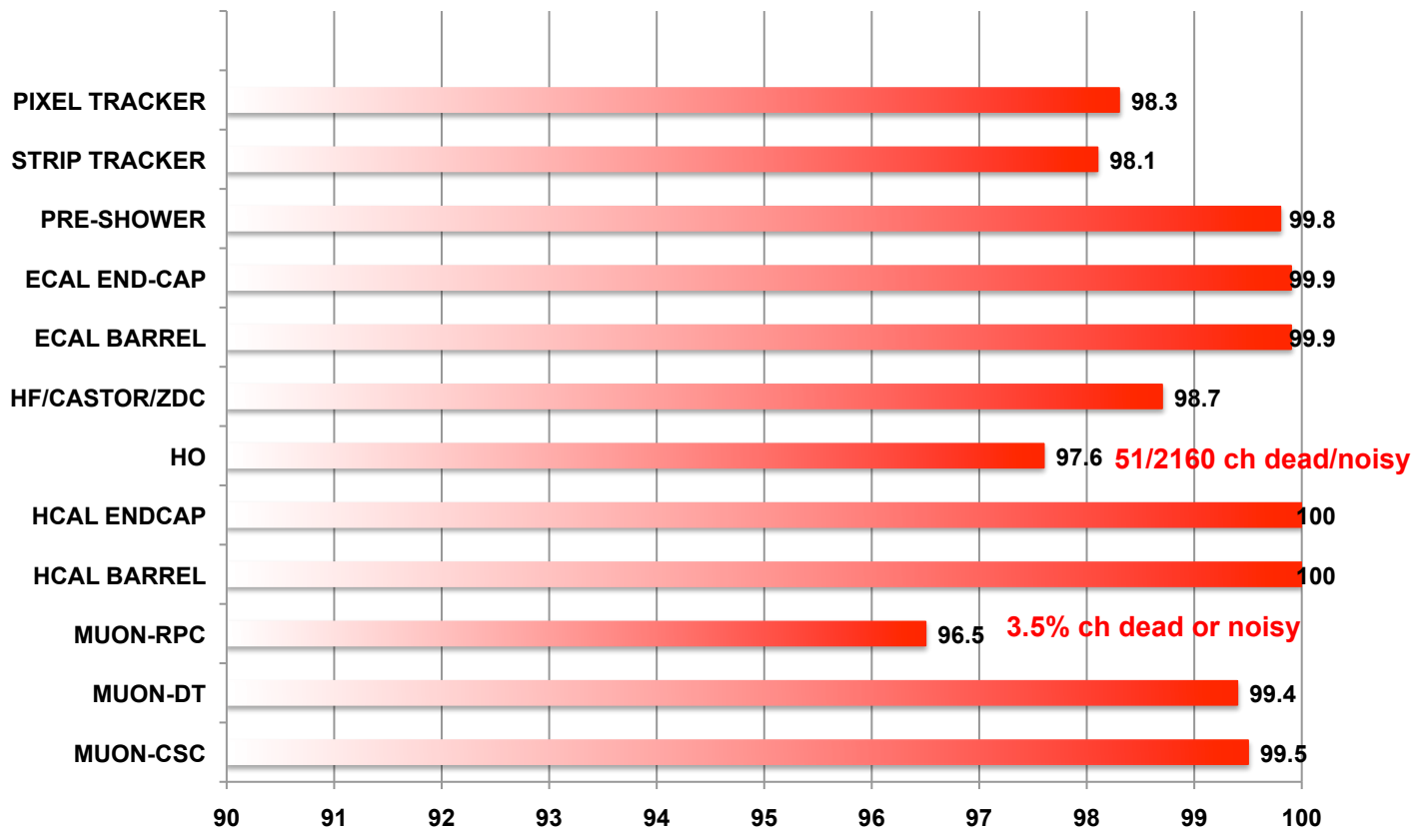


Tier 1 and Tier 2 centers performing reliably

CMS is performing well!



CMS operation: start of 7 TeV



Already since improved: Eg- RPCs 98.8% live by May 21.

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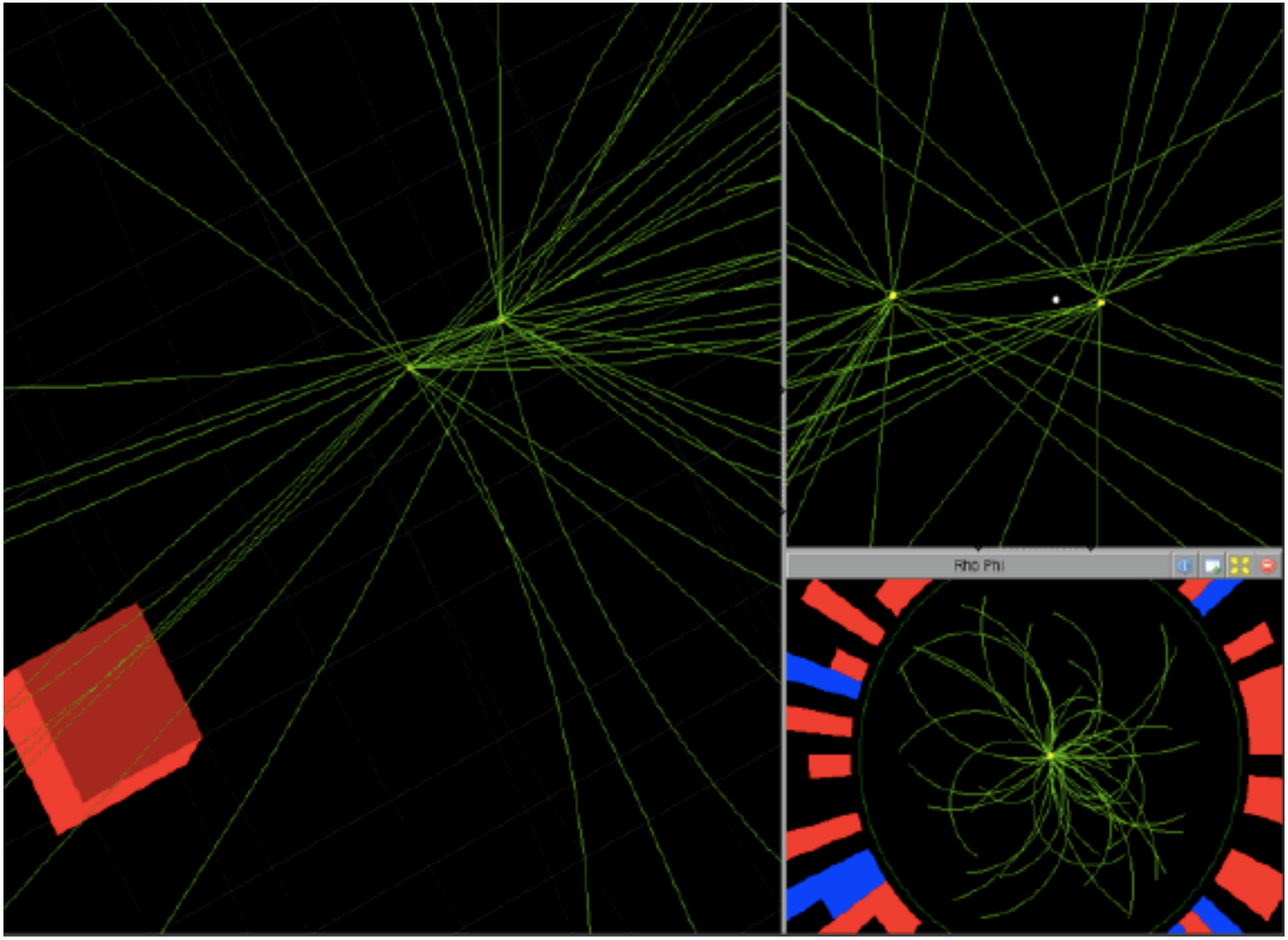
Low luminosity but...



Two vertex event. Pile-up seen (>0.5%) already at start. Currently 10%, soon 100%! Will be an issue, but we're ready.

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Squeezed stable beams

May 1-2: Squeezed, stable beams (30 hours).
Luminosity > 1 x 10^{29} $cm^{-2}s^{-1}$, achieved Monday!

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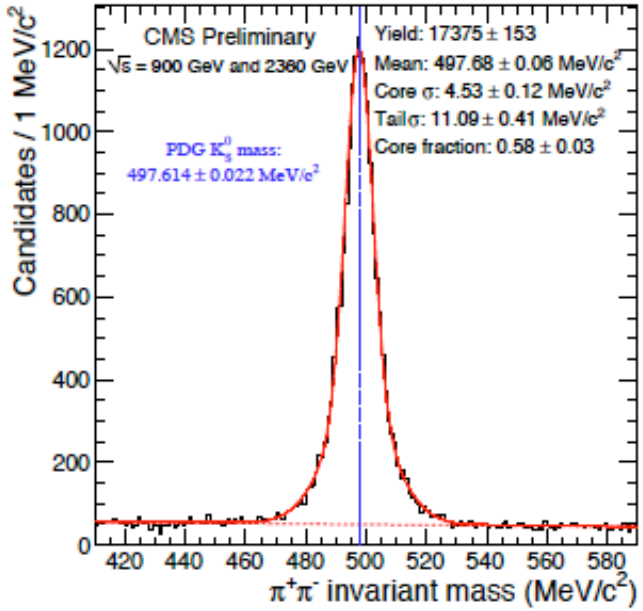
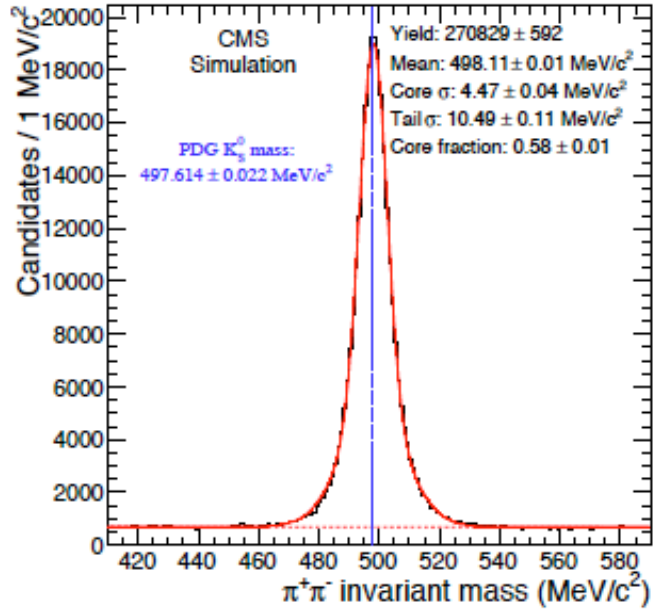
Tracker Performance

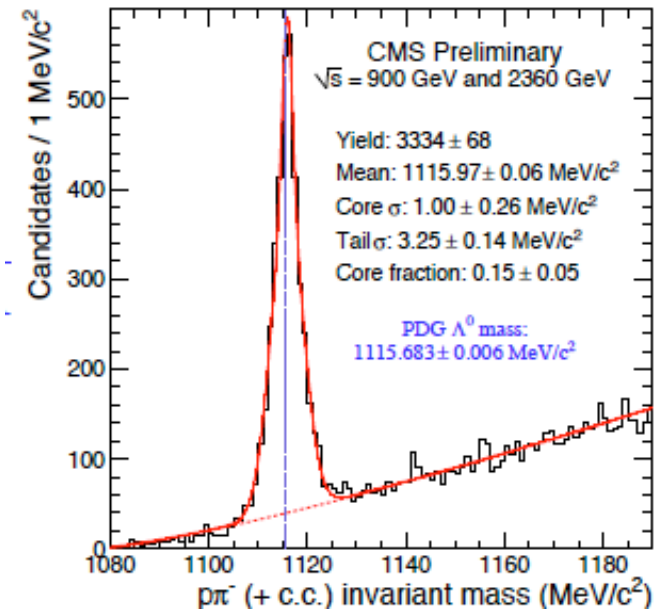
data | simulation

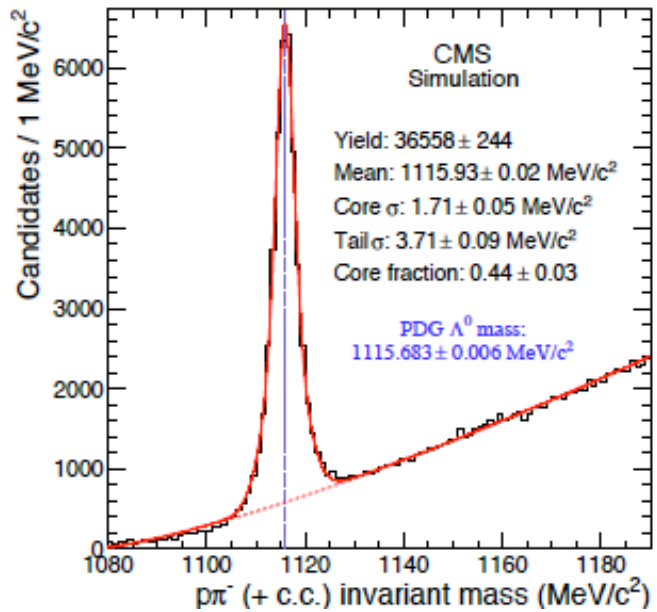
K_s





Λ





Pixels and strips are doing very well

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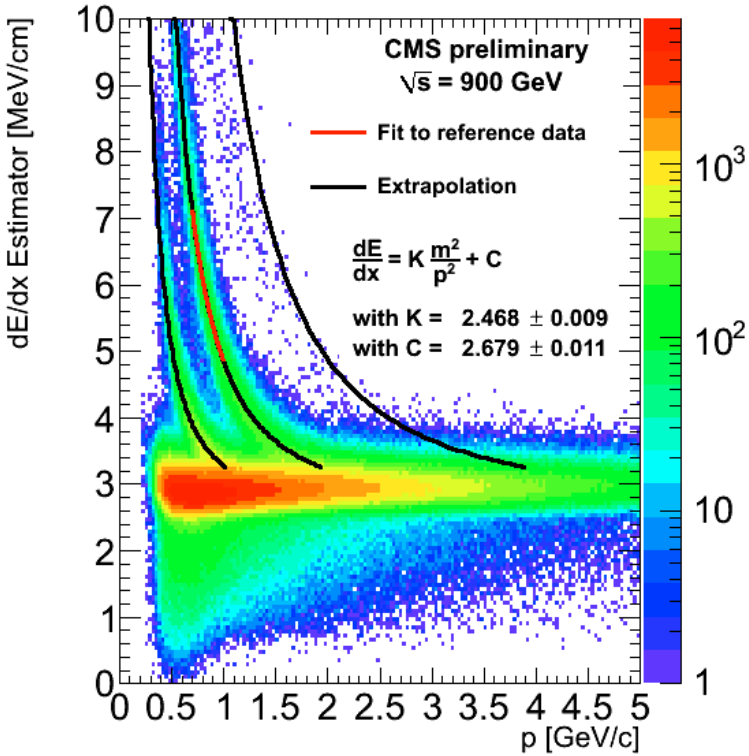
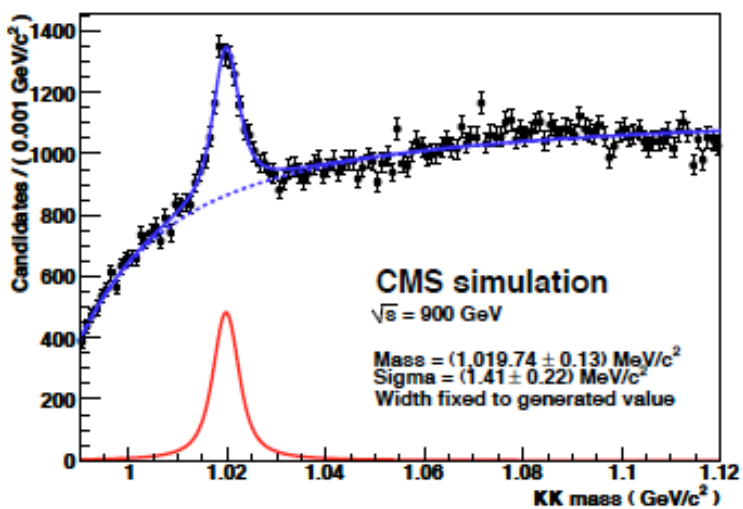
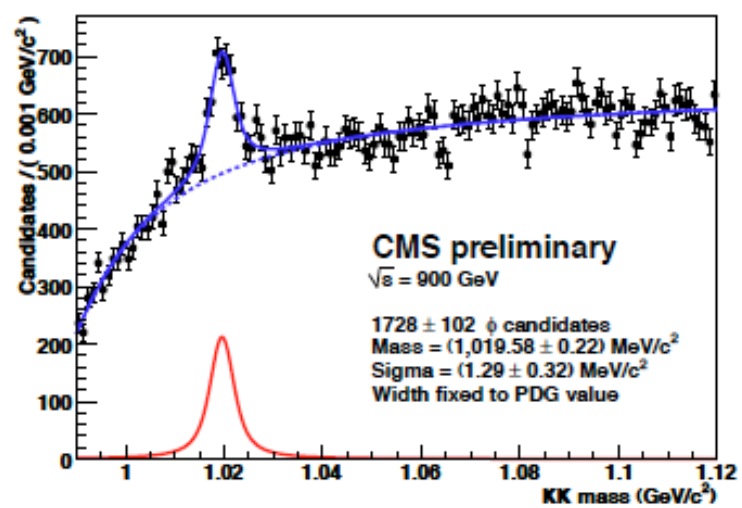
Tracking: dE/dx



Use large sampling along tracks for particle ID with dE/dx

$\phi \rightarrow KK$





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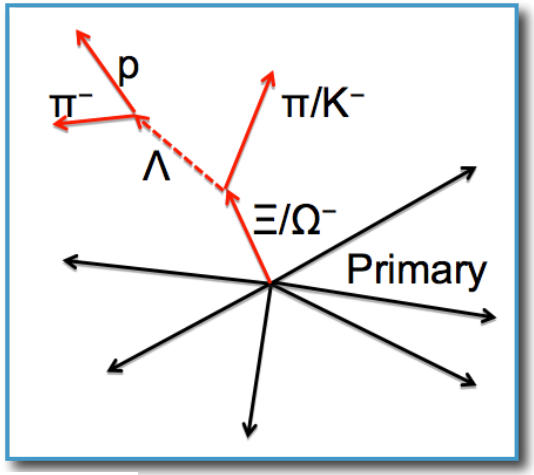
More Resonances

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

ΛK^{-} or anti- ΛK^{+} invariant mass

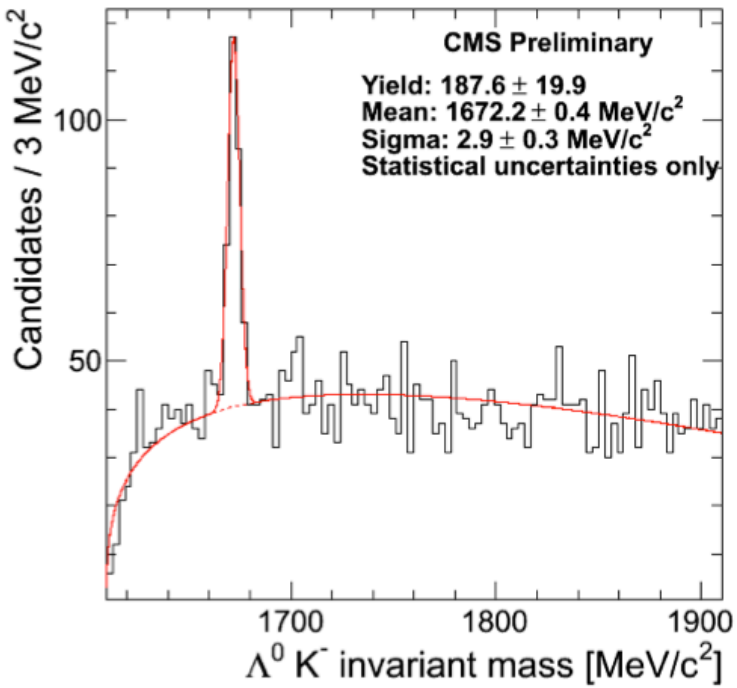
- combinations fit to a common vertex

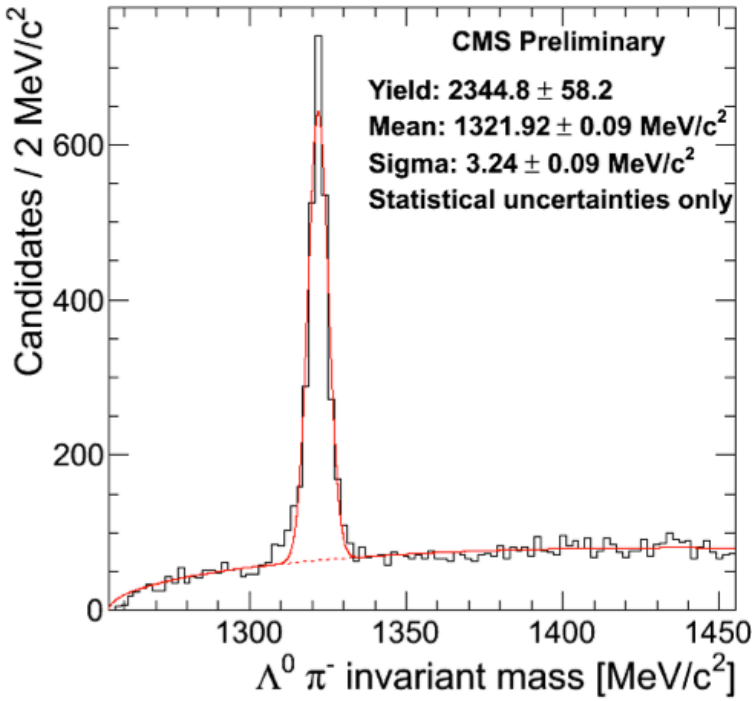


$\Xi^{\pm} \rightarrow \Lambda\pi^{\pm}$

$\Lambda\pi$ invariant mass

- tracks displaced from primary vertex
- common displaced vertex





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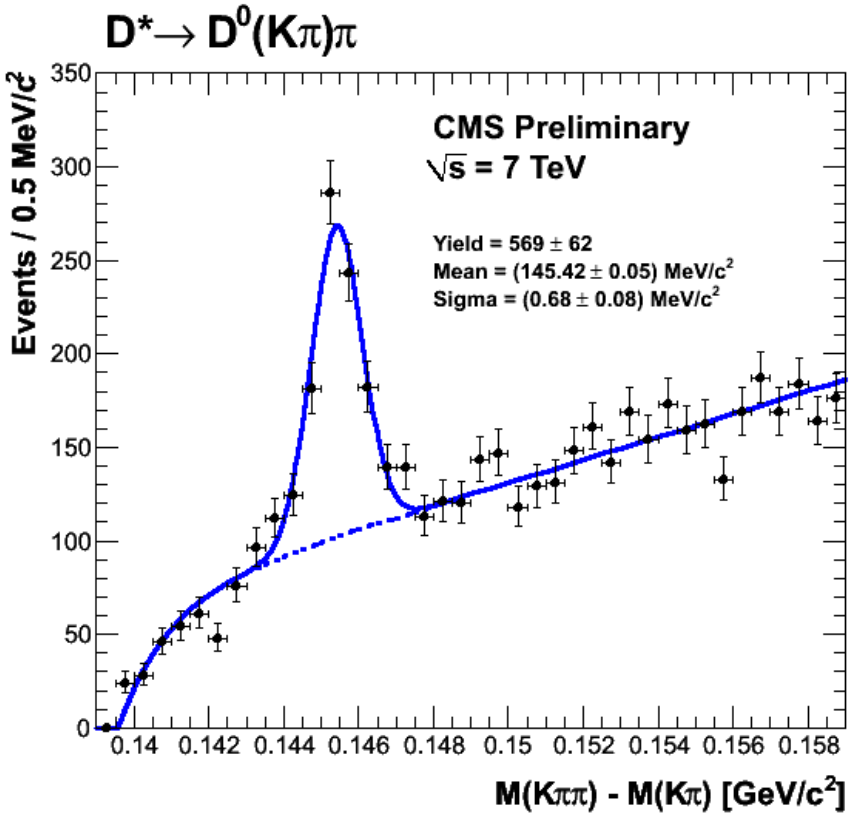
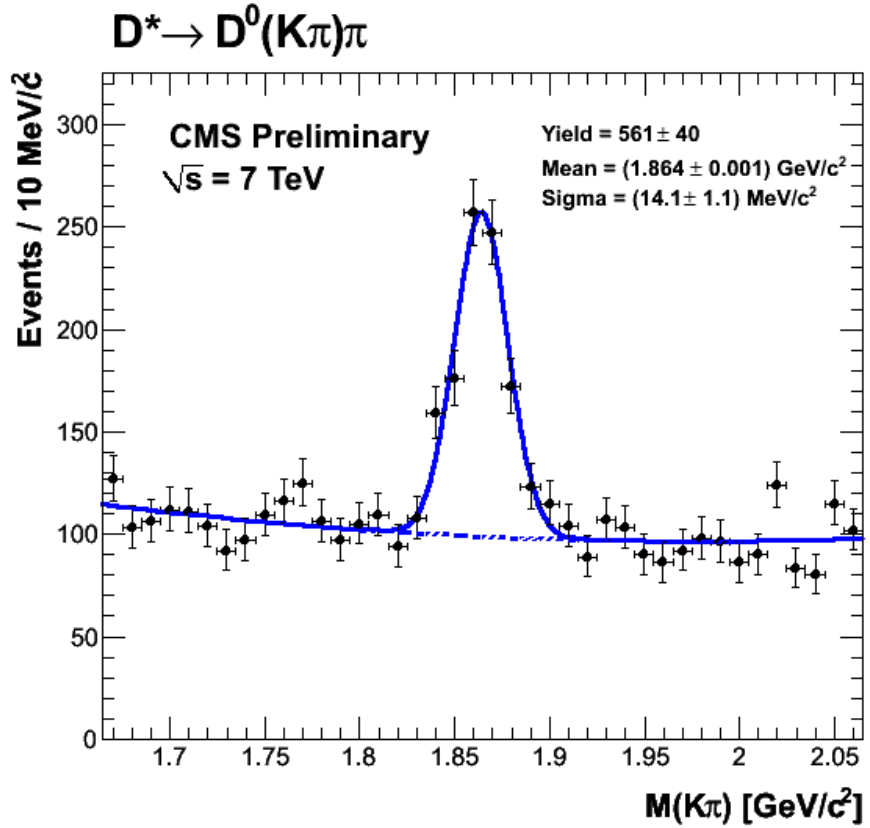
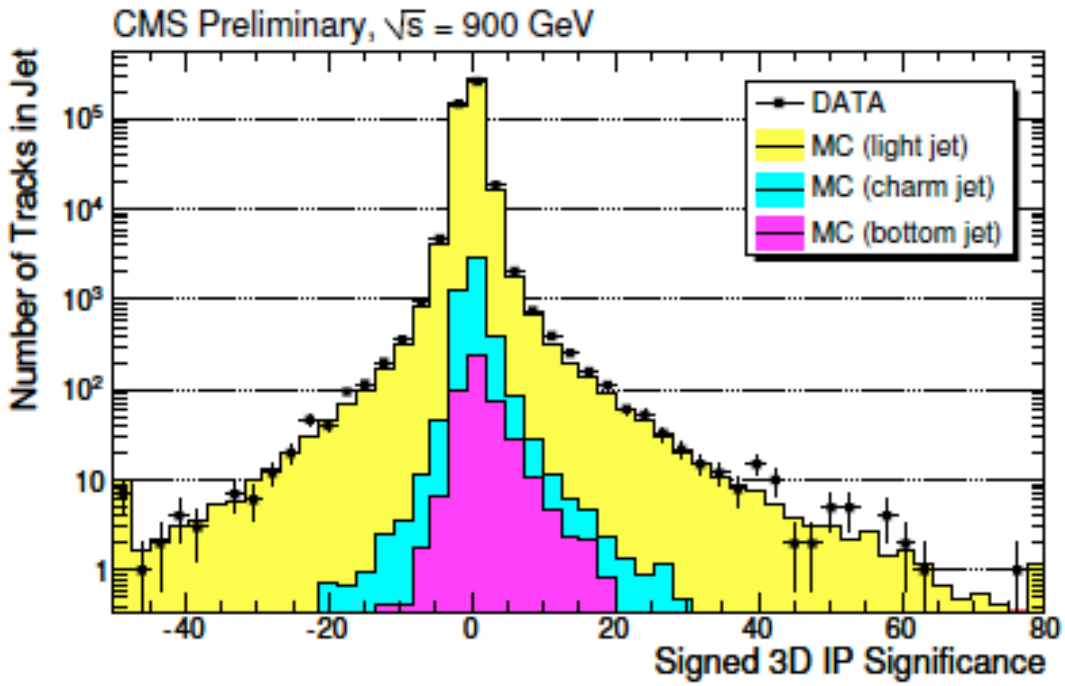
D* in 7 TeV data!



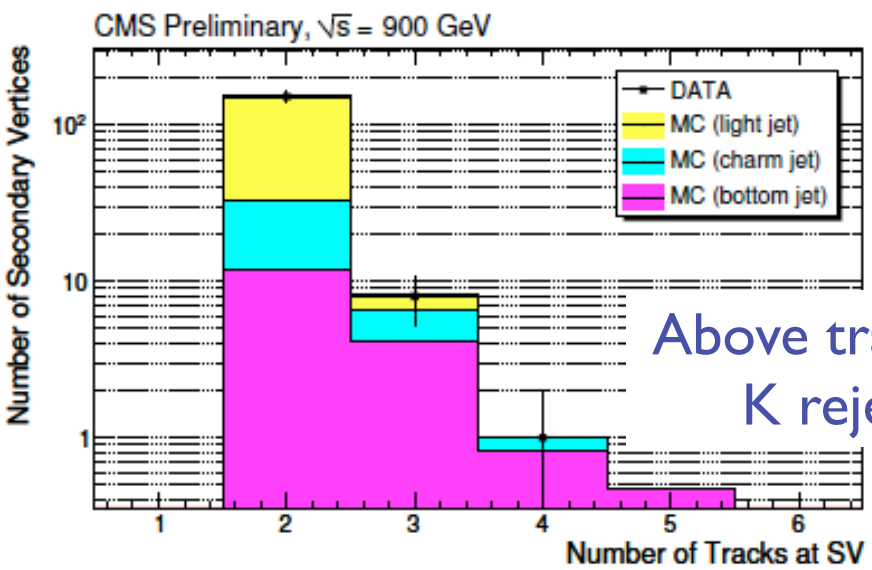


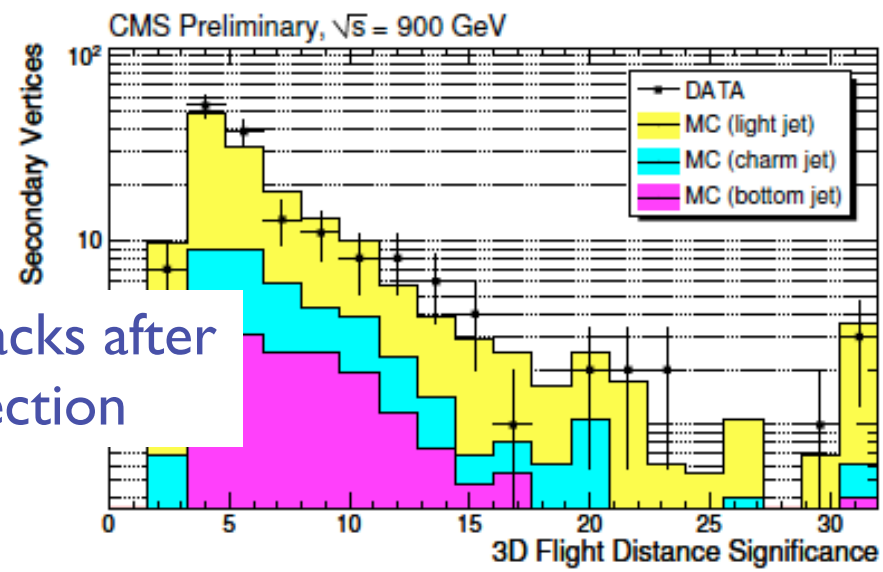
See very clean $D^* \rightarrow D^0\pi$, $D^0 \rightarrow K\pi$

Secondary Vertices: b-tagging



(900 GeV) Basic b-tagging variables look good v. sim. Need more tuning with new data.





Above tracks after K rejection

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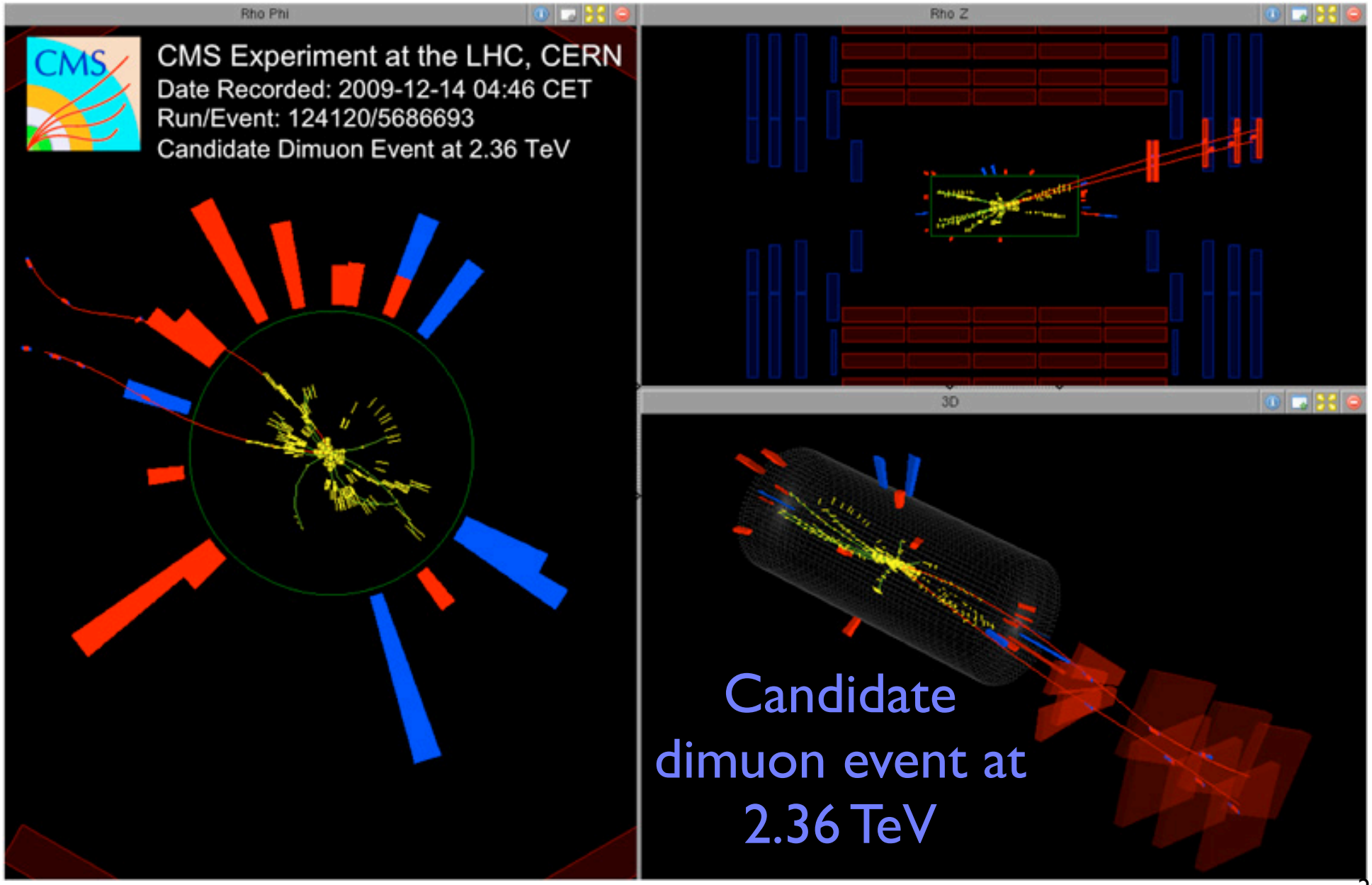
Compact MUON Solenoid



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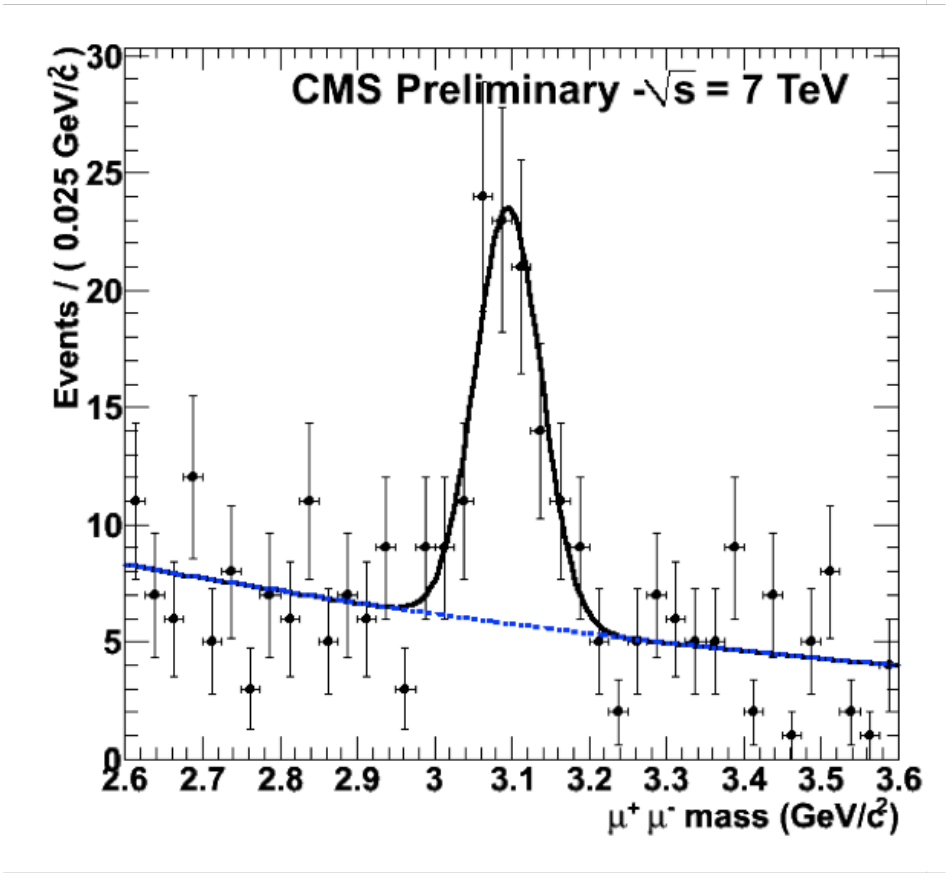
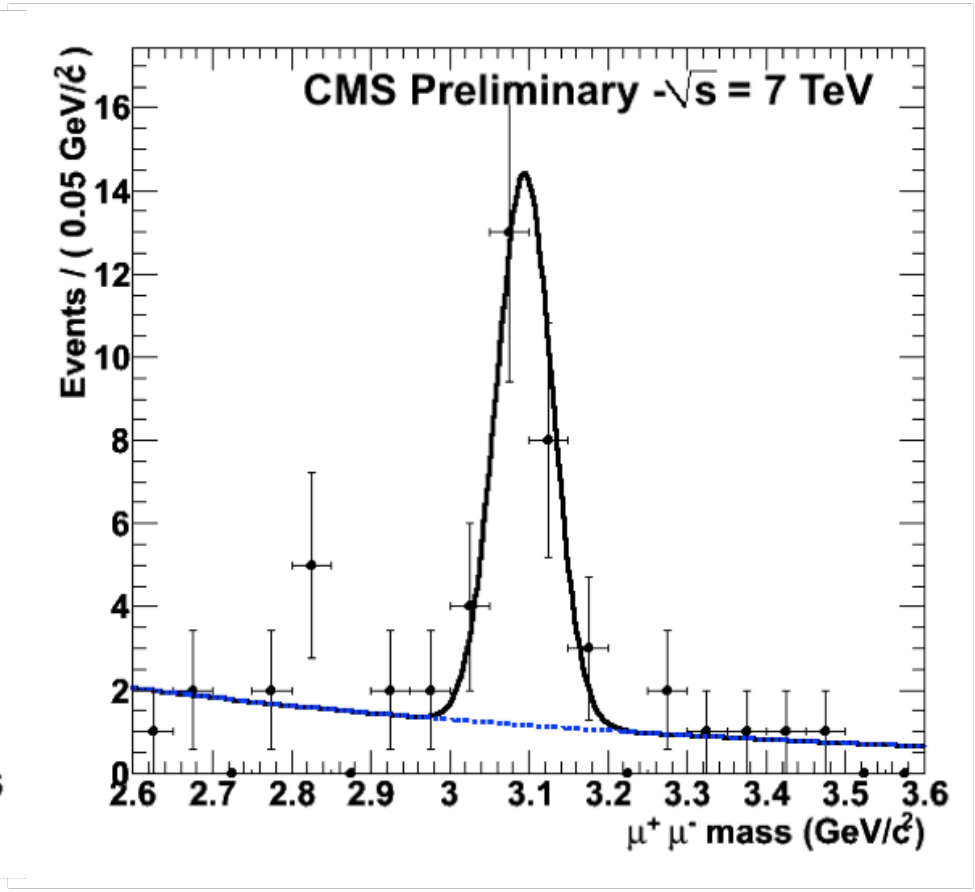
J/Ψ decaying to muons

Clear J/Ψ signal in the data.





Loose: 76 ± 12 signal events

Tight: 24 ± 5 signal events

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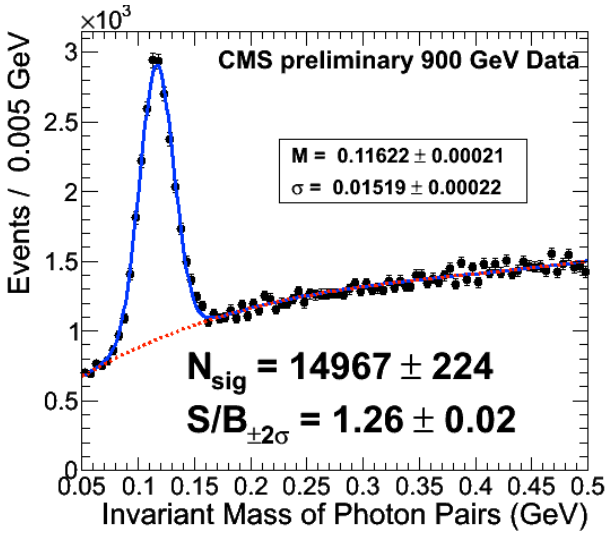
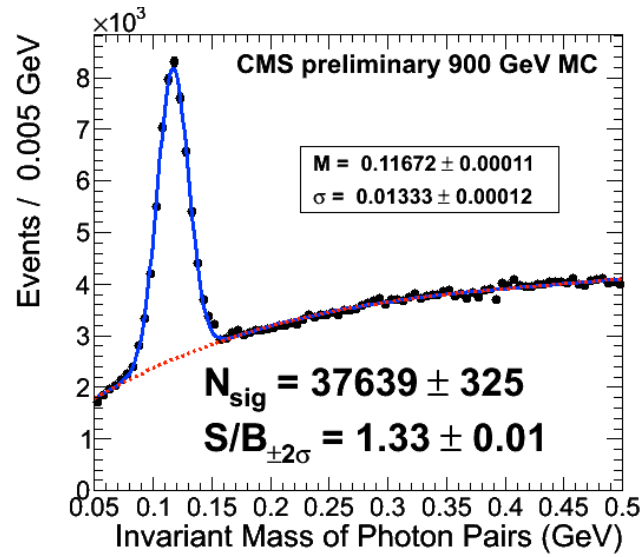
Electromagnetic Calorimeter

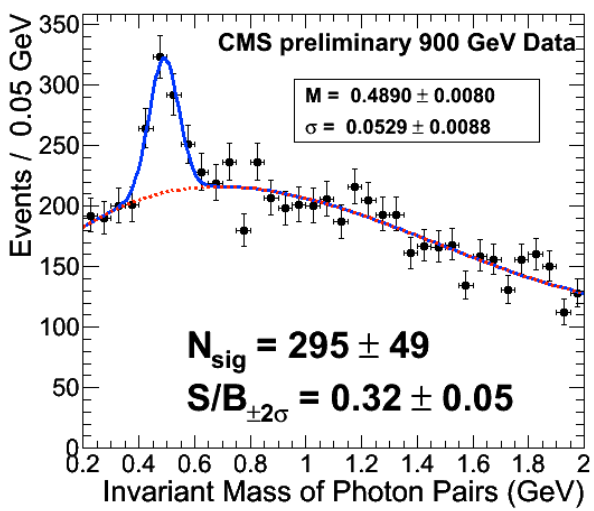
π^0 data



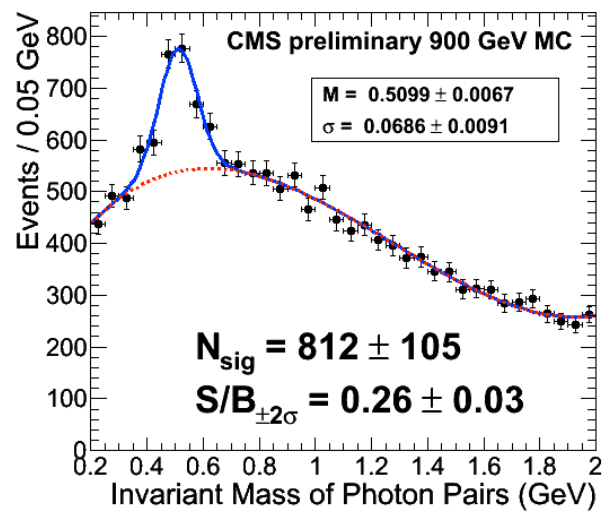
π^0 sim



η data



η sim



π^0 and η useful for inter-crystal calibration

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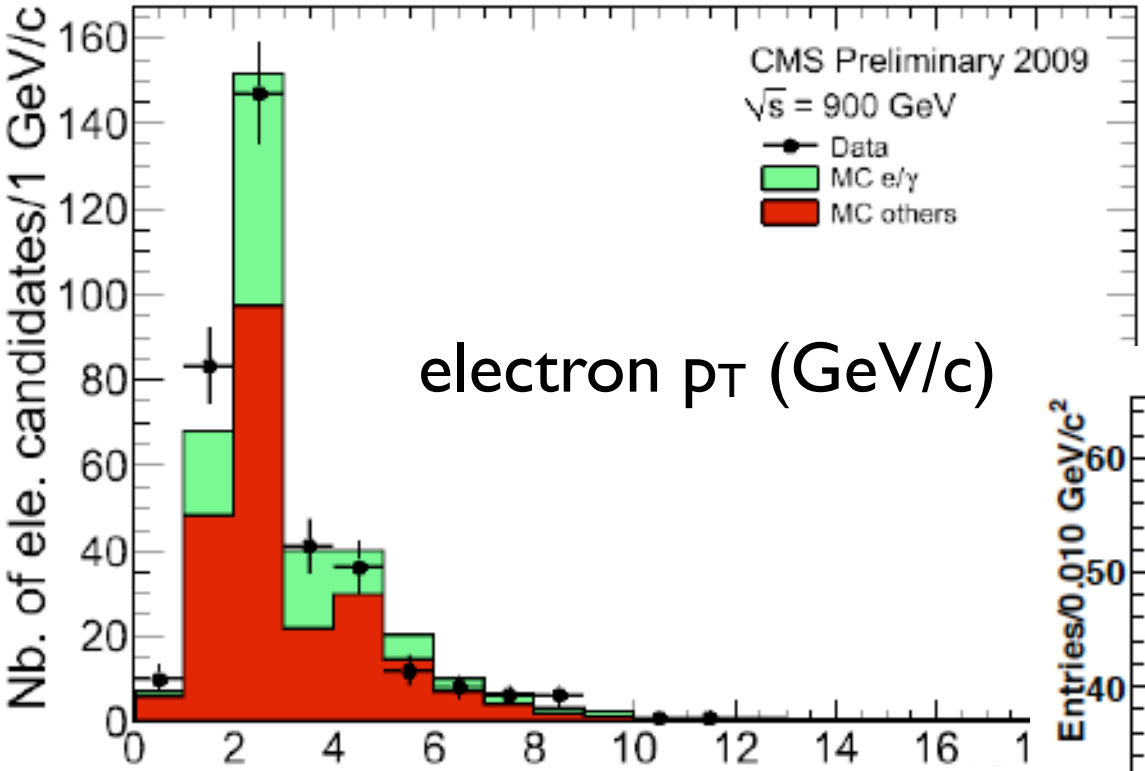
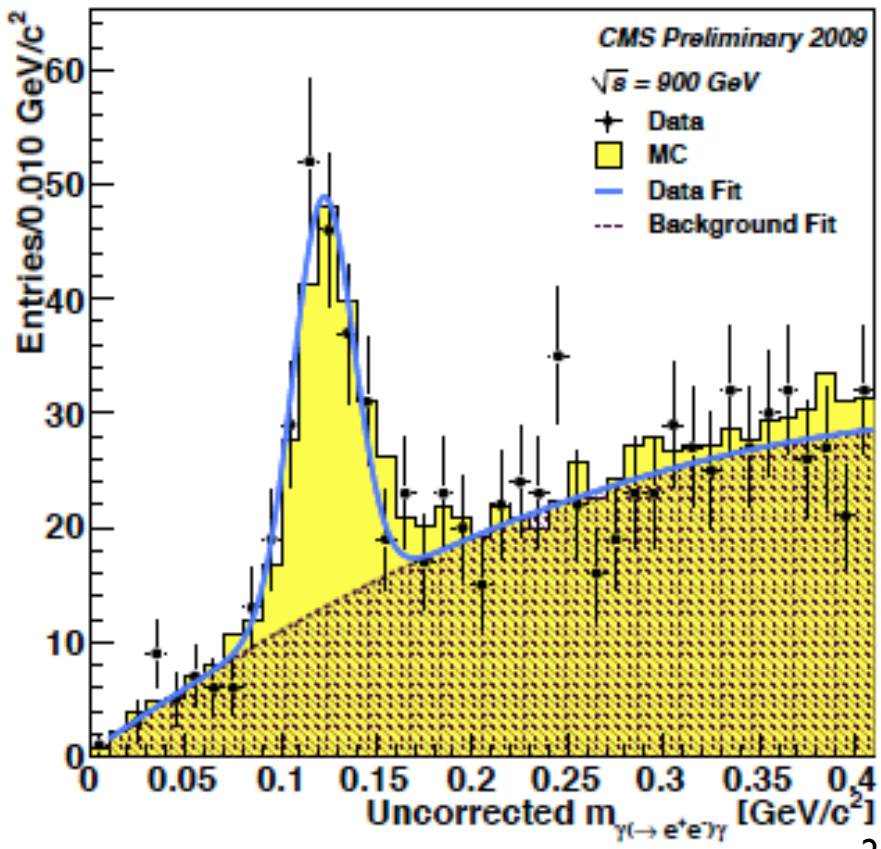
Electrons, photons, conversions



π^0 from γ +($\gamma \rightarrow ee$)



electron and photon reconstruction doing well

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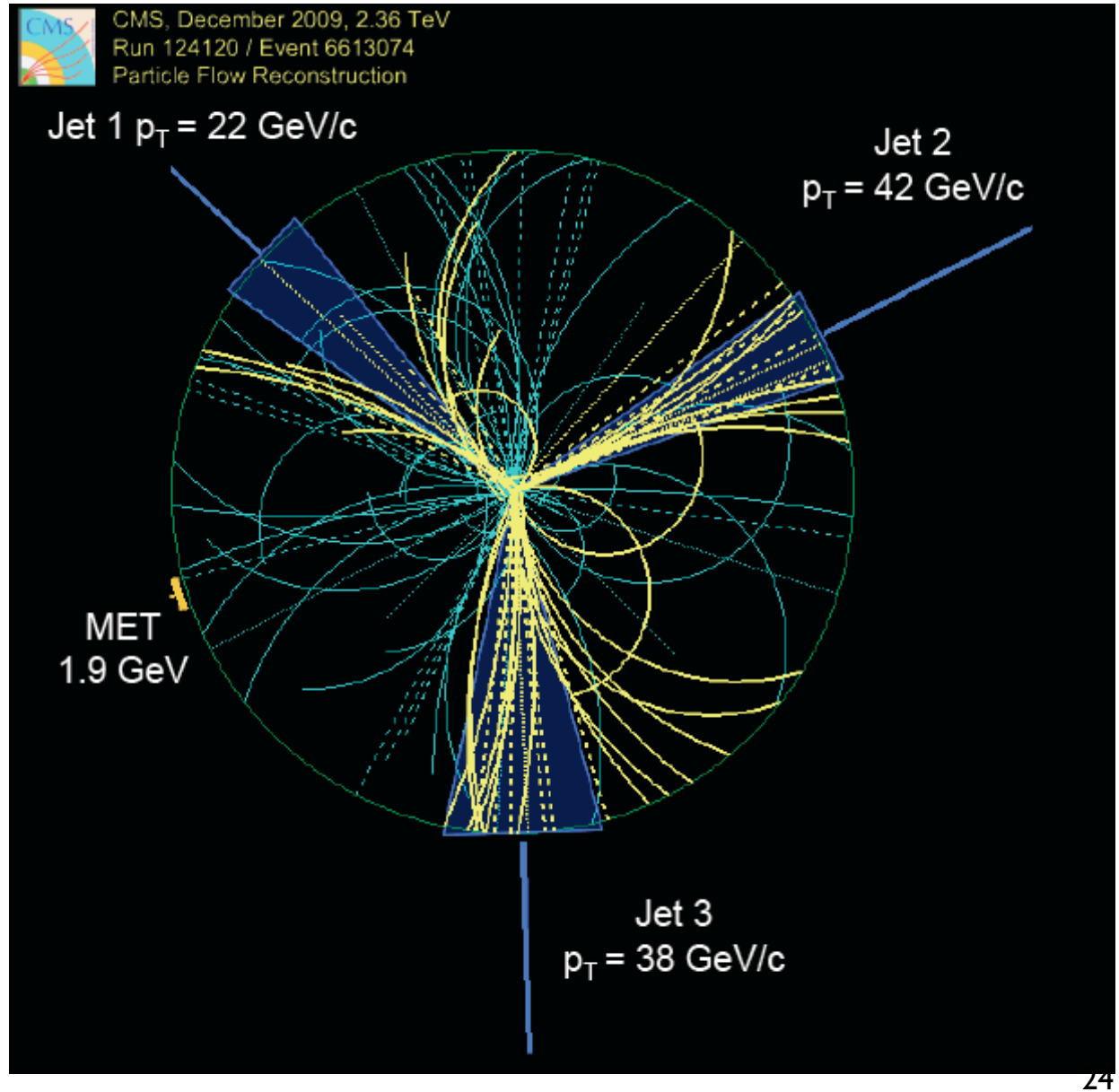
Jets, Jets and more Jets!

1. Calorimeter jets (CALO)

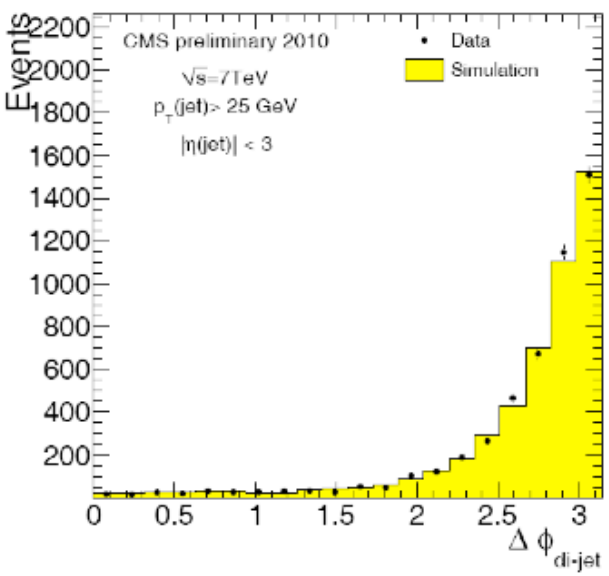
2. "Jet Plus Tracks" jets (JPT)

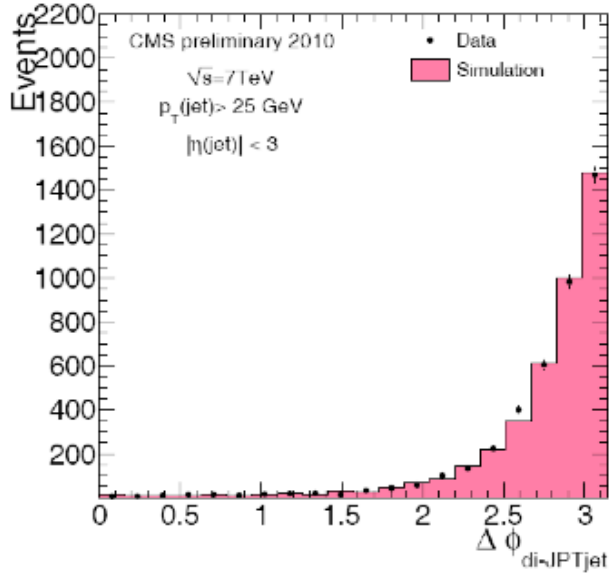
3. Particle flow jets

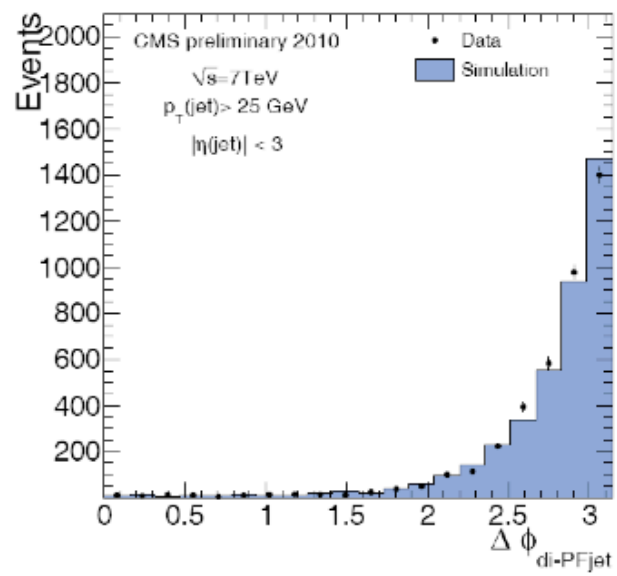
jet algorithm:
anti-k_T, R = 0.5



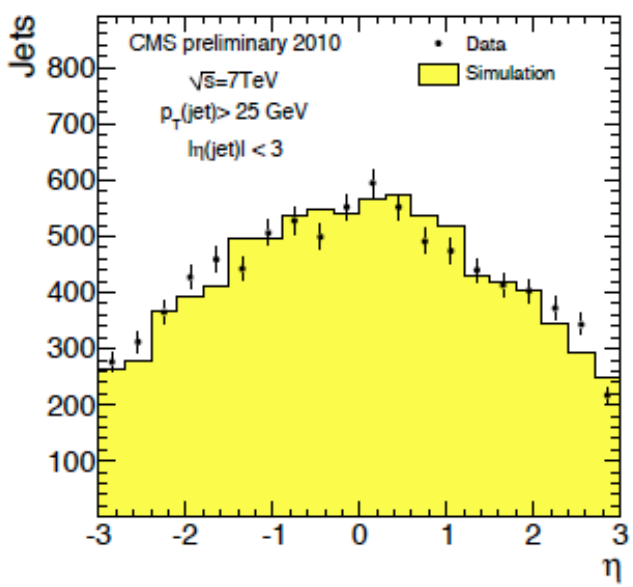
Jets with the first nb^{-1} at 7 TeV

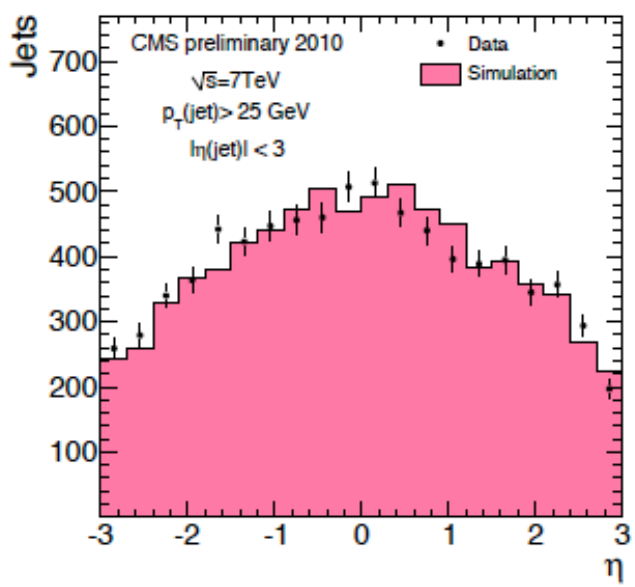


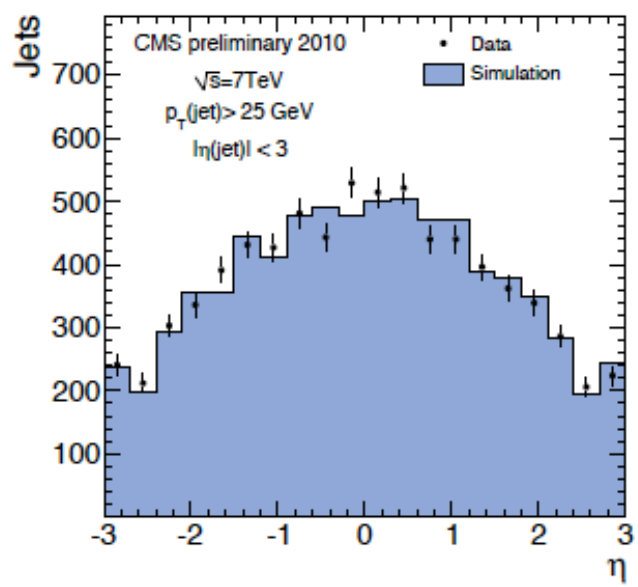




calorimeter jet plus track particle flow







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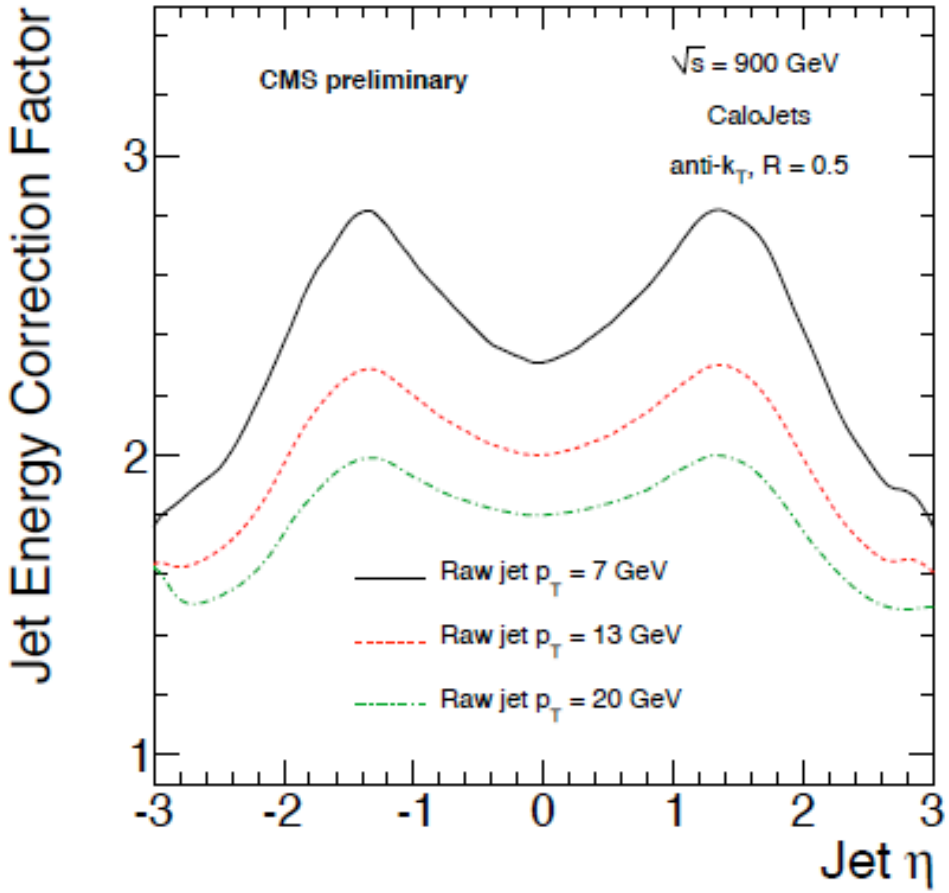
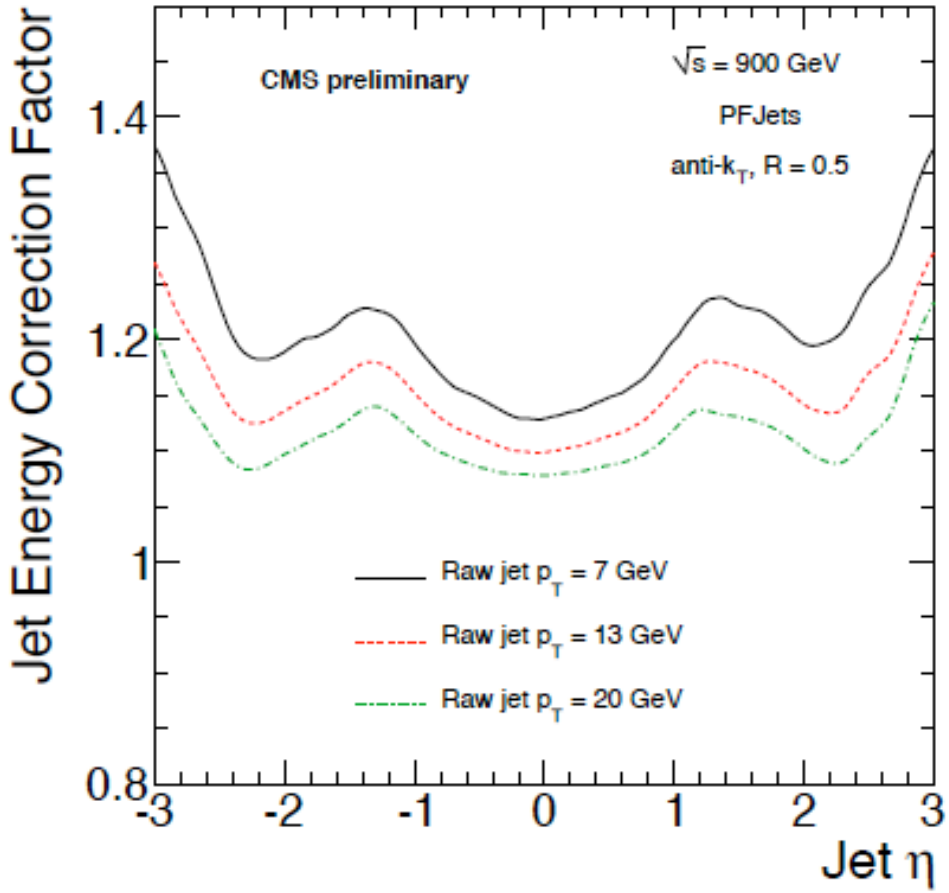
Jet Corrections





Particle flow reduces magnitude of jet corrections

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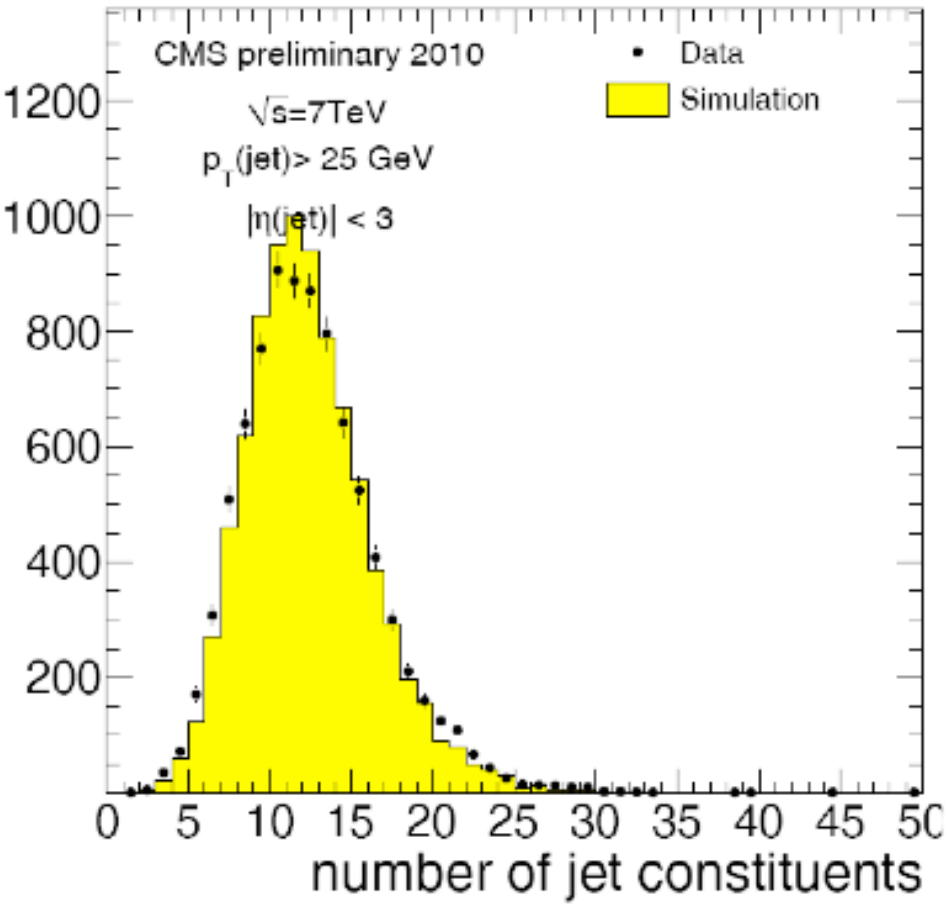
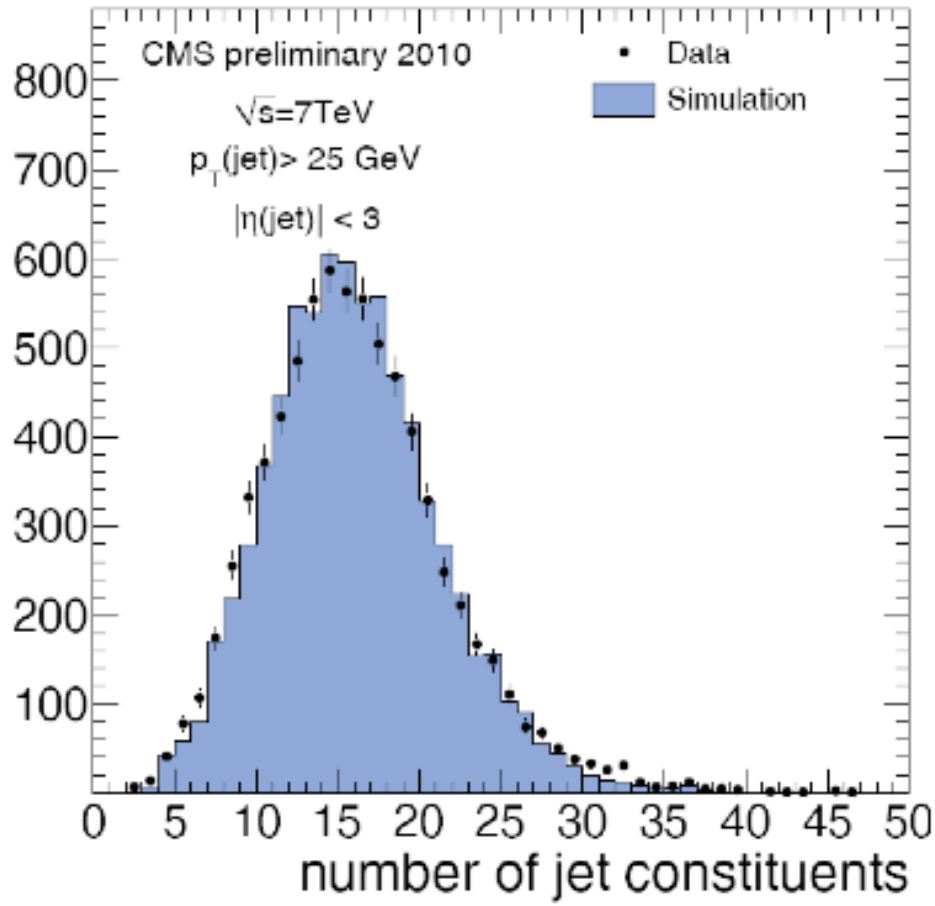
Particle flow jet performance

calorimeter



particle flow



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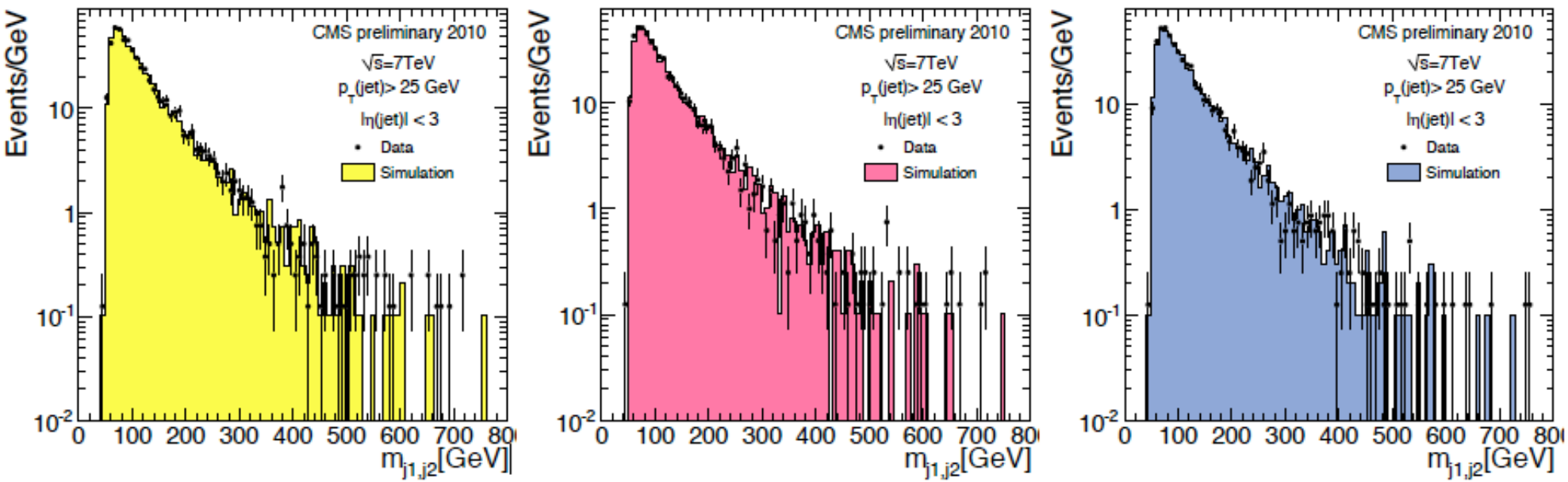
Di-Jets in first nb^{-1} at 7 TeV

Creeping up to Tevatron turf...



...will soon surpass it!

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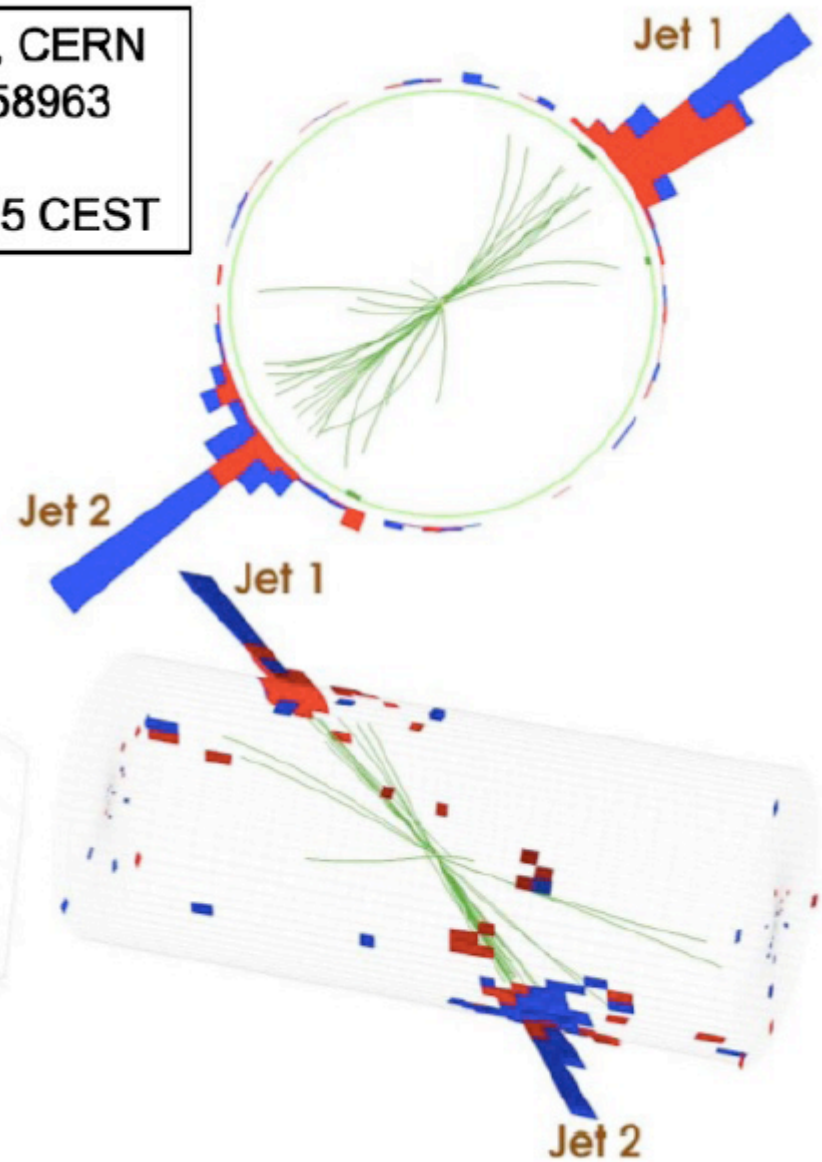
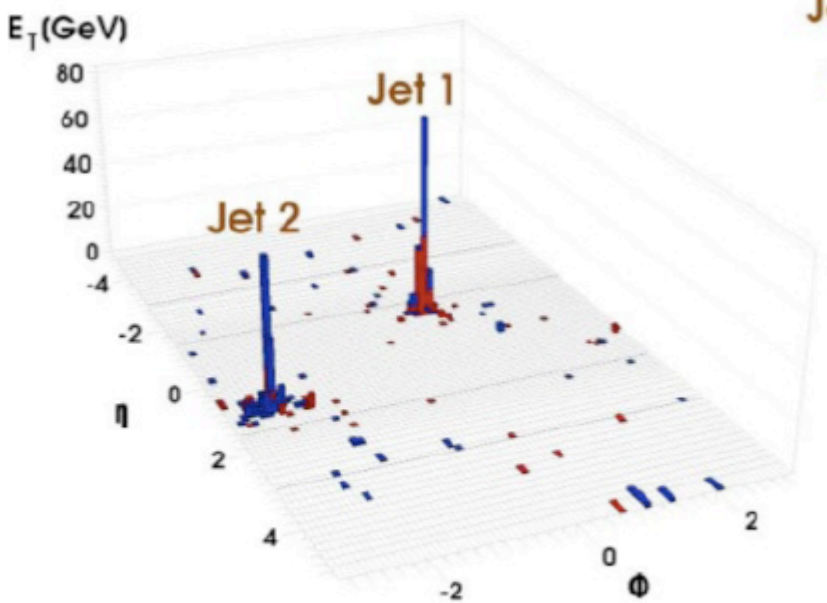
High-mass Di-Jet event at 7 TeV

CMS Experiment at LHC, CERN
Run 133450 Event 16358963
Lumi section: 285
Sat Apr 17 2010, 12:25:05 CEST

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





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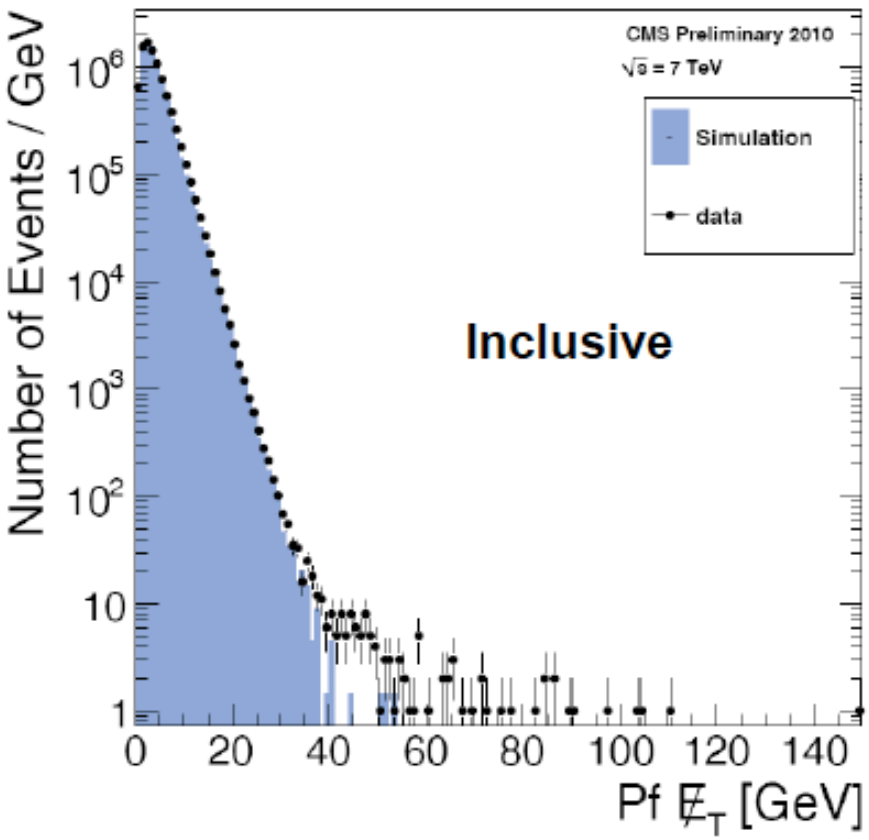
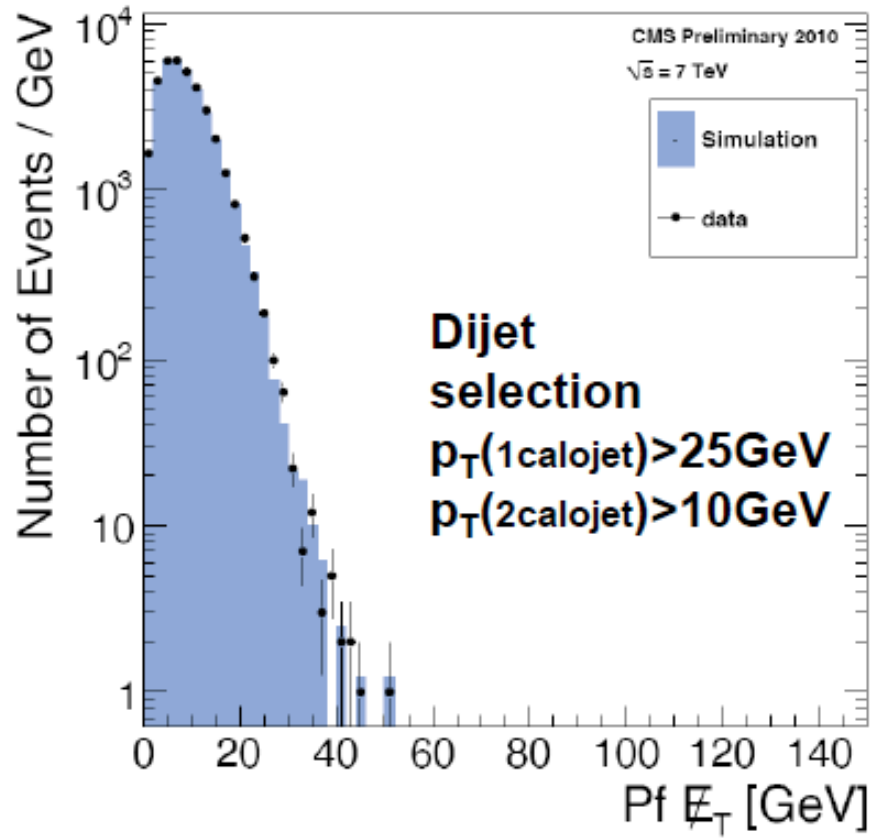
Missing Transverse Energy





Monte Carlo (minbias) describes the data well over 5 orders of magnitude. High tails subject of ongoing study.

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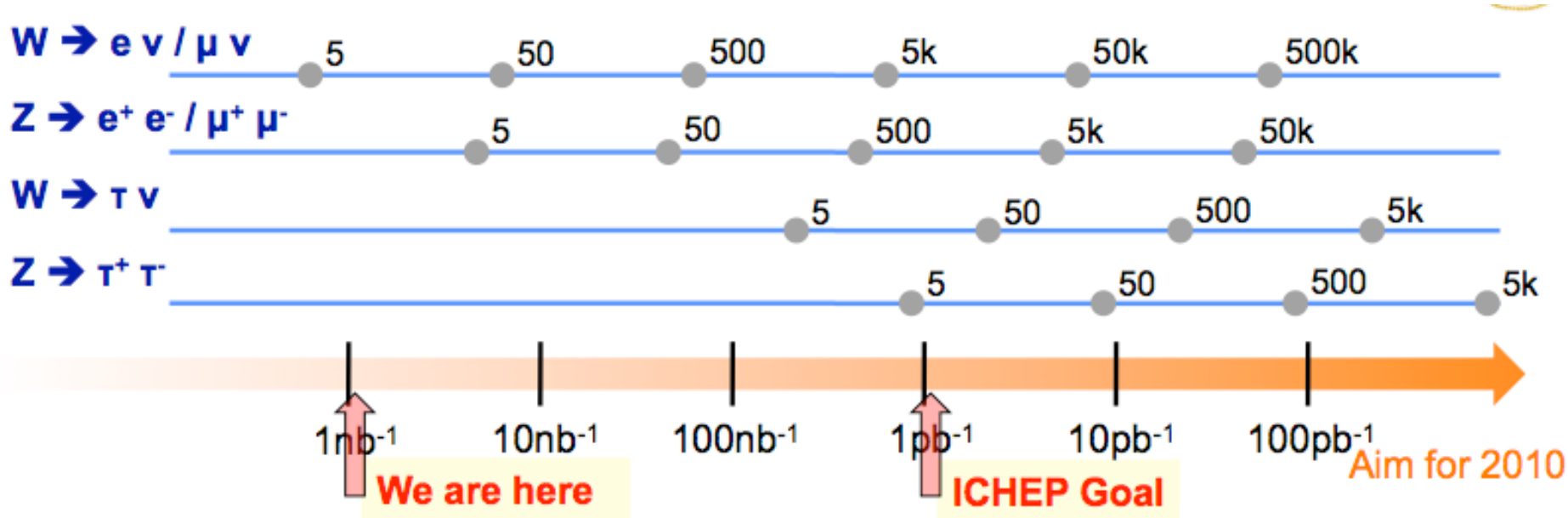
Early Physics: Ws and Zs

W^+ : 56 nb W^- : 39.5 nb total: 95.5 nb

Z/γ^* : 49.5 nb



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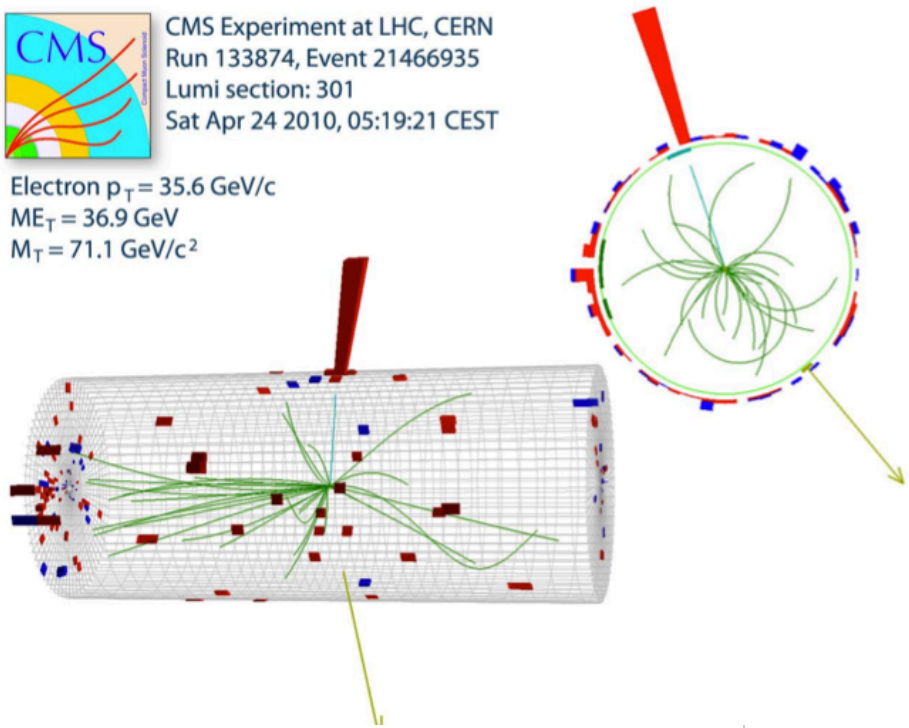
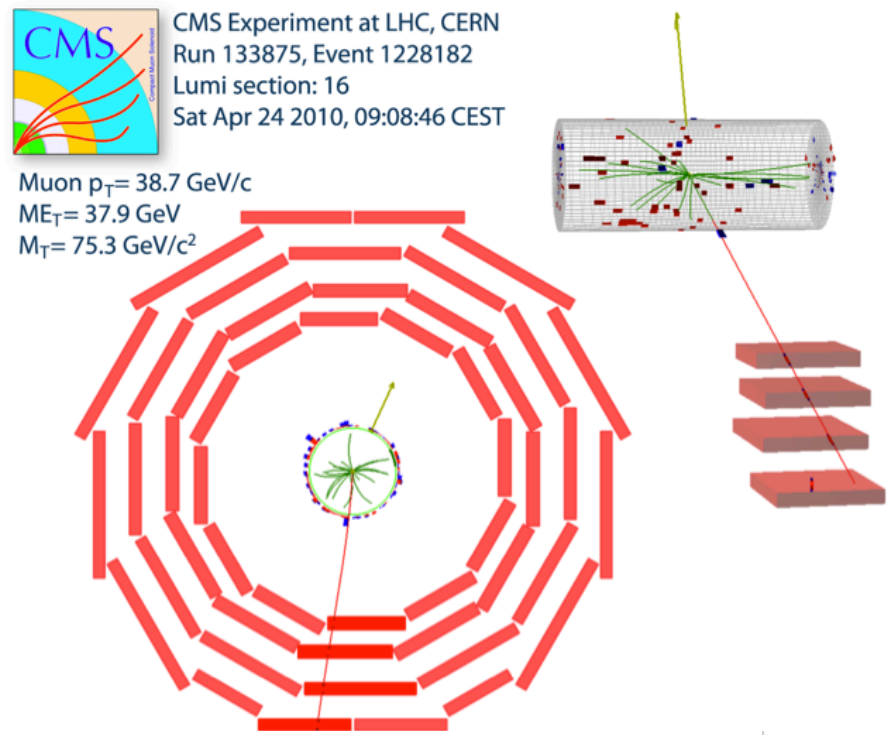
Expected/Observed, 1 nb^{-1}

For 1 nb^{-1} at 7 TeV, after acceptance, expect 8 W candidates and 0.8 Z candidates.



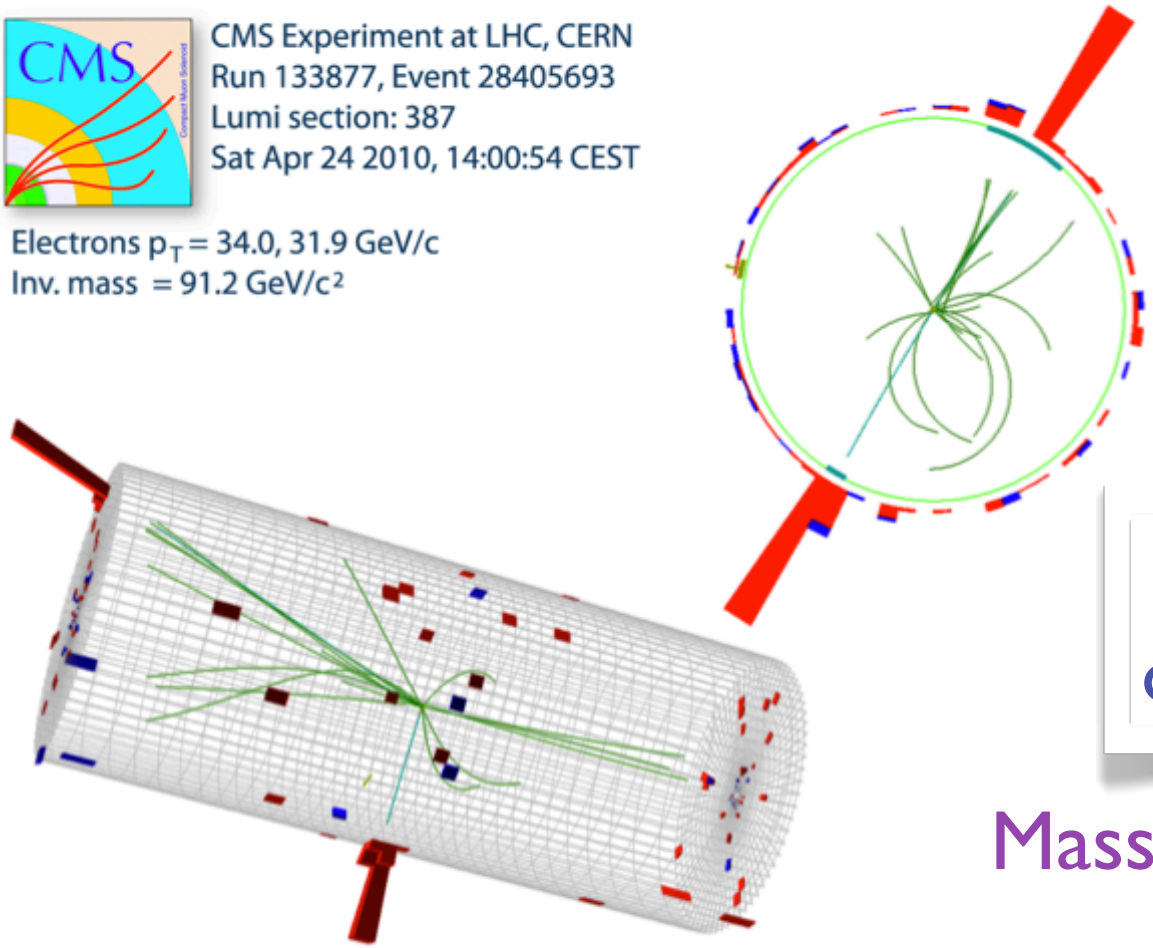


$W \rightarrow e\nu$:
3 candidates found

$W \rightarrow \mu\nu$:
3 candidates found

32

Expected/Observed, 1 nb^{-1}



$Z \rightarrow ee$:
one candidate found

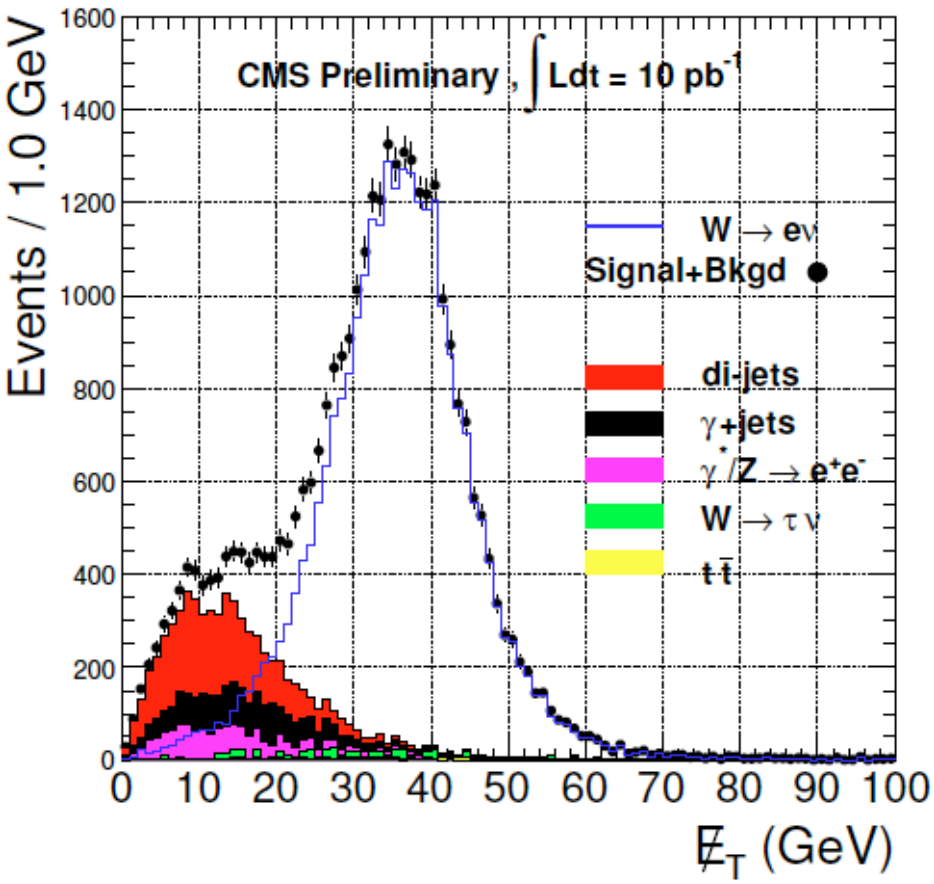
Mass(ee) = 91.2 GeV/c^2

Now we have >10 nb-1 so things are moving...

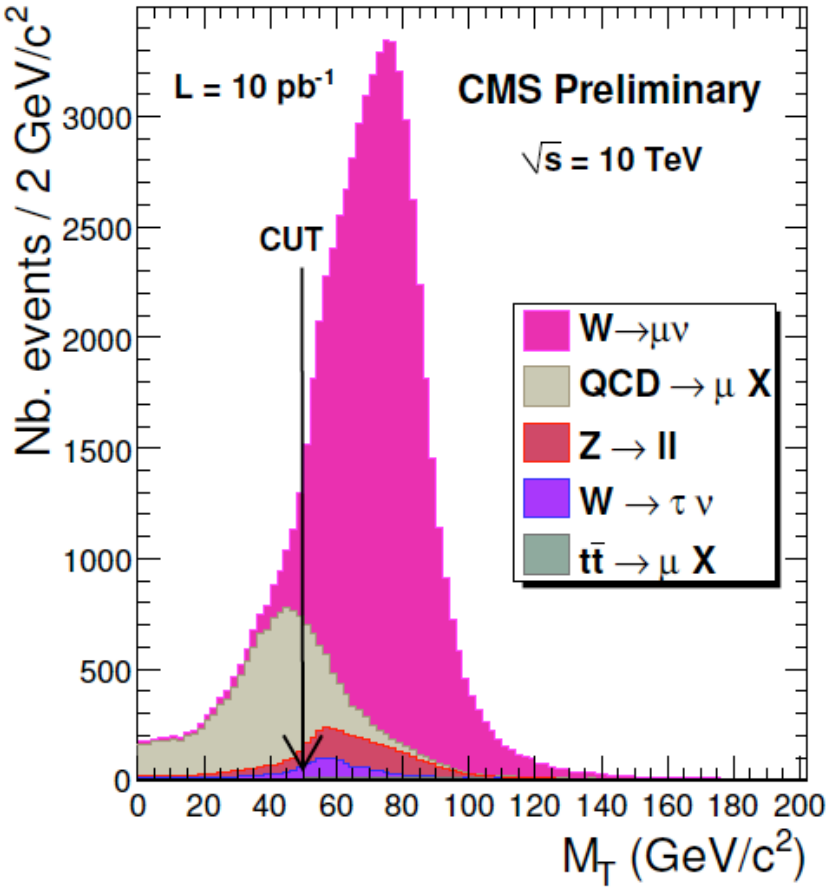
Early Physics: $W \to \ell\nu$

Pseudo-data

electrons



muons



Expect very clean $W \to \ell\nu$ distributions

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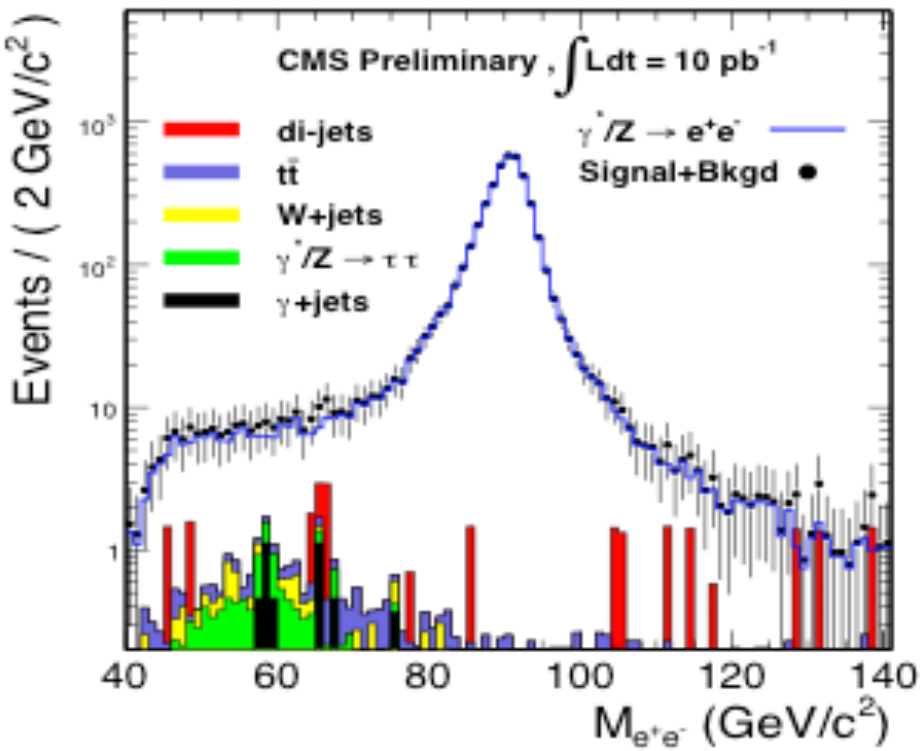
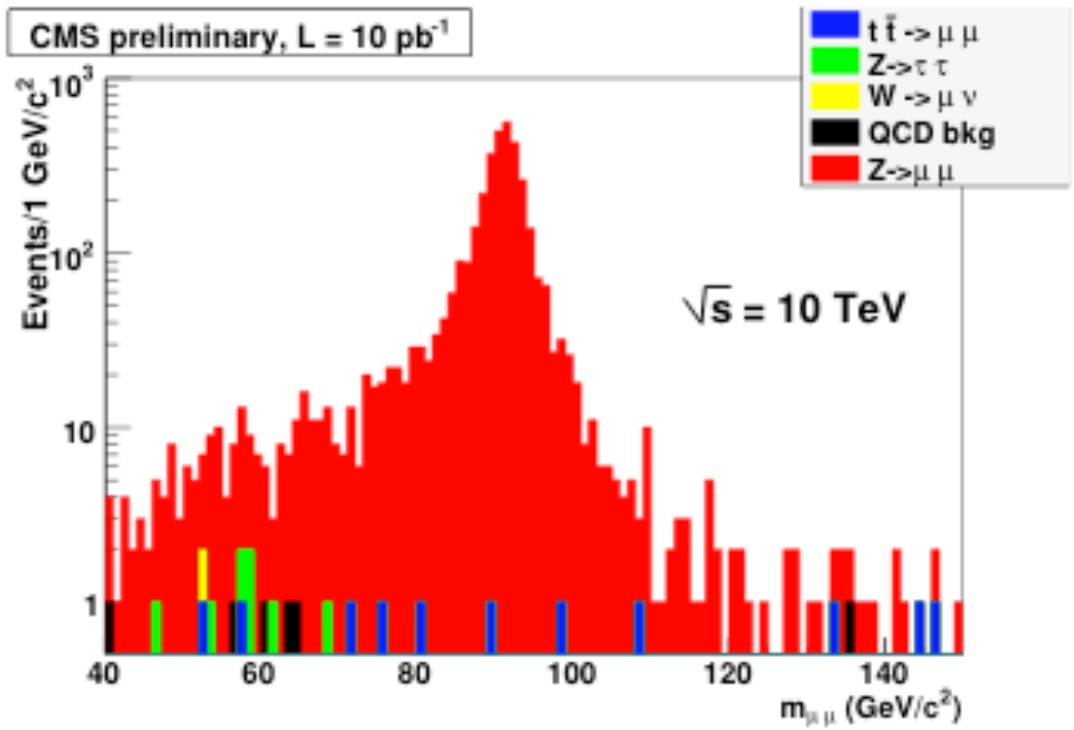
Early Physics: $Z \rightarrow \ell\ell$

Pseudo-data

electrons



muons



$Z \rightarrow \ell\ell$ is our most important early calibration.
Significant samples expected very soon!

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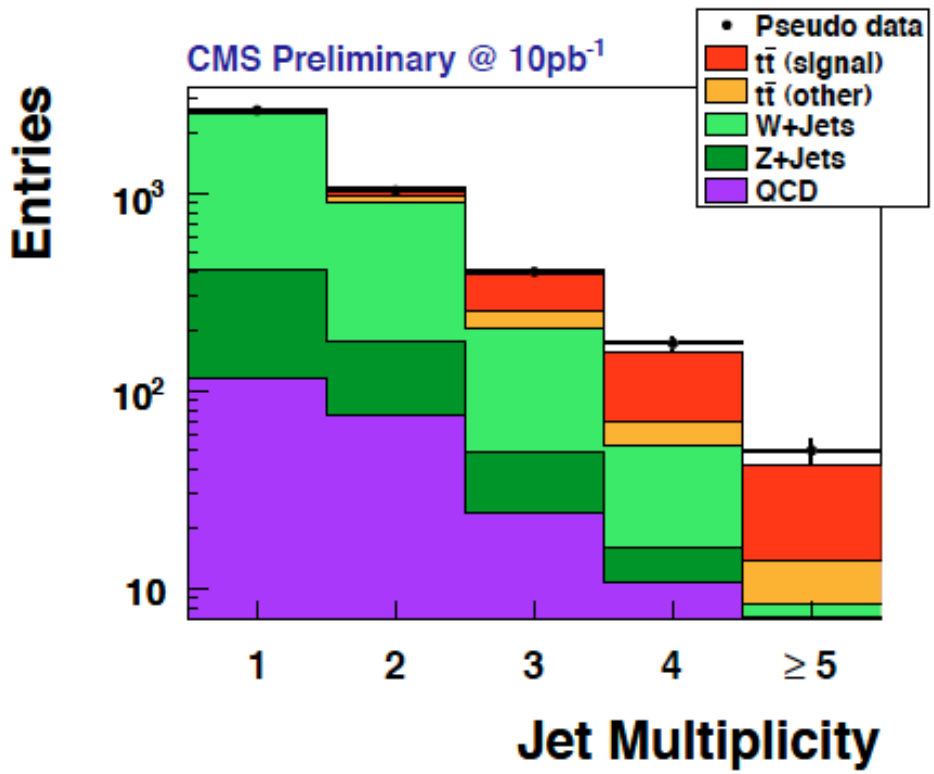
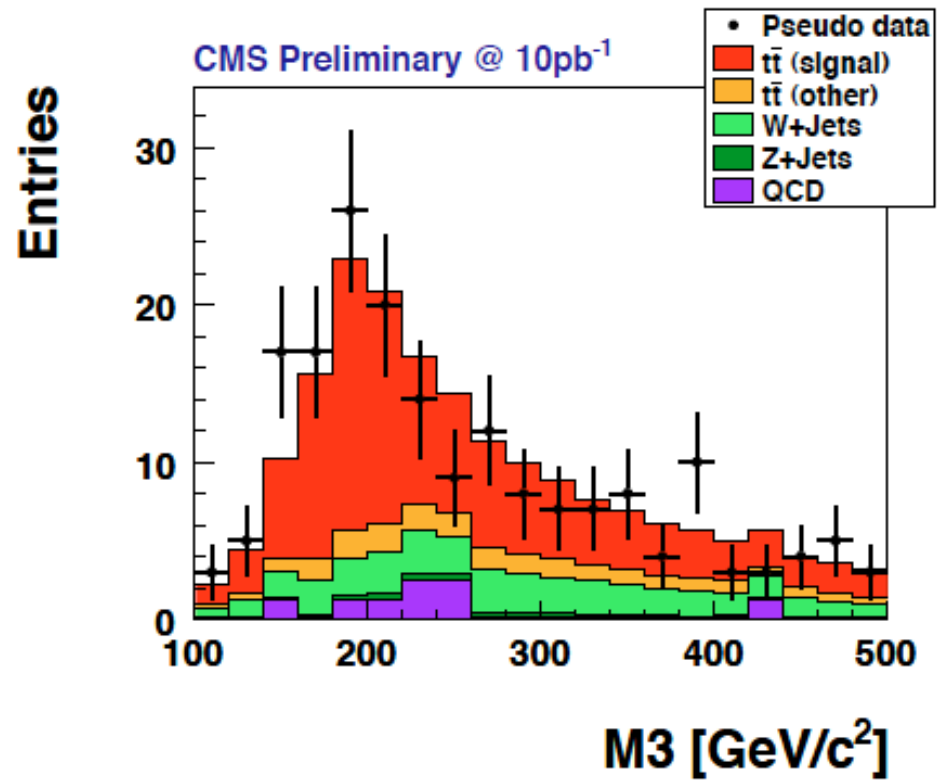
Early Physics: Top quarks

Pseudo-data





With ~20 pb^{-1} at 7 TeV expect to find hundreds of ttbar events. Can use to help calibrate jet energy scale, b-tagging, MET, and later test boosted top algorithms.

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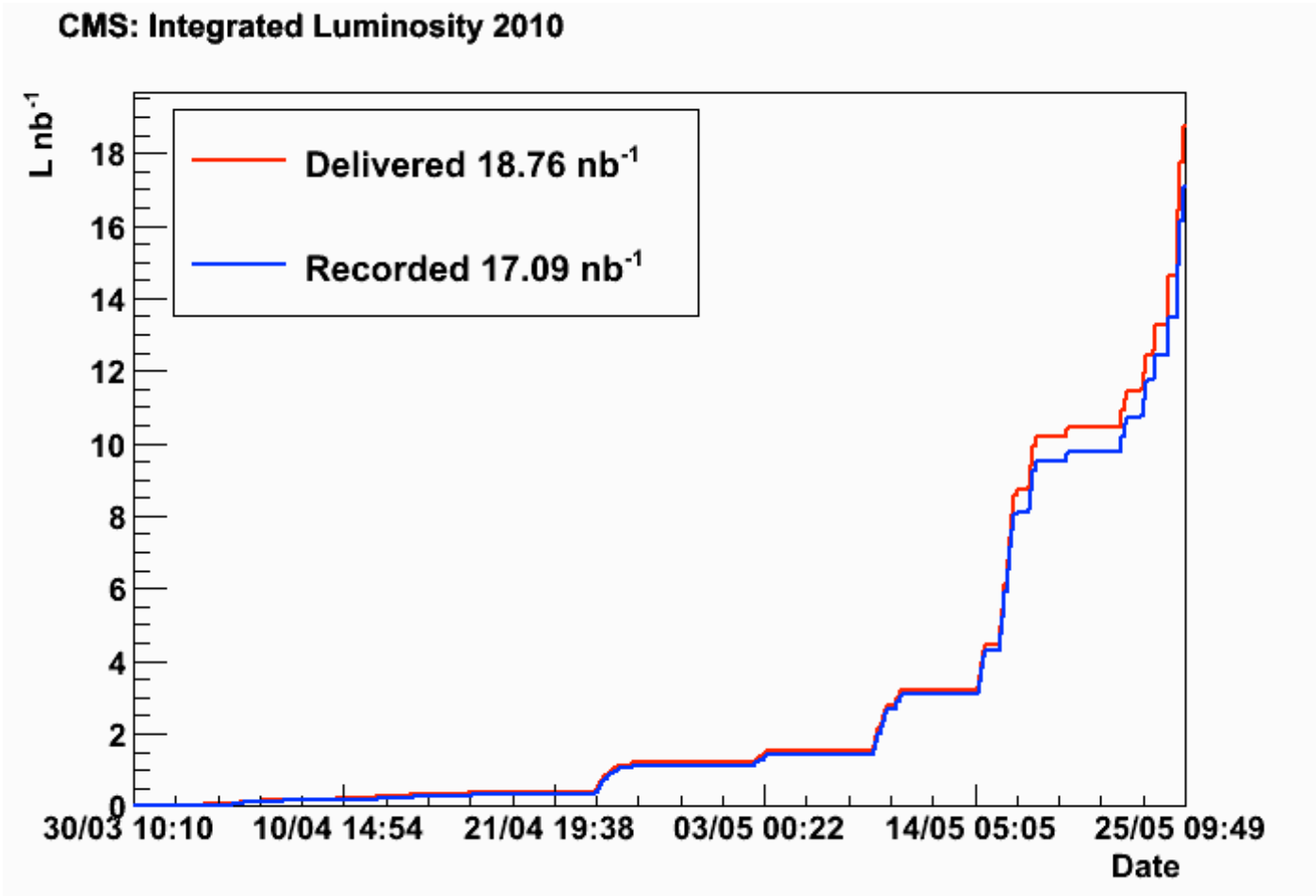
Integrated luminosity last week



Last night's store almost doubled our delivered dataset... Data are starting to come at a faster pace!

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Progression of 7 TeV Run

Summer 2010	End of 2010	Fall 2011
~ 1 pb^{-1}	~ 100 pb^{-1}	~ 1000 pb^{-1} = 1 fb^{-1}

- QCD, b measurements
- W, Z cross sections
- Electroweak program
- Early ttbar observation
- Early searches, mainly Exotica

- + top physics program
- + broad search program: Mainly Exotica, SUSY

- + Higgs program

Early SM studies are critical for laying the foundation for searches.

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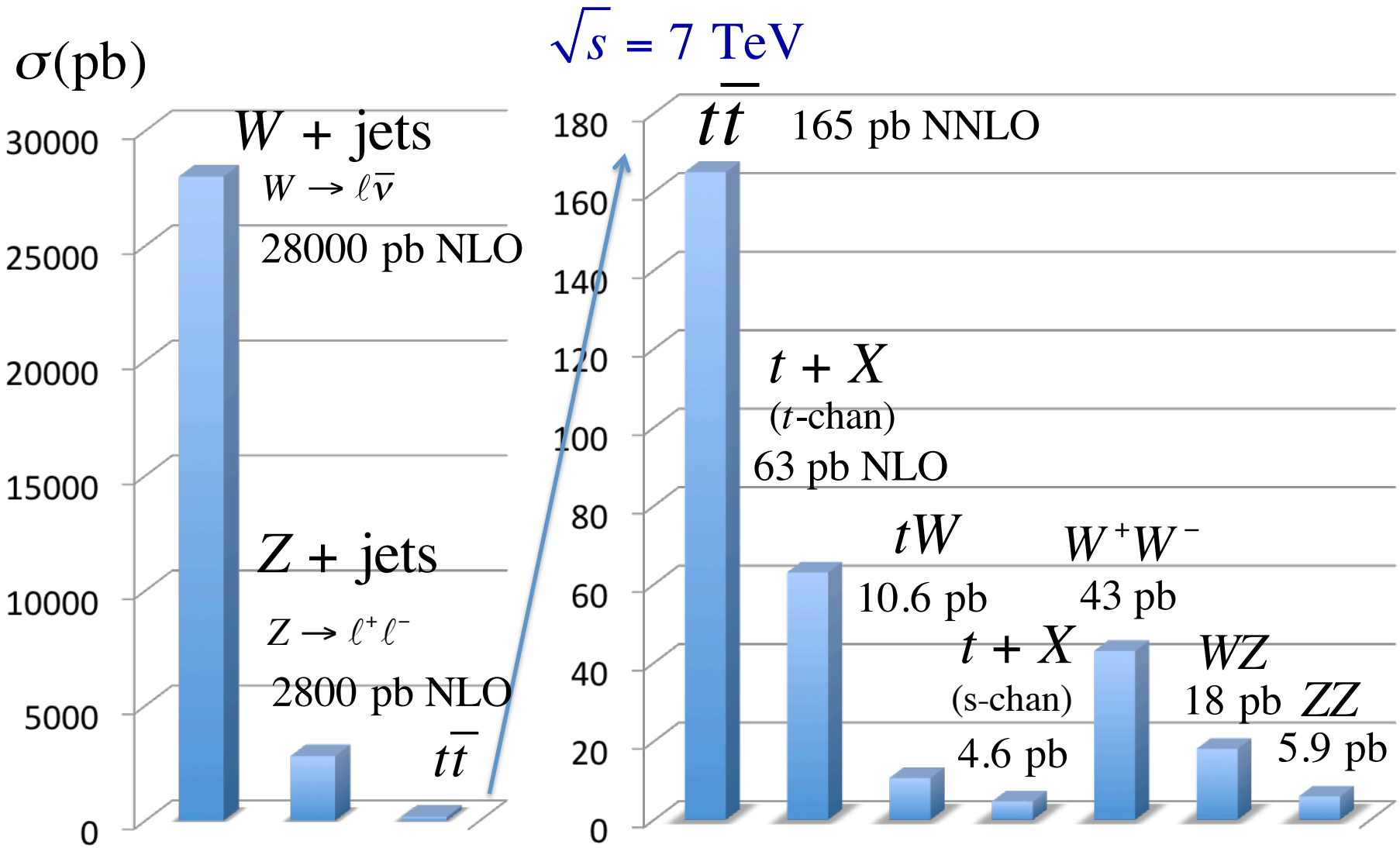
Cross Sections for SM Processes



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Recent 7 TeV BSM projections

Available on CMS information server

CMS NOTE 2010/008

The Compact Muon Solenoid Experiment

CMS Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

5th May 2010

The CMS physics reach for searches at 7 TeV

The CMS Collaboration

Abstract

Some examples of the expected reach of CMS in terms of searches for new physics, for a proton-proton centre-of-mass energy of 7 TeV, are shown. Integrated luminosities between 100 pb^{-1} and 1 fb^{-1} are considered. The prospects are preliminary, and based on existing studies at higher energies.

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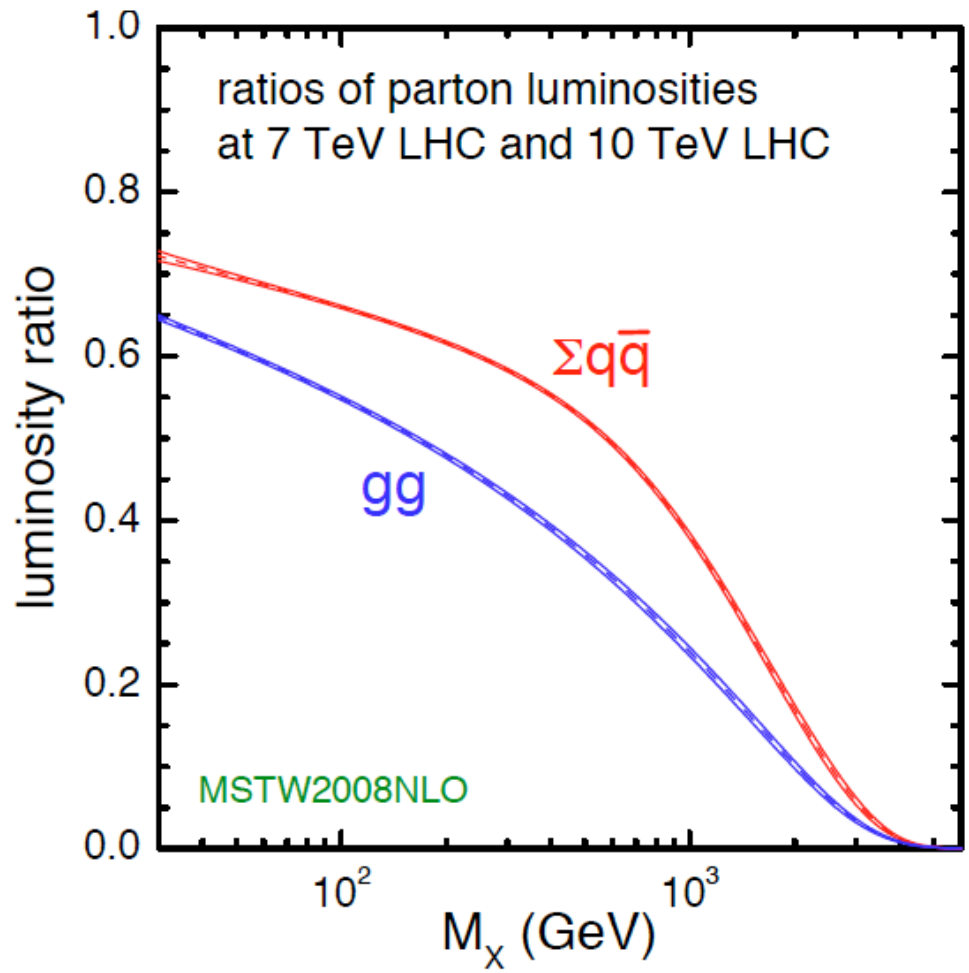
Rescaling 10 TeV to 7 TeV

Take 10 TeV results for new particle searches and simply scale by expected qq, gg luminosity ratio.

(Ratio courtesy of James Stirling)



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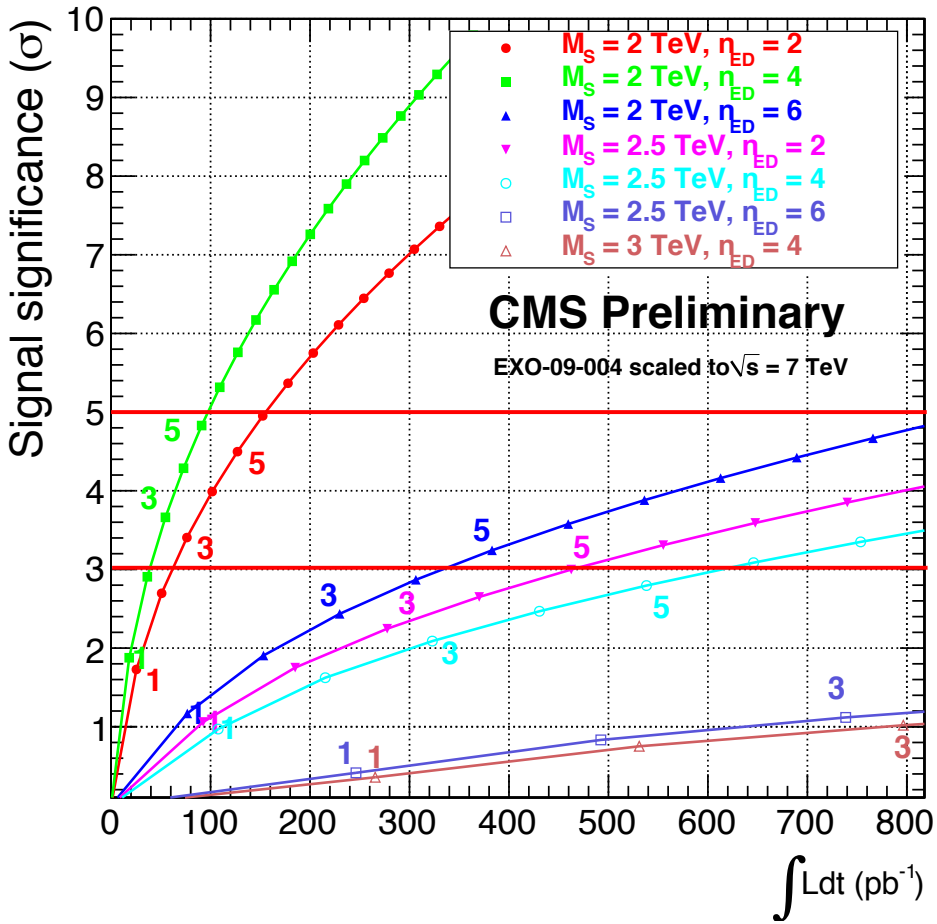
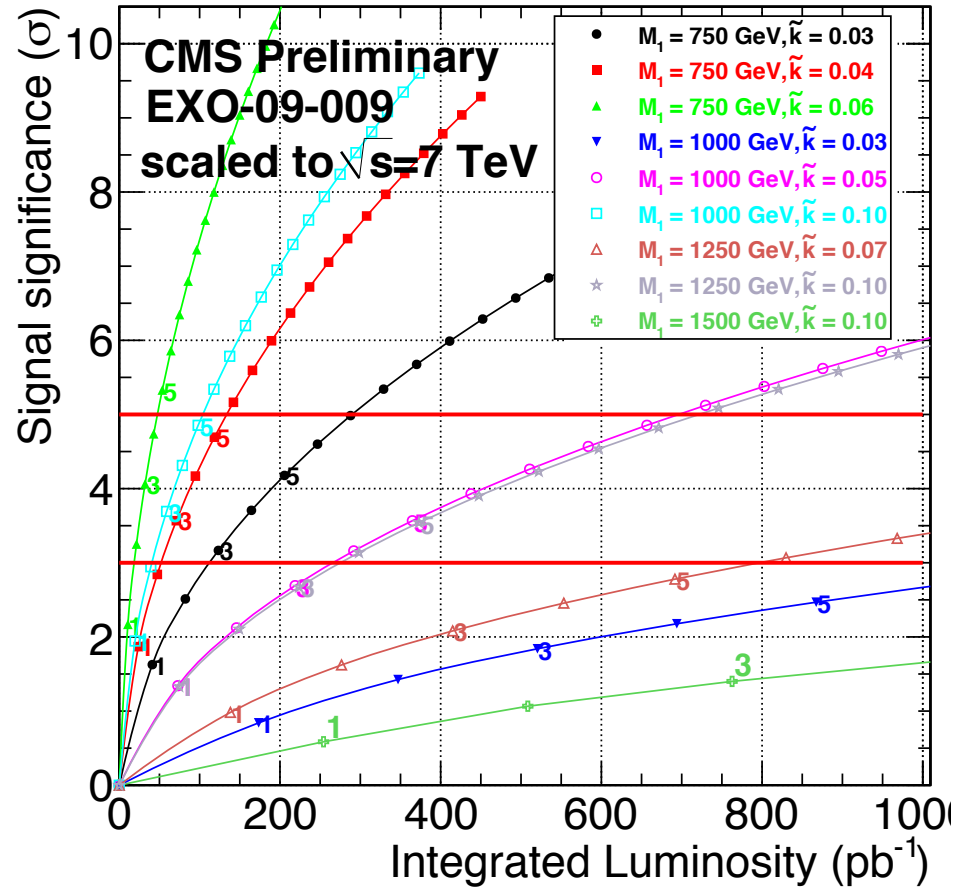
Early searches: ED in diphotons





Searches for *very* high mass γγ pairs in large extra dimensions (ED) and Randall-Sundrum models

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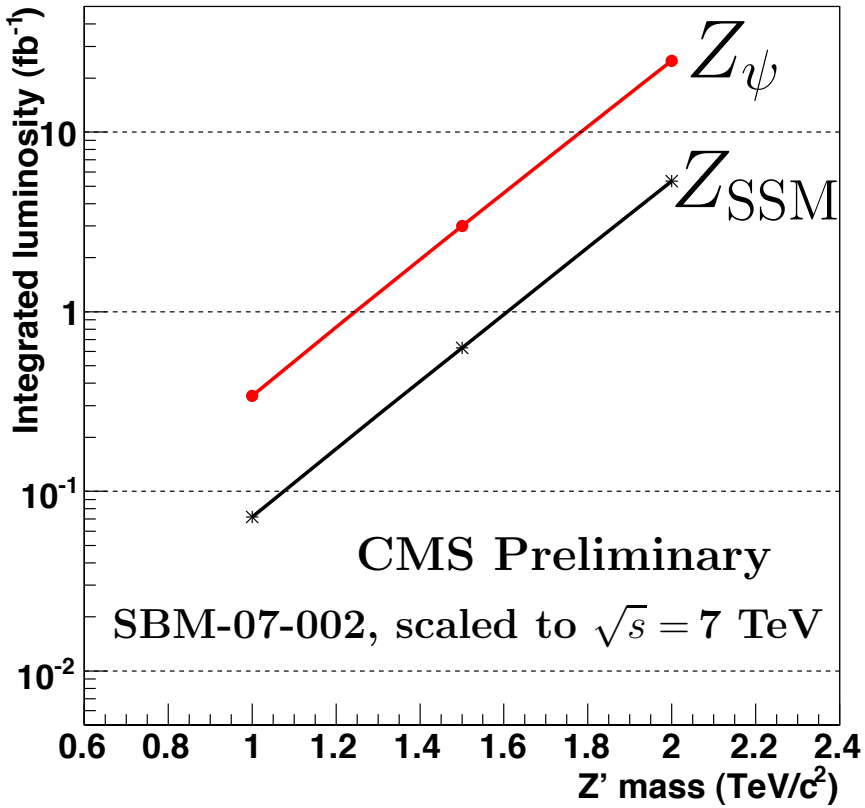
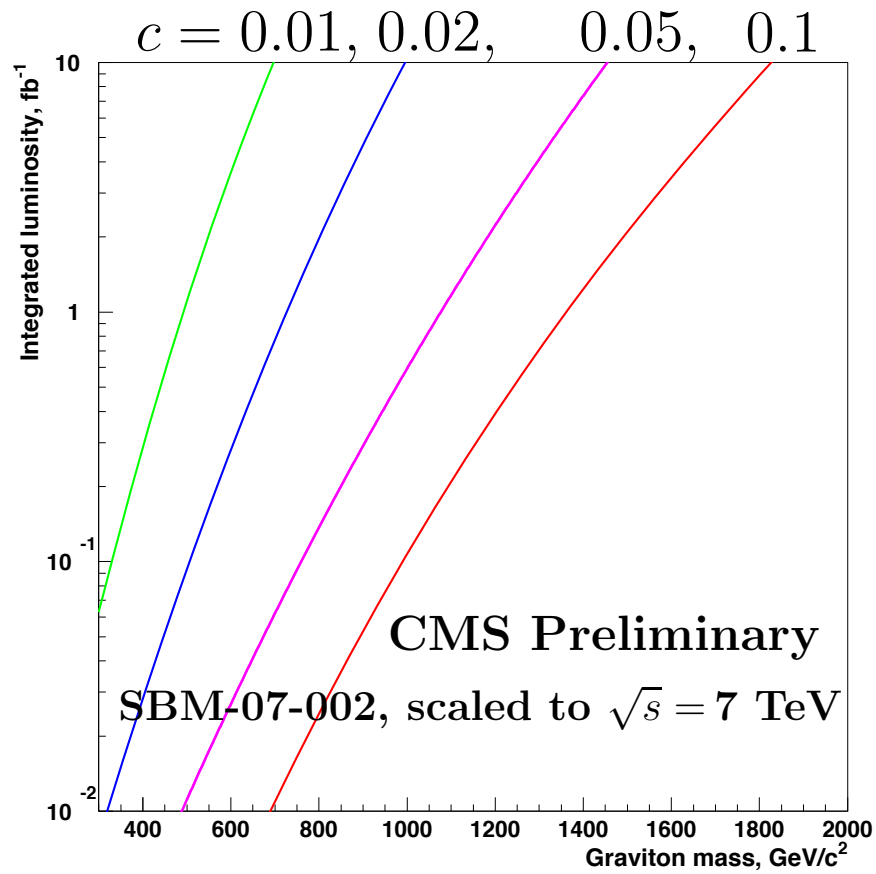
Early searches: Z′, ED→μμ





Will beat Tevatron limits with 1 fb^{-1}.

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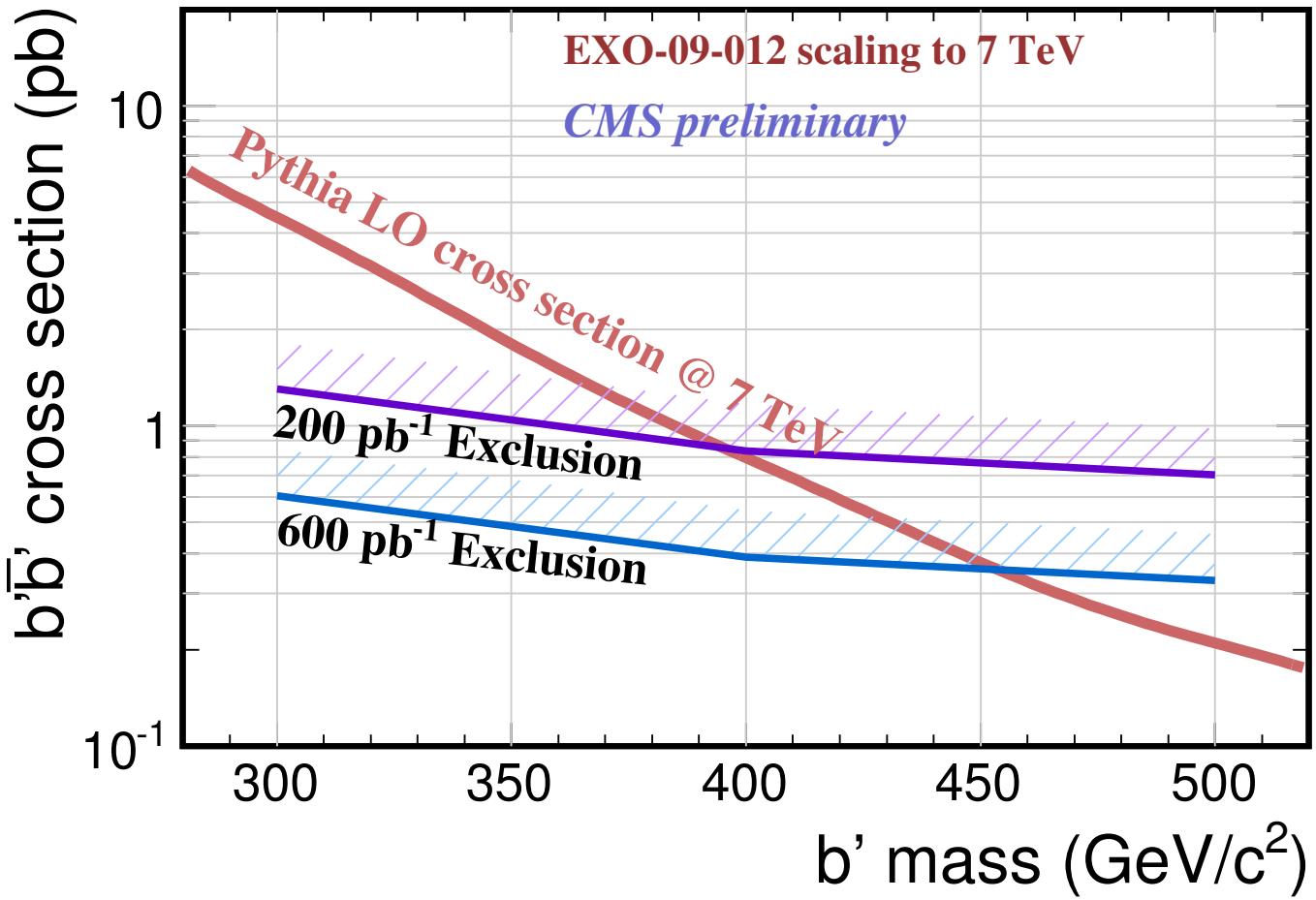
Early searches: b′



With ~200 pb^{-1} we expect to exceed Tevatron sensitivity

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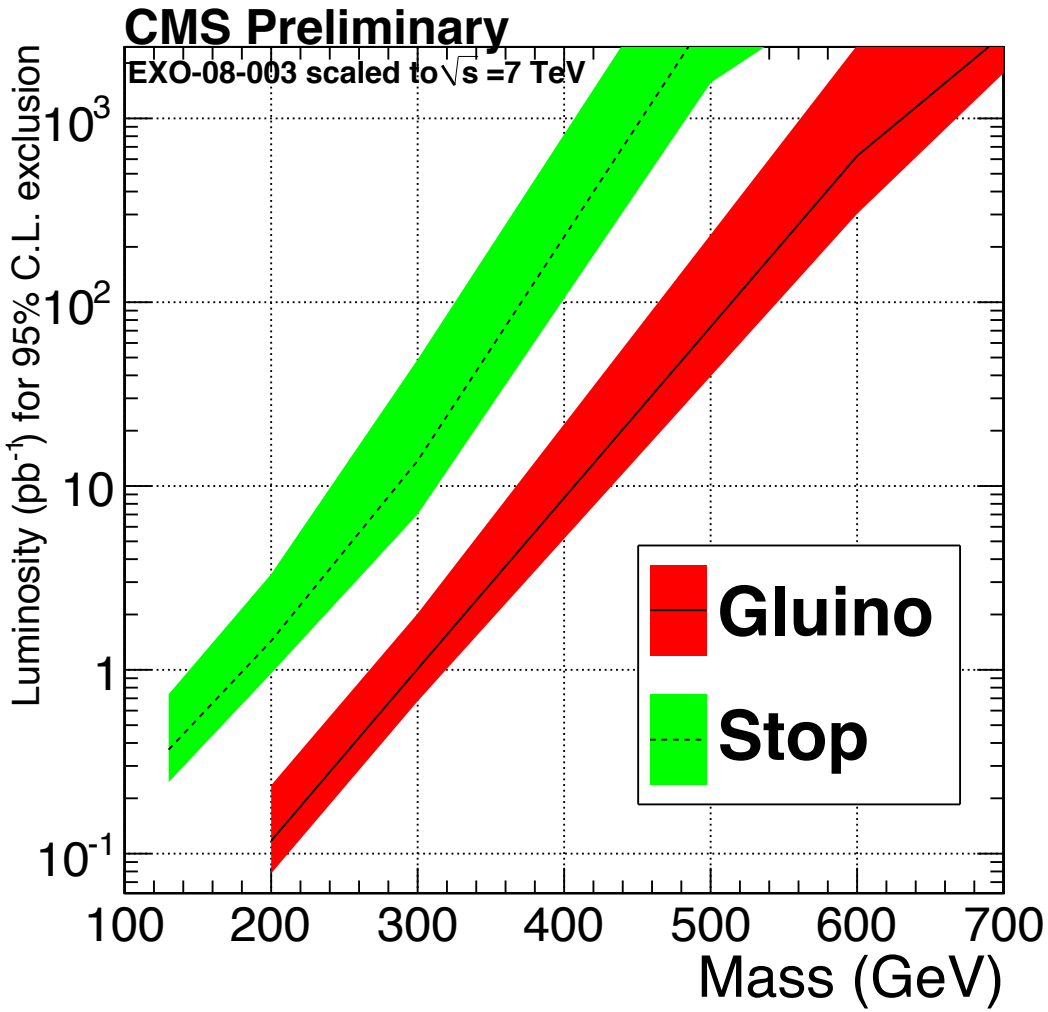
Early searches: HSCP



Heavy stable charged particles (formerly CHAMPS)

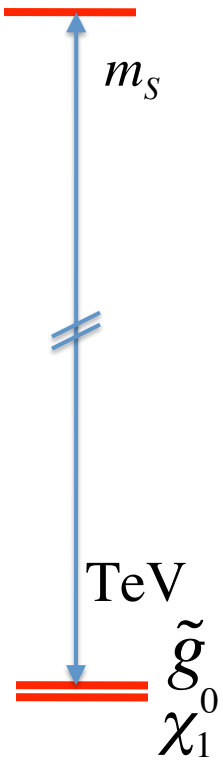
45

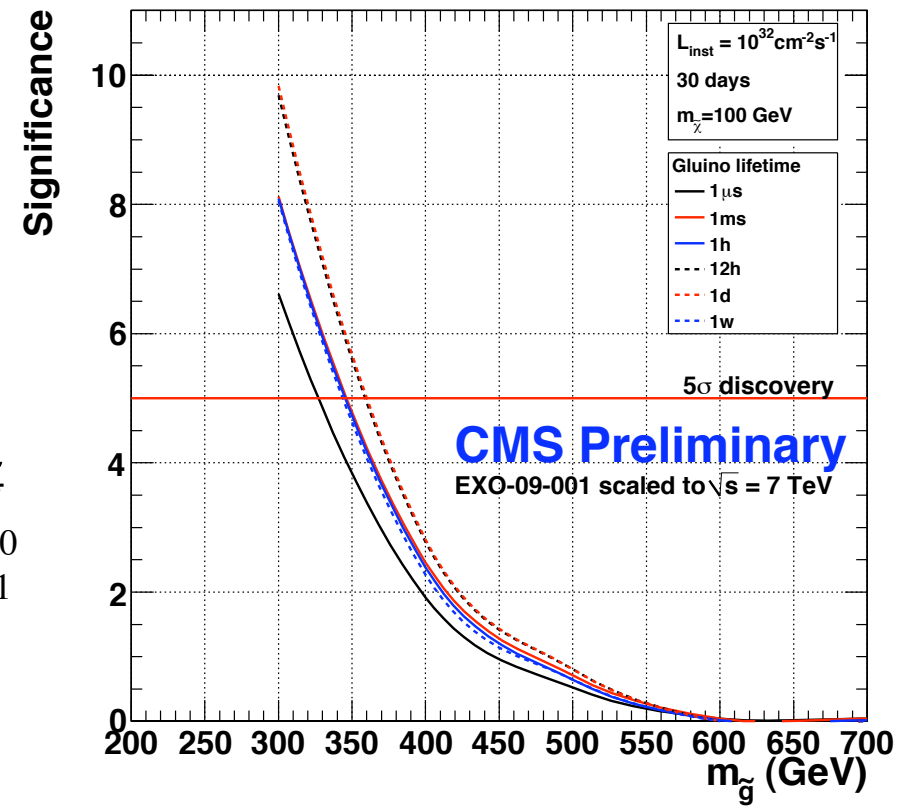
Early searches: stopped gluinos

- Split SUSY: Large ΔM b/w scalars & gluino

$$\tilde{g} \rightarrow \tilde{q}^* \bar{q}; \;\; \tilde{q}^* \rightarrow q\chi_1^0$$

- Look for delayed gluino decays during periods of no beam including
  - inter-bunch gaps
  - no-beam periods
- Result from 30 days running at 10^{32} $cm^{-2}s^{-1}$





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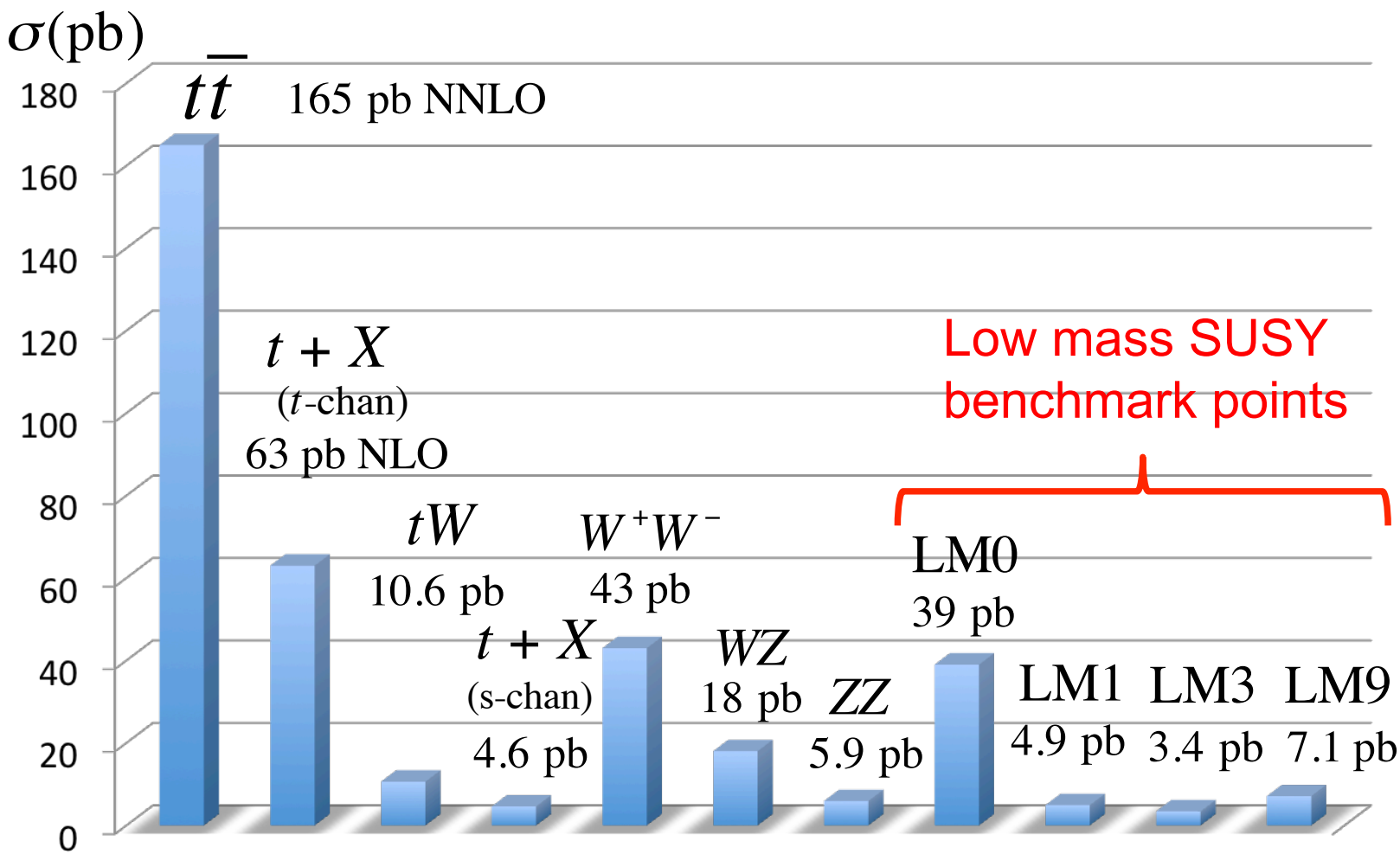
Benchmark SUSY v. SM cross sections



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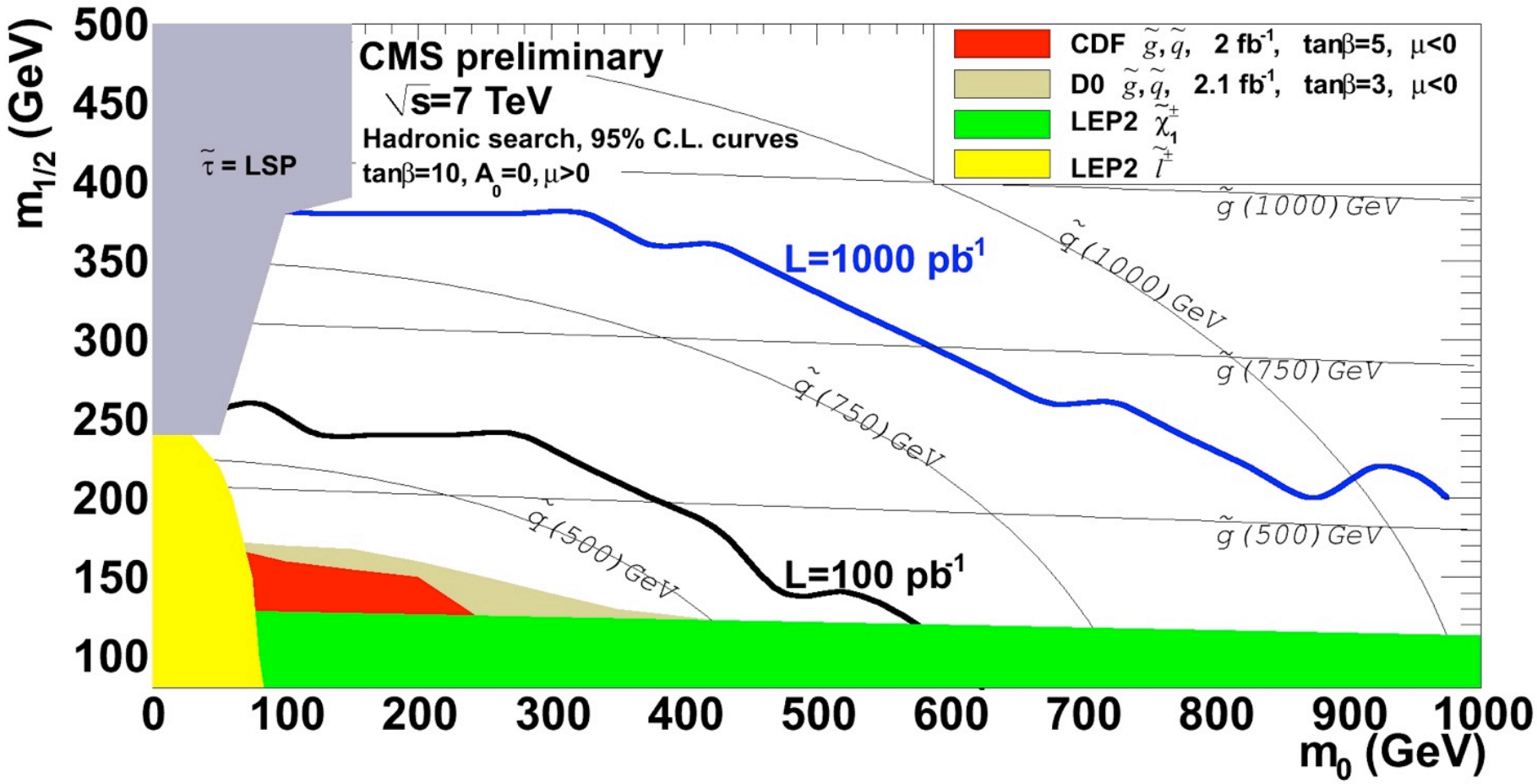
SUSY: Jets + missing E_T

"Classic" all-jets search:

- 3 or more jets, E_T > 50 GeV
- missing E_T > 250 GeV
- no leptons



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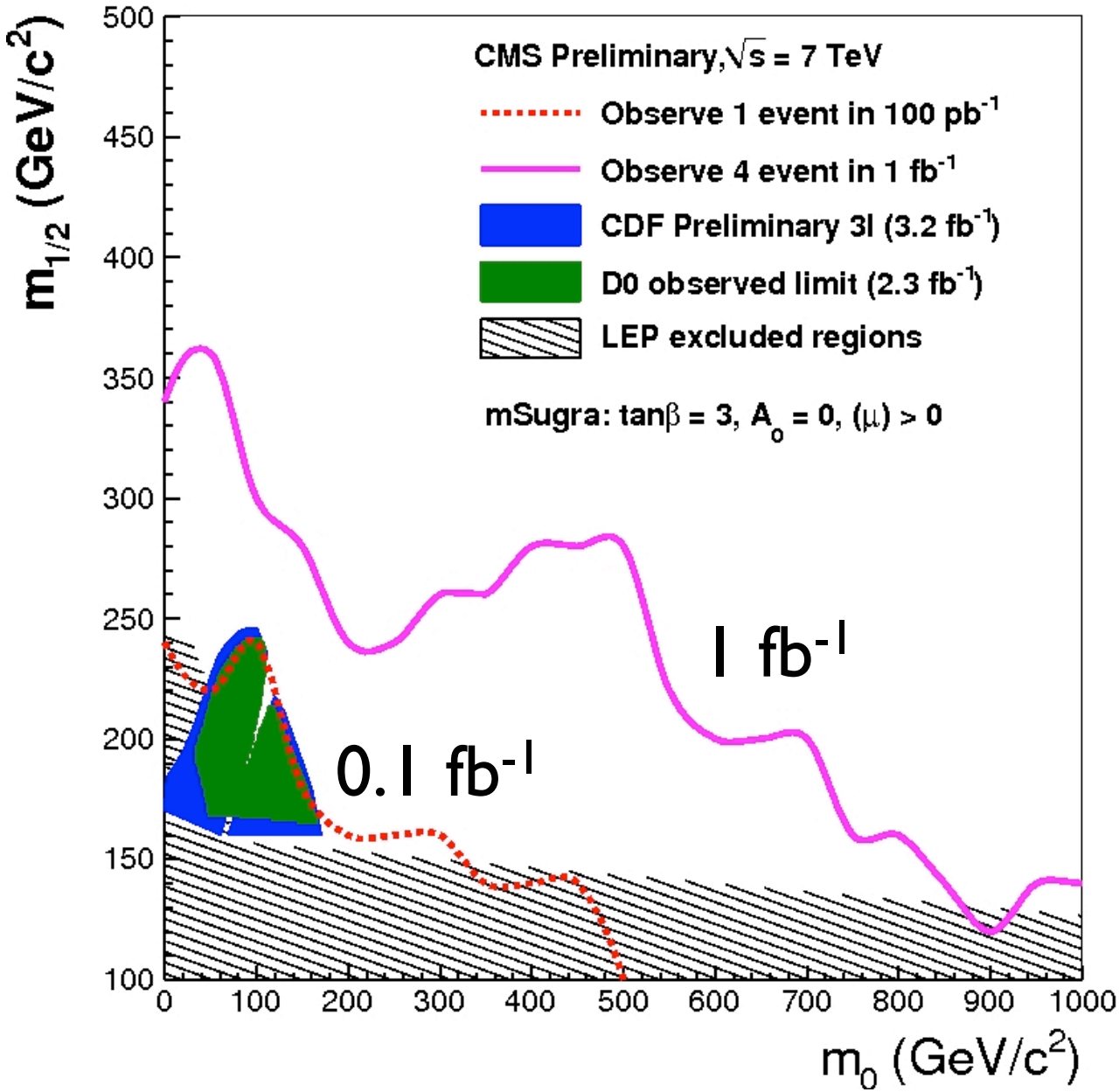
SUSY: like-sign dileptons



Very soon the LHC will surpass the Tevatron in the search for SUSY

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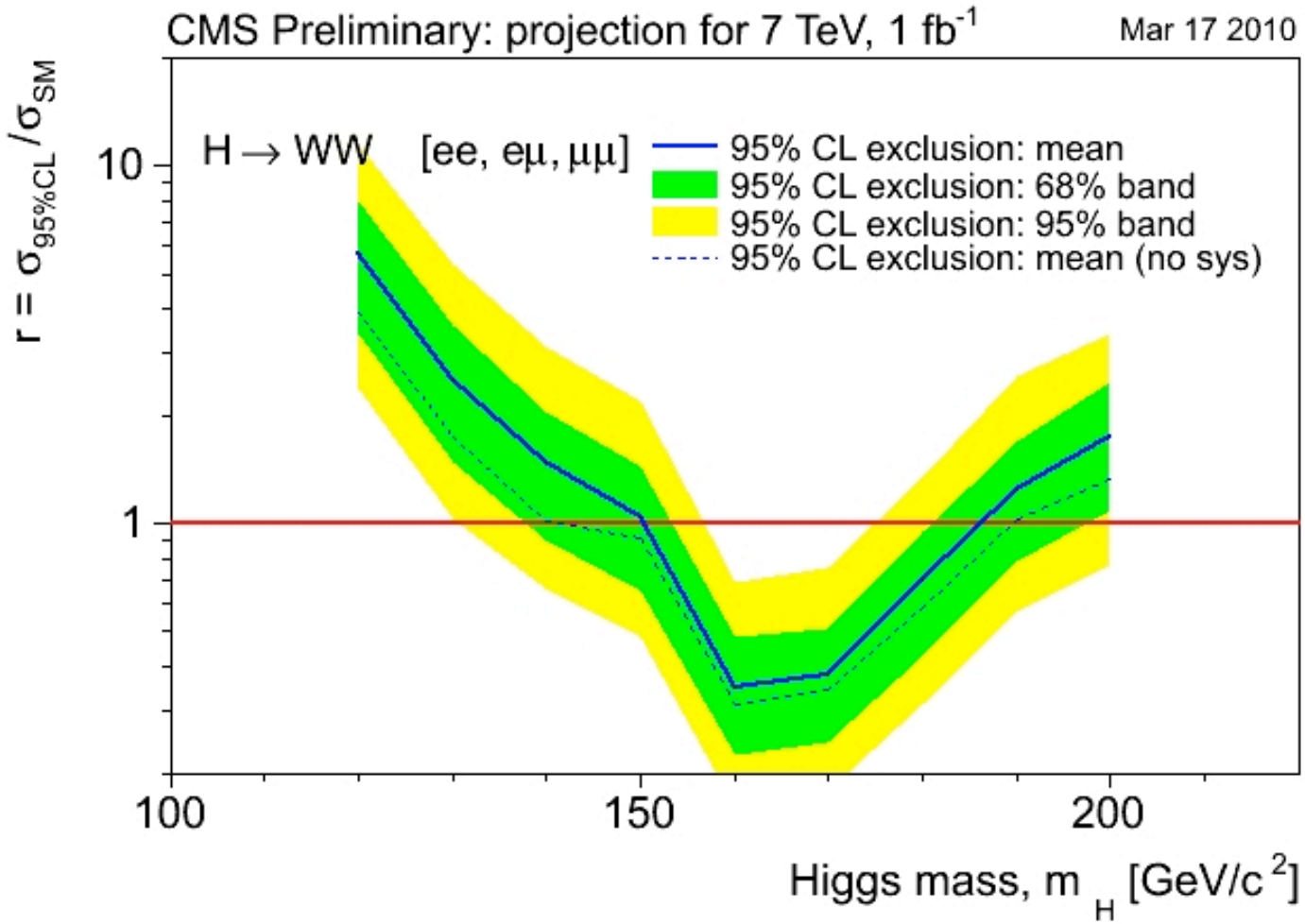
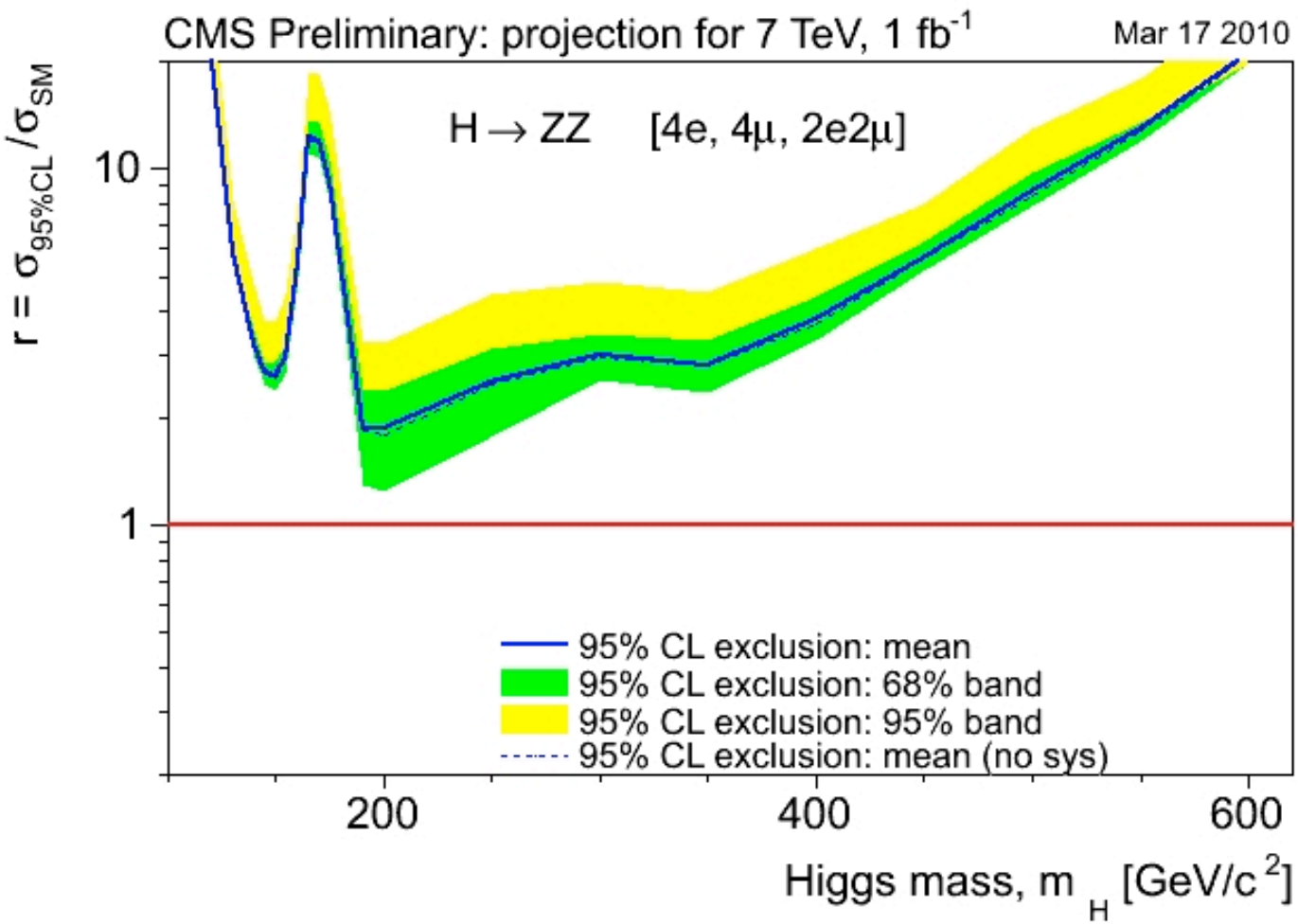
Standard Model Higgs: WW→2ℓ2ν



High mass has greater sensitivity. Yet no discovery of SM Higgs in 7 TeV run. With 1 fb^{-1}, similar to Tevatron.

50

Standard Model Higgs: ZZ→4ℓ



H→ZZ has sensitivity going to much higher masses.

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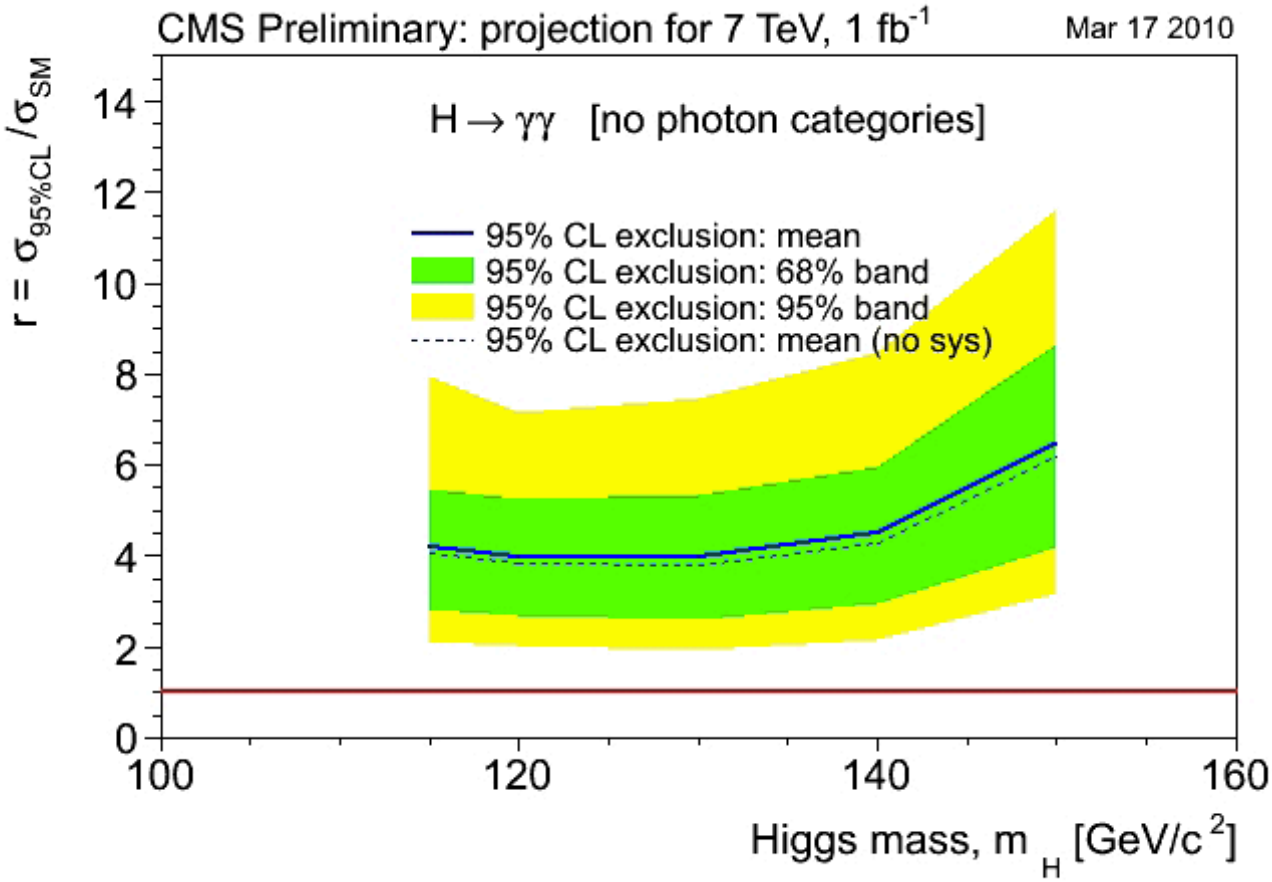
Standard Model Higgs: H→γγ



No exclusion of low mass SM Higgs anticipated in with 1 fb^{-1} at 7 TeV.

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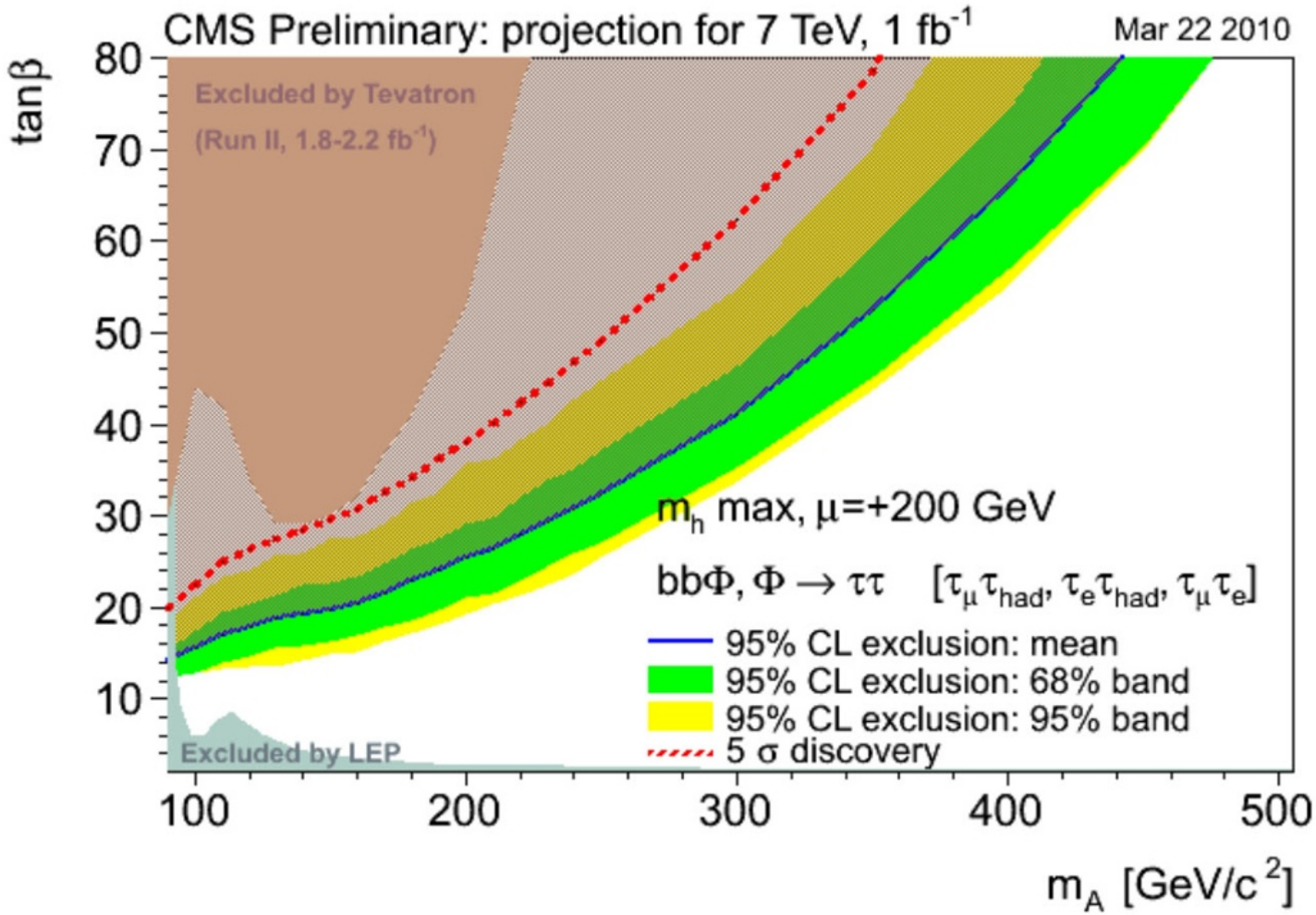
MSSM Higgs



Di-tau sensitivity for H/A will soon exceed Tevatron.

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Expected Luminosity in Coming Years

Year	Months	energy	beta	ib	nb	Peak Lumi	Lumi per month	Int Lumi Year	Int Lumi Cul
2010	6	3.5	2.5	7 e10	720	1.0 e32	-	0.1	0.1
2011	9	3.5	2.5	9 e10	720	2.0 e32	0.1	1	1.1
2012	18-month stop for splice solution and retraining (partial), re-arrange DS for cryo collim								
2013	6	6.5	1	9 e10	720	9 e32	0.45	2.7	3.8
2014	9	6.5	1	9 e10	1404	1.7 e33	0.6	5.3	9.1

--- 8-month stop for collimators phase 2 (remove RPs) + train to 7 TeV

2015 (Aug-Nov): 7.0 TeV 8.0 / fb up to 2808 bch * 9e10 @ 1.0 m (up to 3.6e33)

2016 (Feb-Oct) : 7.0 TeV 29.0 / fb up to 2808 bch * 9e10 @ 0.55 m (up to 6.2e33)

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CMS Physics Public Results...

- Underlying Event in proton-proton collisions at $\sqrt{s}$ = 900 GeV (published)
- Measurement of Bose-Einstein Correlations with first CMS data (submitted to journal)
- Two-particle correlations and cluster properties from two-particle angular correlations
- Transverse-momentum and pseudorapidity distributions of charged hadrons (submitted)
- Muon charge asymmetry in cosmic data

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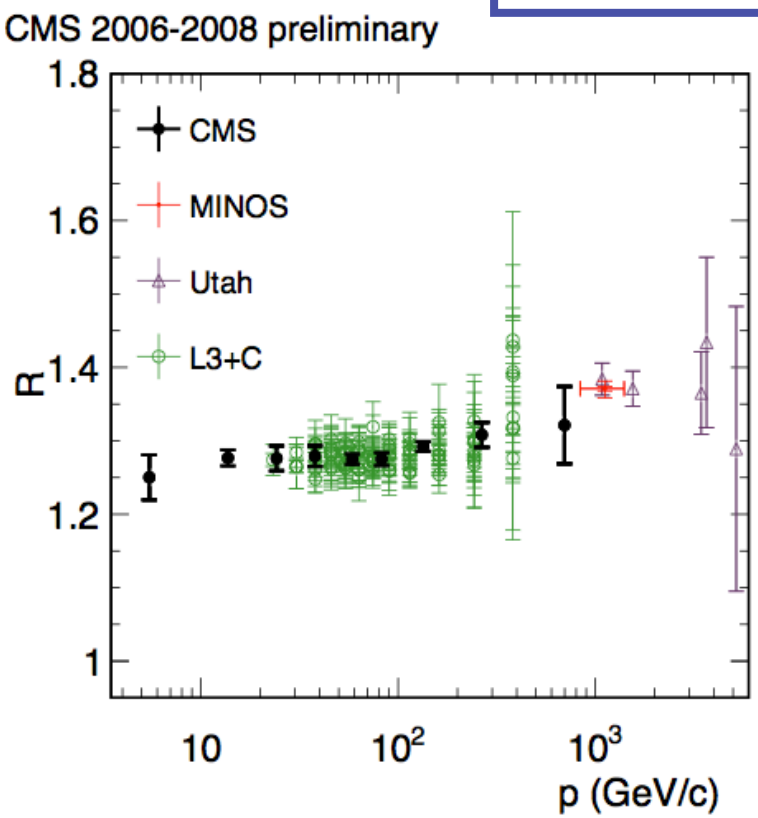
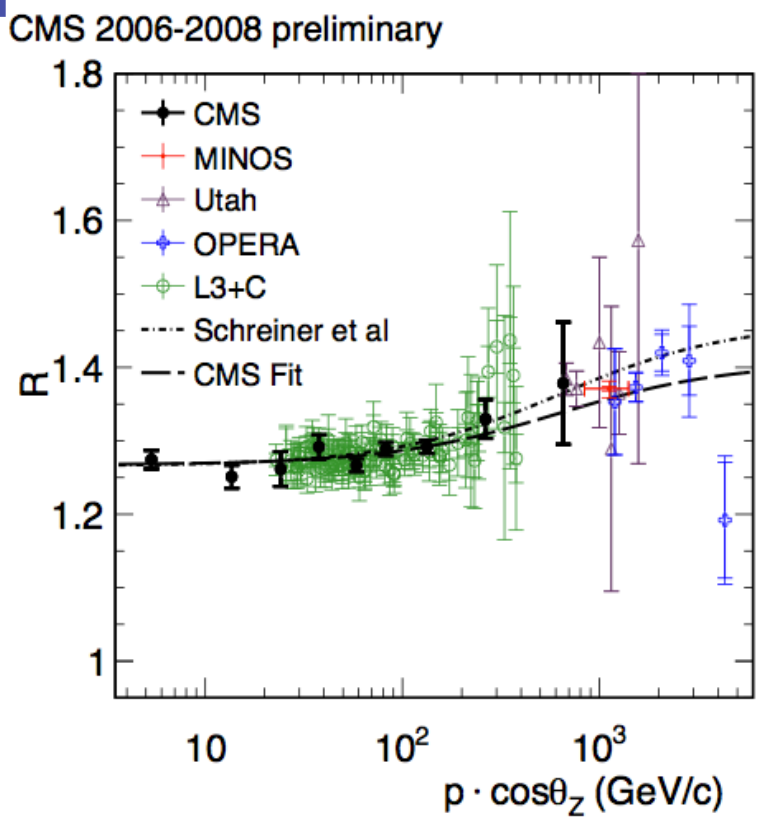
New: Muon Charge Asymmetry

- Cosmic data from '06, '08, '09: first measurement of a physical quantity from CMS.
- Results agree with other expts; provided useful alignment and calibration experience.

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





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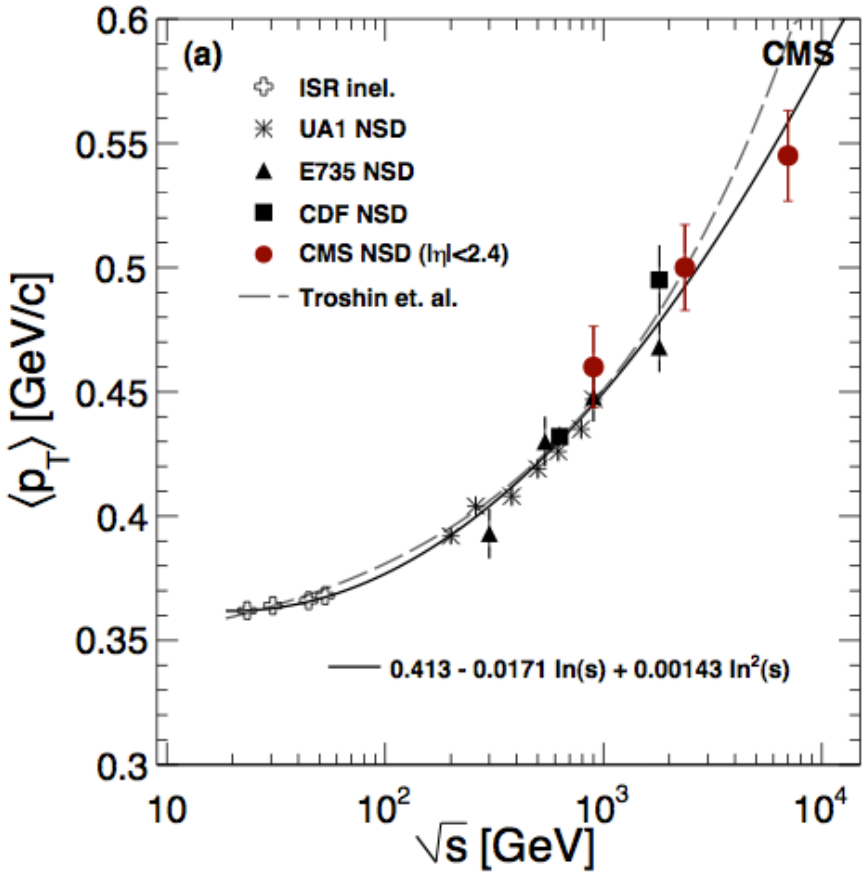
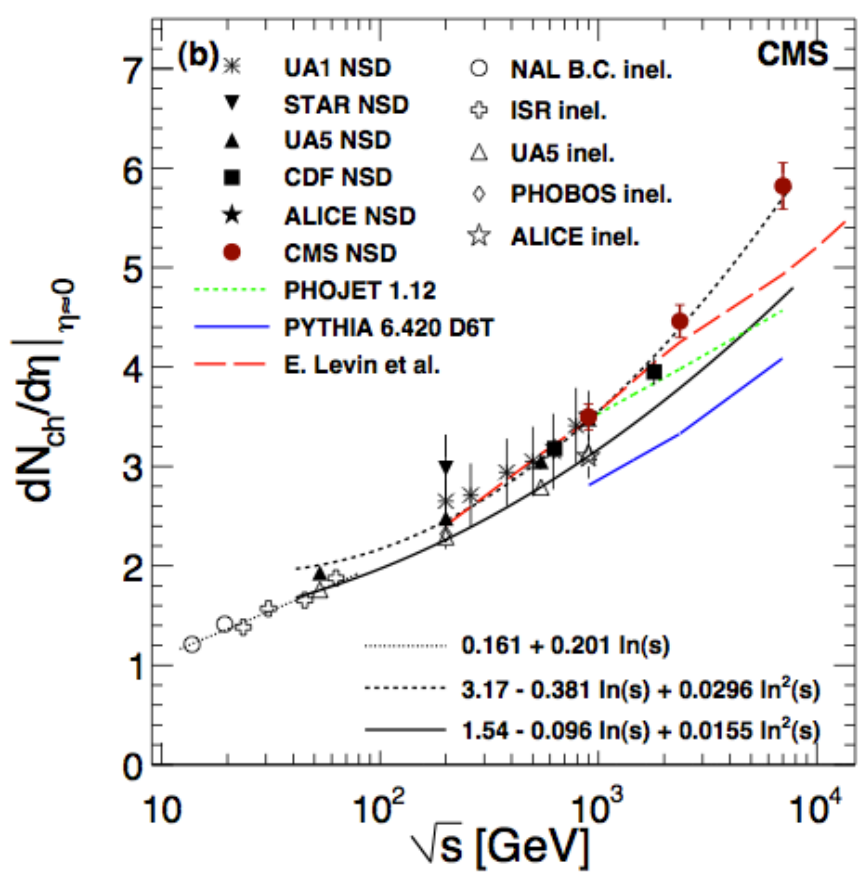
New: Charged Hadrons

- p_T and η distns of charged hadrons at 7 TeV: Important in understanding isolation in events.
- Rise of particle density stronger than current models.





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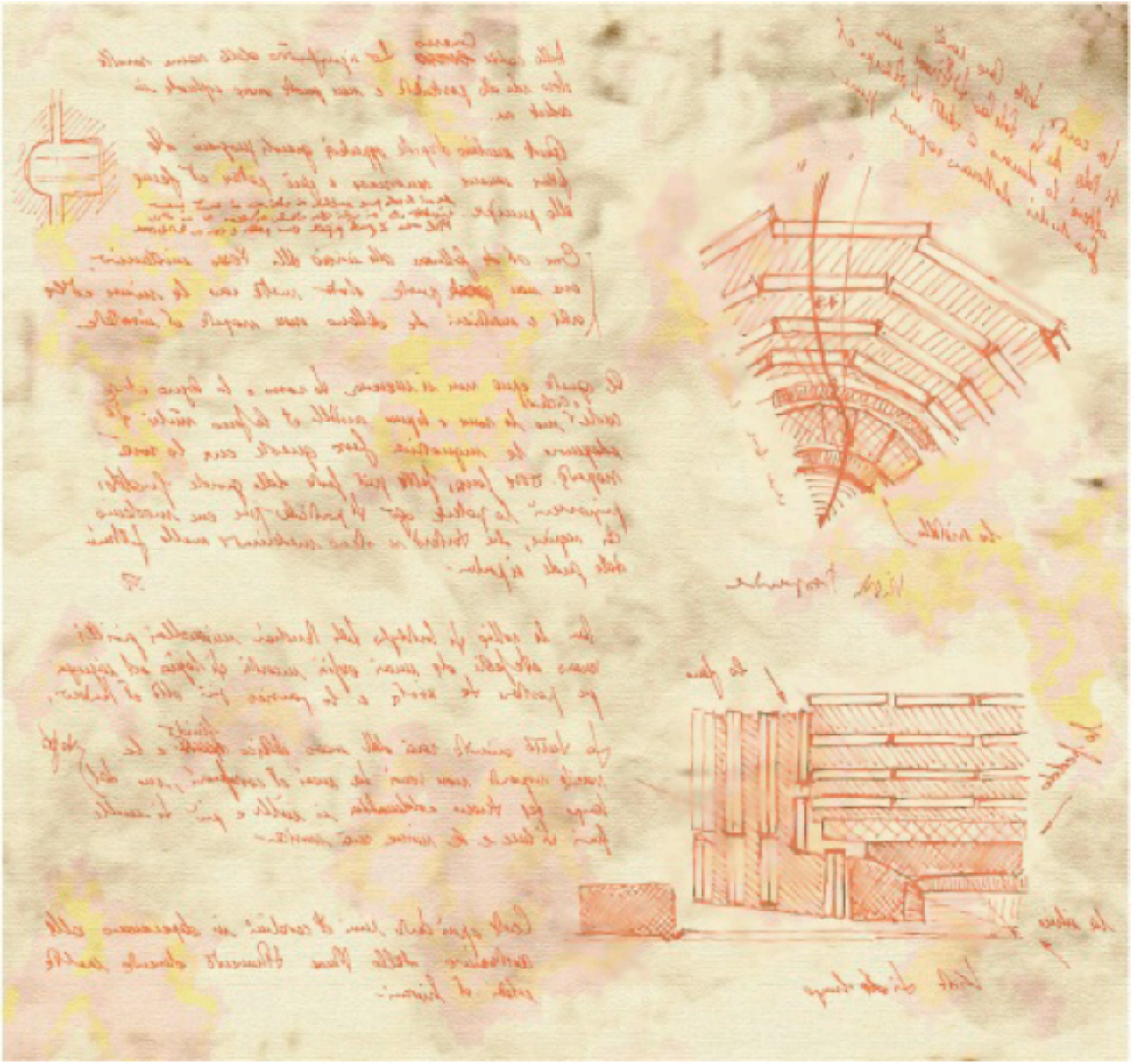
No longer just a sketch...



CMS technical proposal in style of Leonardo da Vinci

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Look for the Revolution to come!

John the Baptist

-da Vinci

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