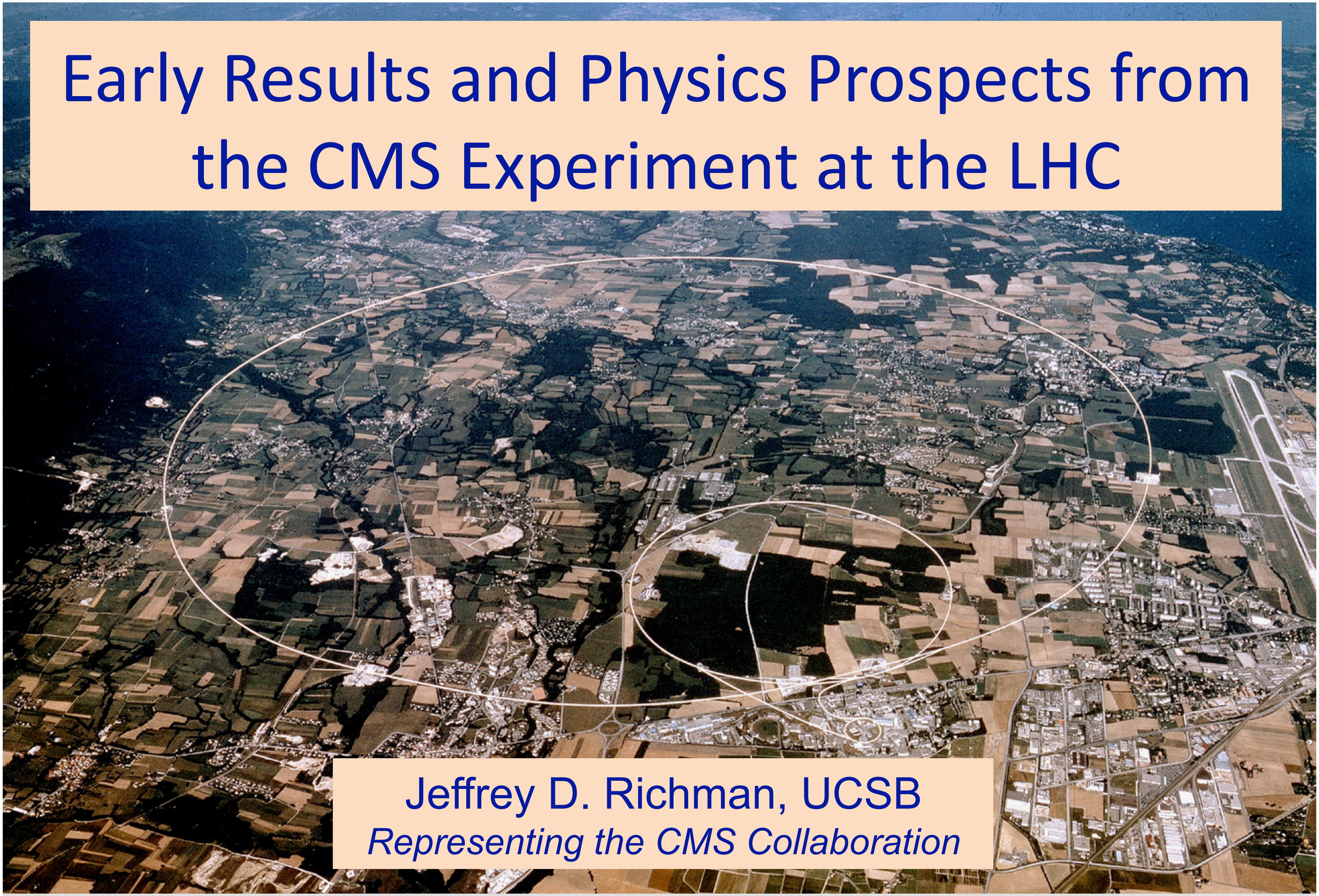
Early Results and Physics Prospects from the CMS Experiment at the LHC



Jeffrey D. Richman, UCSB
Representing the CMS Collaboration

Kavli Insititute for Theoretical Physics
UC Santa Barbara, 7 May 2010

Outline

- Introduction: a little history and LHC status
- Physics overview: cross sections & signatures
- CMS detector performance and early results
- Prospects for Standard Model measurements and New Physics searches in 2010-2011
  - Top quark production
  - SUSY
  - Higgs

  What is expected physics reach for run with 1 fb^{-1} at 7 TeV?
- Conclusions

This talk is far from comprehensive…see CMS public results:

https://twiki.cern.ch/twiki/bin/view/CMS/PublicPhysicsResults

The struggle establish a TeV-scale facility

Chris Llewellyn Smith http://www.nature.com/nature/journal/v448/n7151/full/nature06076.html

1977: An LHC-like machine is in the air; SSC is proposed after a series of accelerator workshops and CERN Director proposes an LHC-like machine in the LEP tunnel

1983: Preliminary SSC design work

1985: long-range planning committee, chaired by Carlo Rubbia, recommended an LHC-like machine

1987: SSC approved by President Reagan

1991: CERN council adopts a resolution in favor of LHC

1992: Expressions of interest submitted by LHC collaborations to build detectors

1993: ATLAS and CMS selected.

1993: SSC is cancelled.

1994: Project approved by CERN council (Dec 16).

1997: Turn-on date of 2005 specified.

1998: Construction of LHC started. Alice and LHCb approved.

2000: LEP shut down to provide access to tunnel.

See also: *The Large Hadron Collider: a Marvel of Technology*, ed. by Lyndon Evans, CRC Press, 2009.

Courtesy Sarah Eno

Information Management: A Proposal

Tim Berners-Lee, CERN
March 1989, May 1990

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext system.

Many of the discussions of the future at CERN and the LHC era end with the question - ªYes, but how will we ever keep track of such a large project?º This proposal provides an answer to such questions. Firstly, it discusses the problem of information access at CERN. Then, it introduces the idea of linked information systems, and compares them with less flexible ways of finding information.

a lot has happened since then…

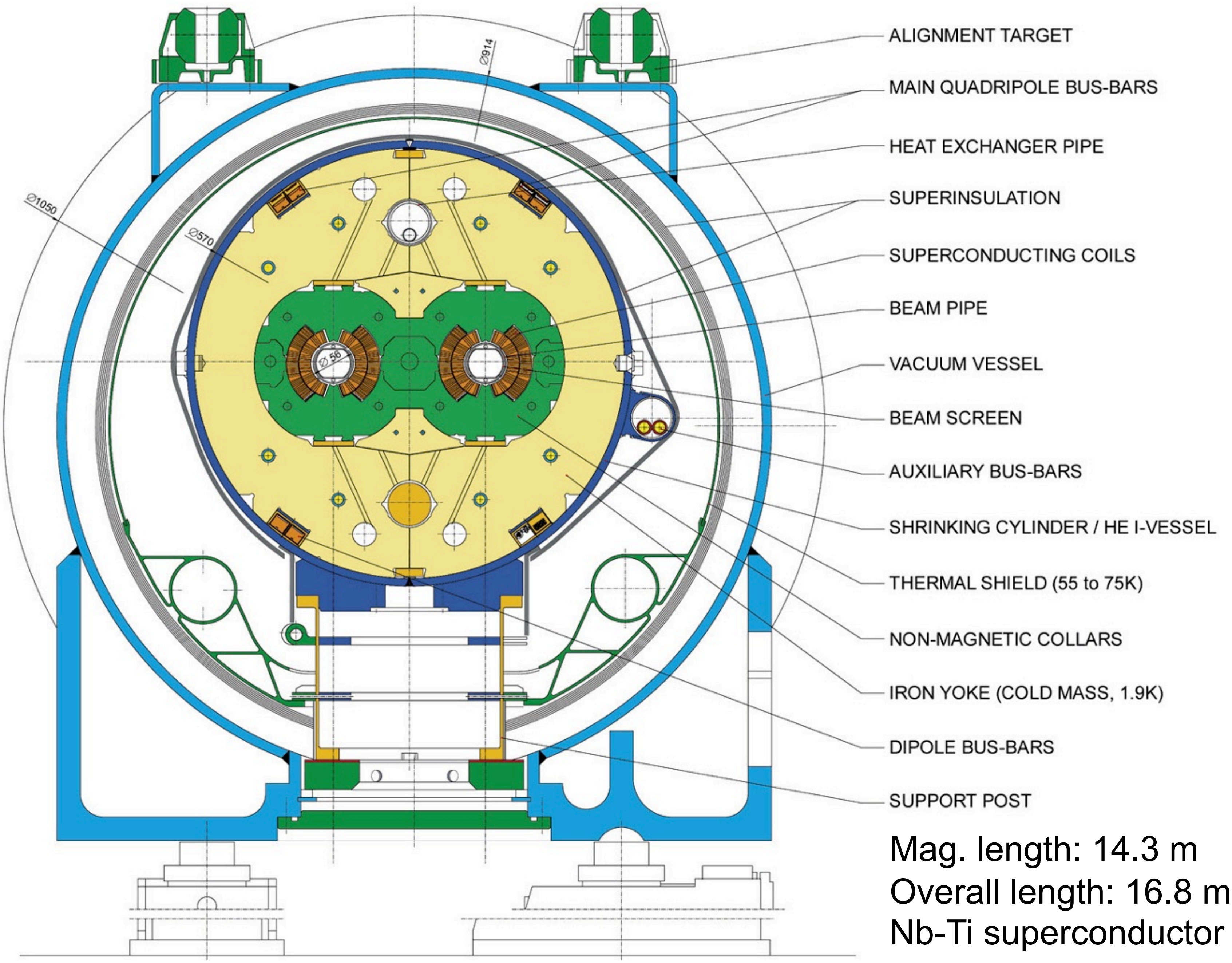
Inside the LHC Tunnel

Total magnets	9300
Num. dipoles	1232
Num. quads	858
RF cavs/beam	8
Bunches/beam	2808
Protons/bunch	1.1 10^{11}
Collisions/sec	600 10^{6}
Bunch spacing	7 m (25 ns)
Dipole field	8.33 T
Dipole op. temp.	1.9 K
Dipole current	11,700 A

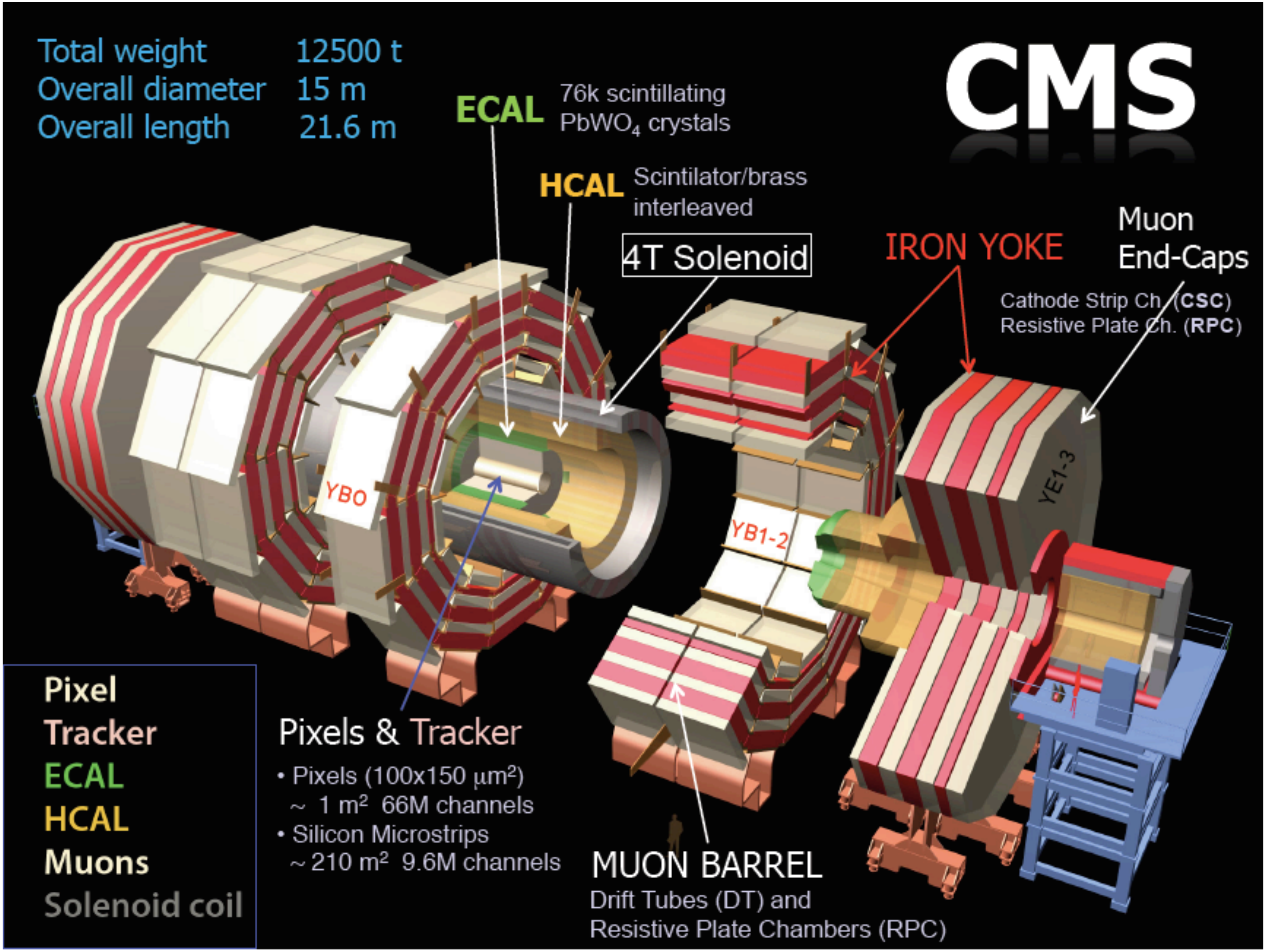
A superb instrument to support a 20 year physics program.

LHC DIPOLE : STANDARD CROSS-SECTION

CERN AC/DI/MM - HE107 - 30 04 1999

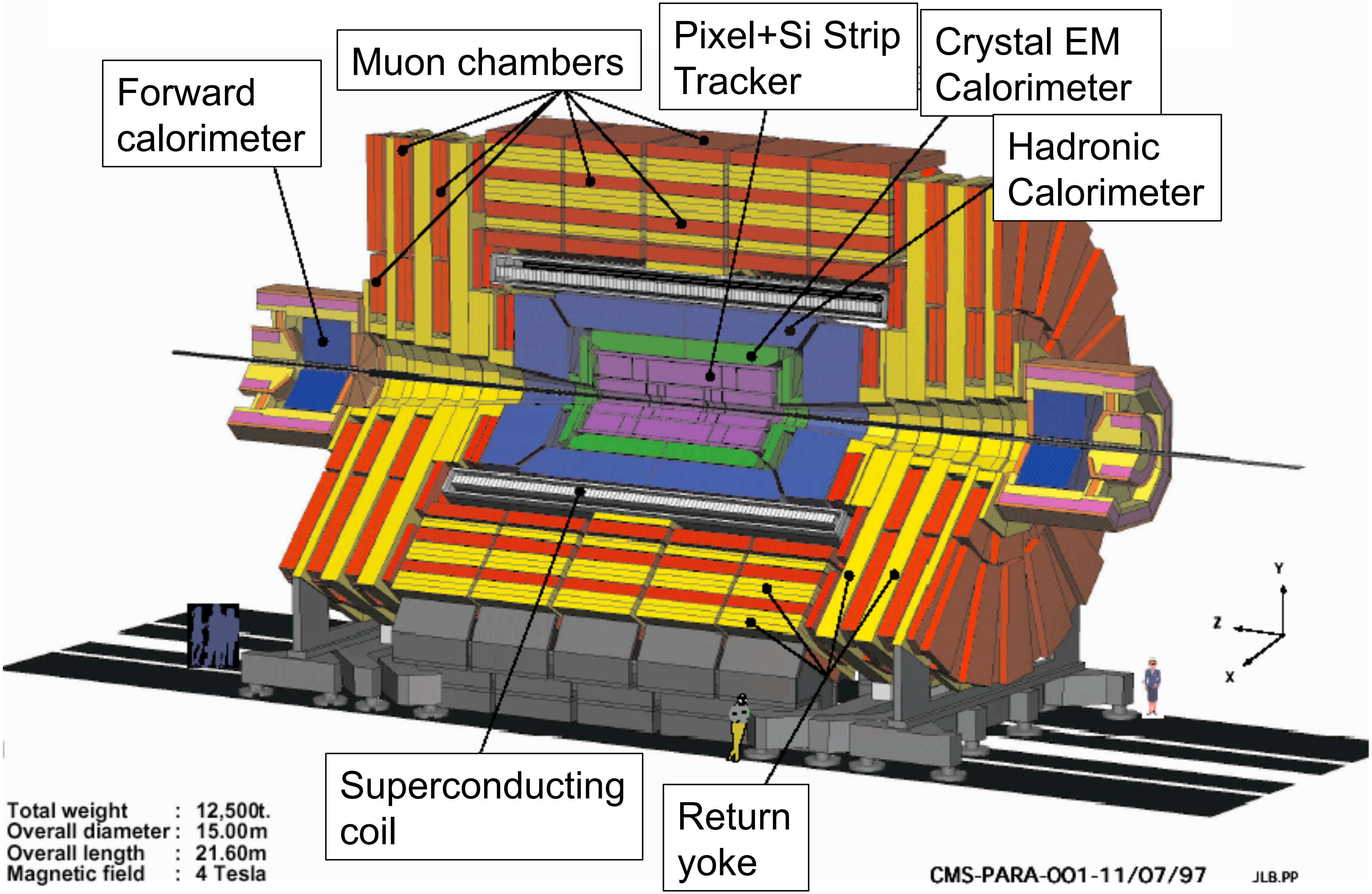


Mag. length: 14.3 m
Overall length: 16.8 m
Nb-Ti superconductor

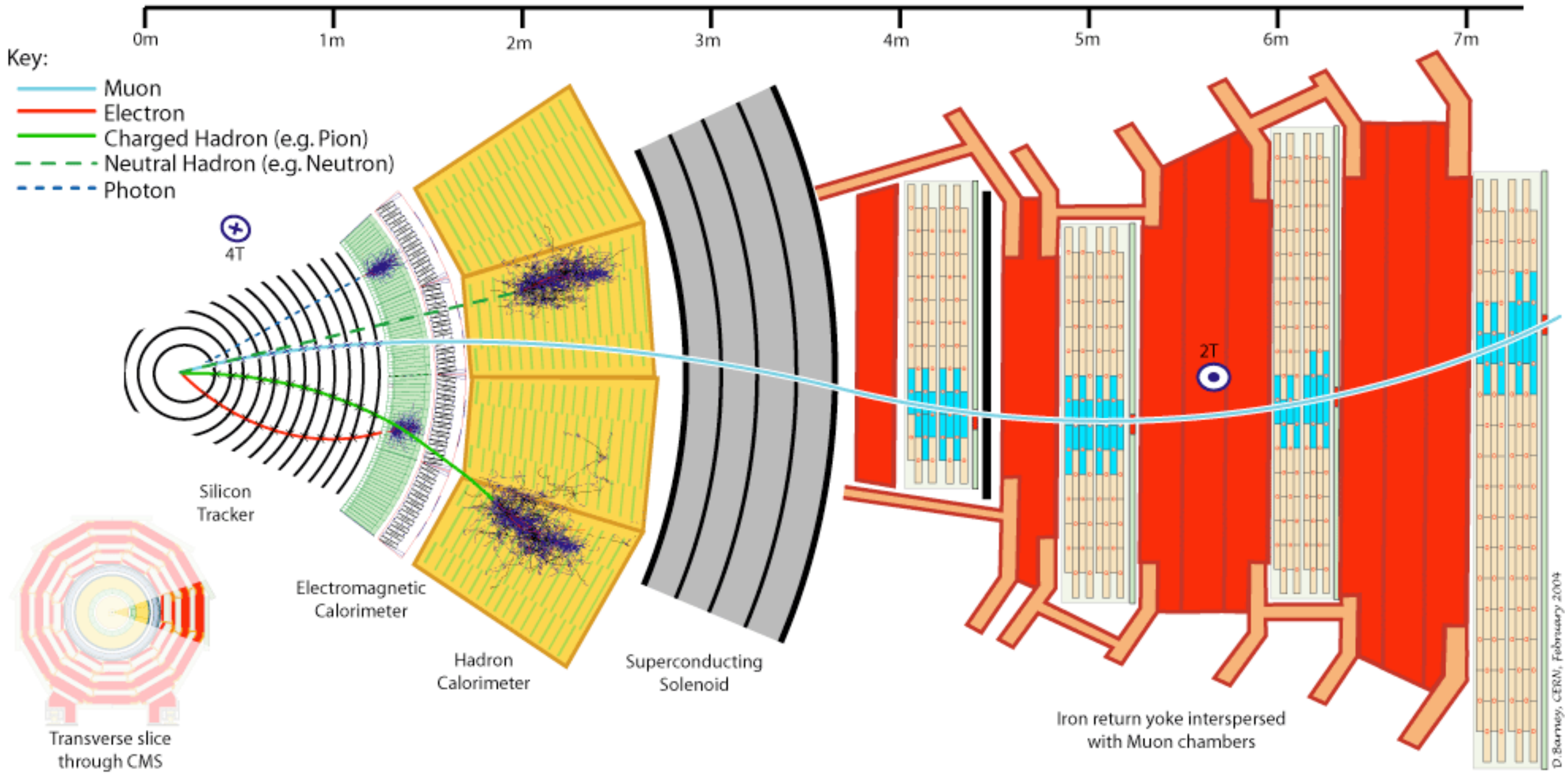


Total weight 12500 t
Overall diameter 15 m
Overall length 21.6 m
ECAL
76k scintillating PbWO4 crystals
HCAL
Scintilator/brass interleaved
4T Solenoid
IRON YOKE
Muon End-Caps
Cathode Strip Ch. (CSC)
Resistive Plate Ch. (RPC)
CMS
YB0
YB1-2
YE1-3
Pixel
Tracker
ECAL
HCAL
Muons
Solenoid coil
Pixels & Tracker
• Pixels (100x150 μm²)
~ 1 m² 66M channels
• Silicon Microstrips
~ 210 m² 9.6M channels
MUON BARREL
Drift Tubes (DT) and
Resistive Plate Chambers (RPC)

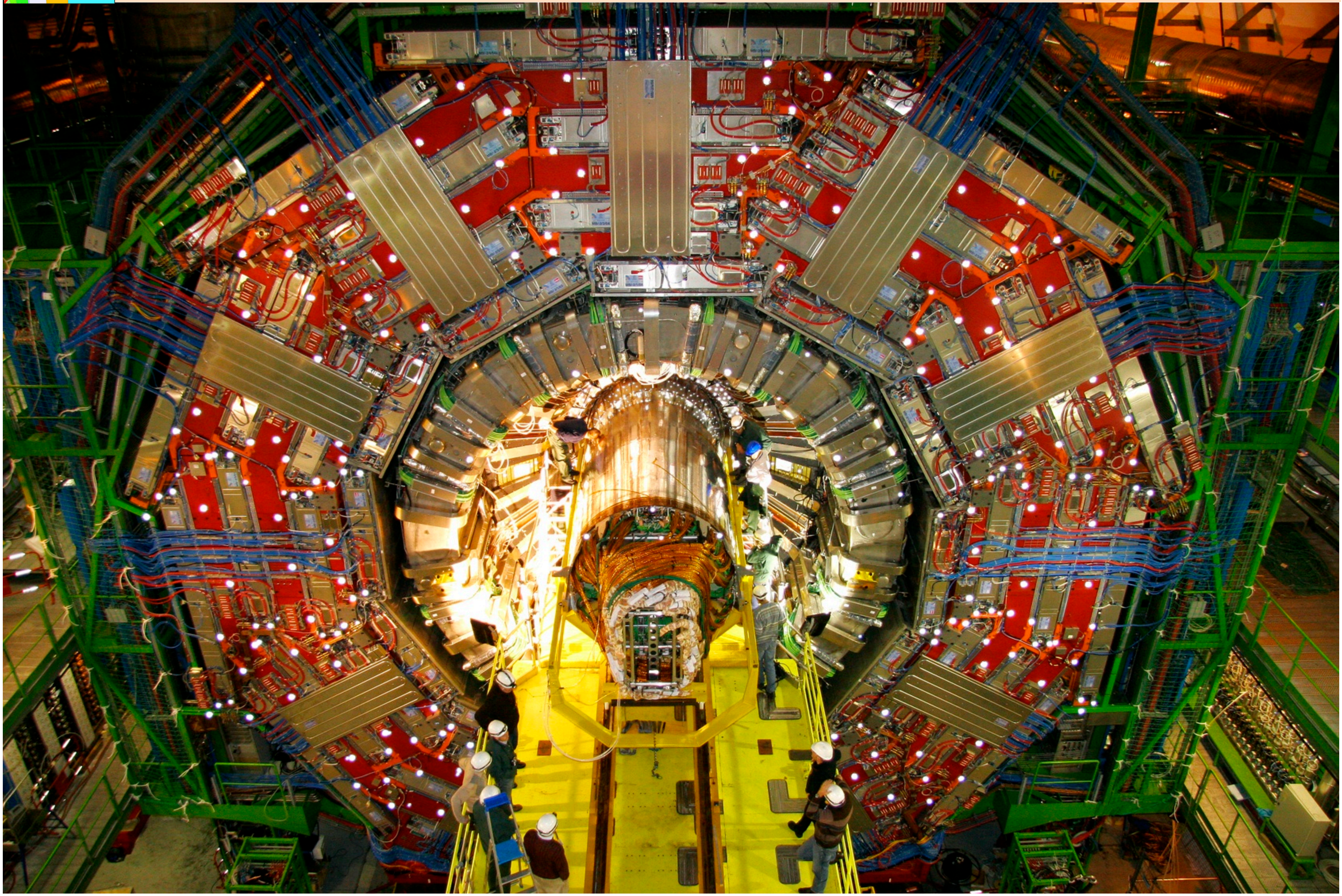
CMS Detector



CMS Detector Functionality

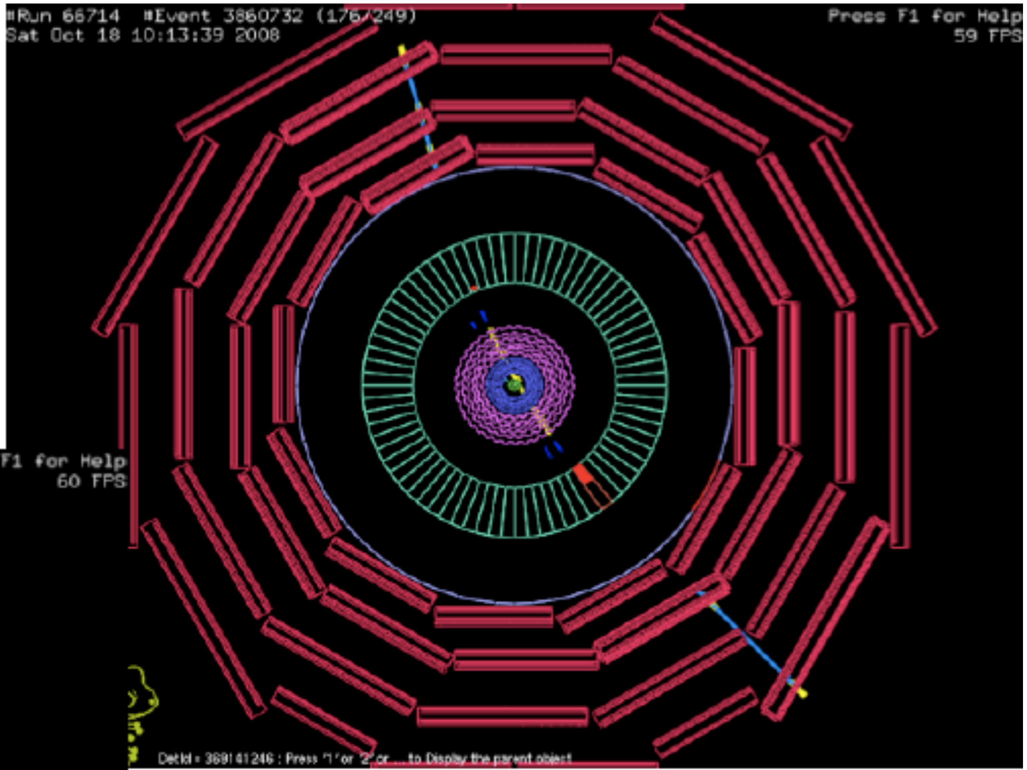


CMS Silicon Tracker Installation: Dec 2007

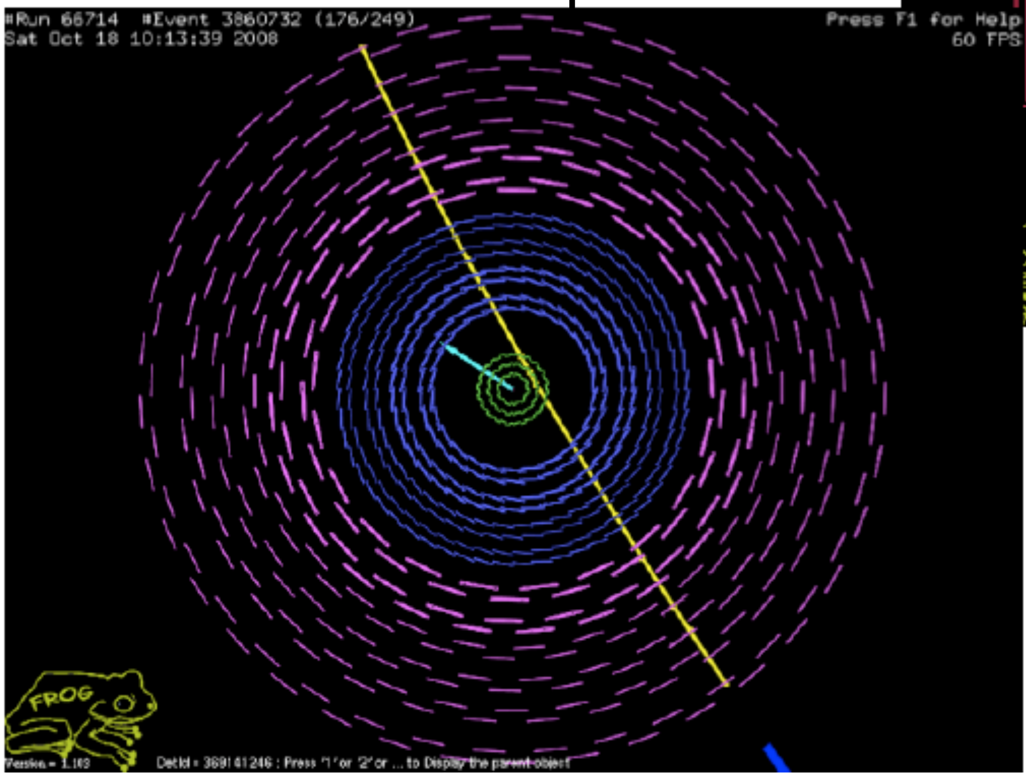


Commissioning with Cosmic Rays

Full detector

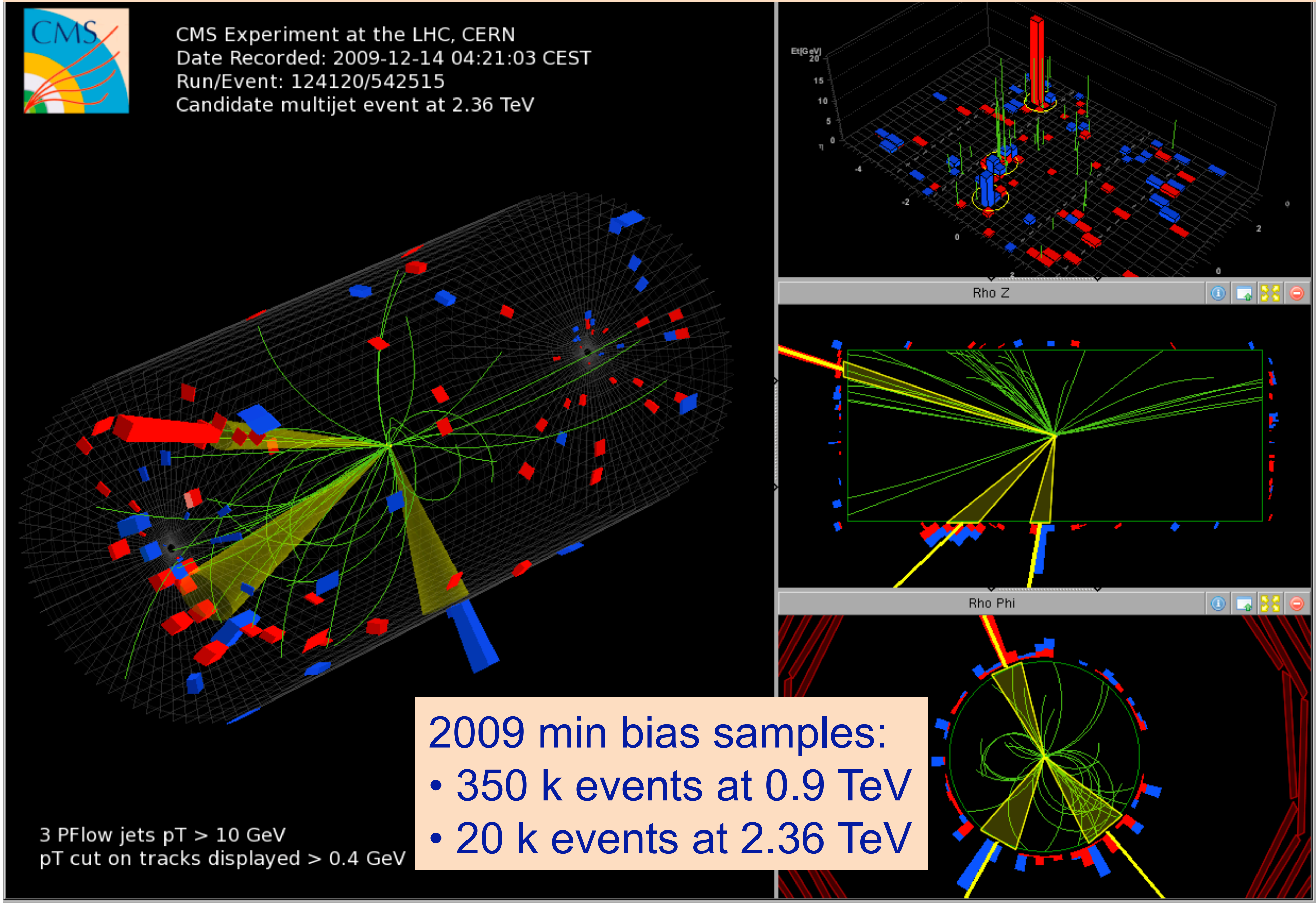


Pixels and Si Strip Tracker



Extensive alignment and calibration performed with cosmic ray running.

Nov-Dec 2009 Running at 0.9 TeV and 2.36 TeV



2009 min bias samples:

- 350 k events at 0.9 TeV
- 20 k events at 2.36 TeV

Collisions at 7 TeV

http://cdsweb.cern.ch/journal/CERNBulletin/2010/14/News%20Articles/1246424?ln=fr

http://press.web.cern.ch/press/PressReleases/Releases2010/PR07.10E.html

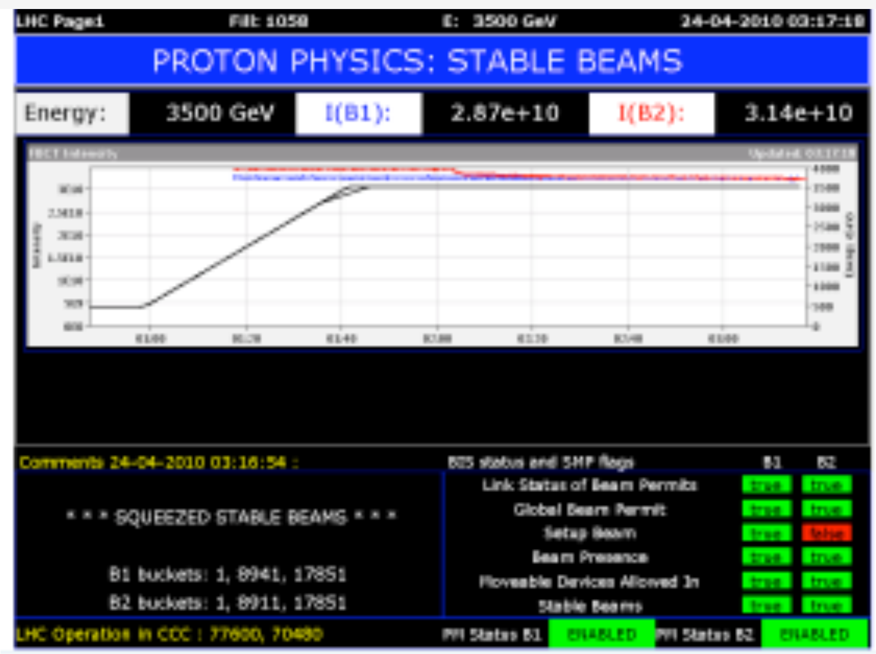
Nous avons réussi !

Presque 20 années de travail acharné accompli par des centaines de personnes ont permis au Grand collisionneur de hadrons (LHC) de passer du rêve à la réalité. Le LHC a livré aujourd'hui

March 30, 2010: 1st 7 TeV Collisions

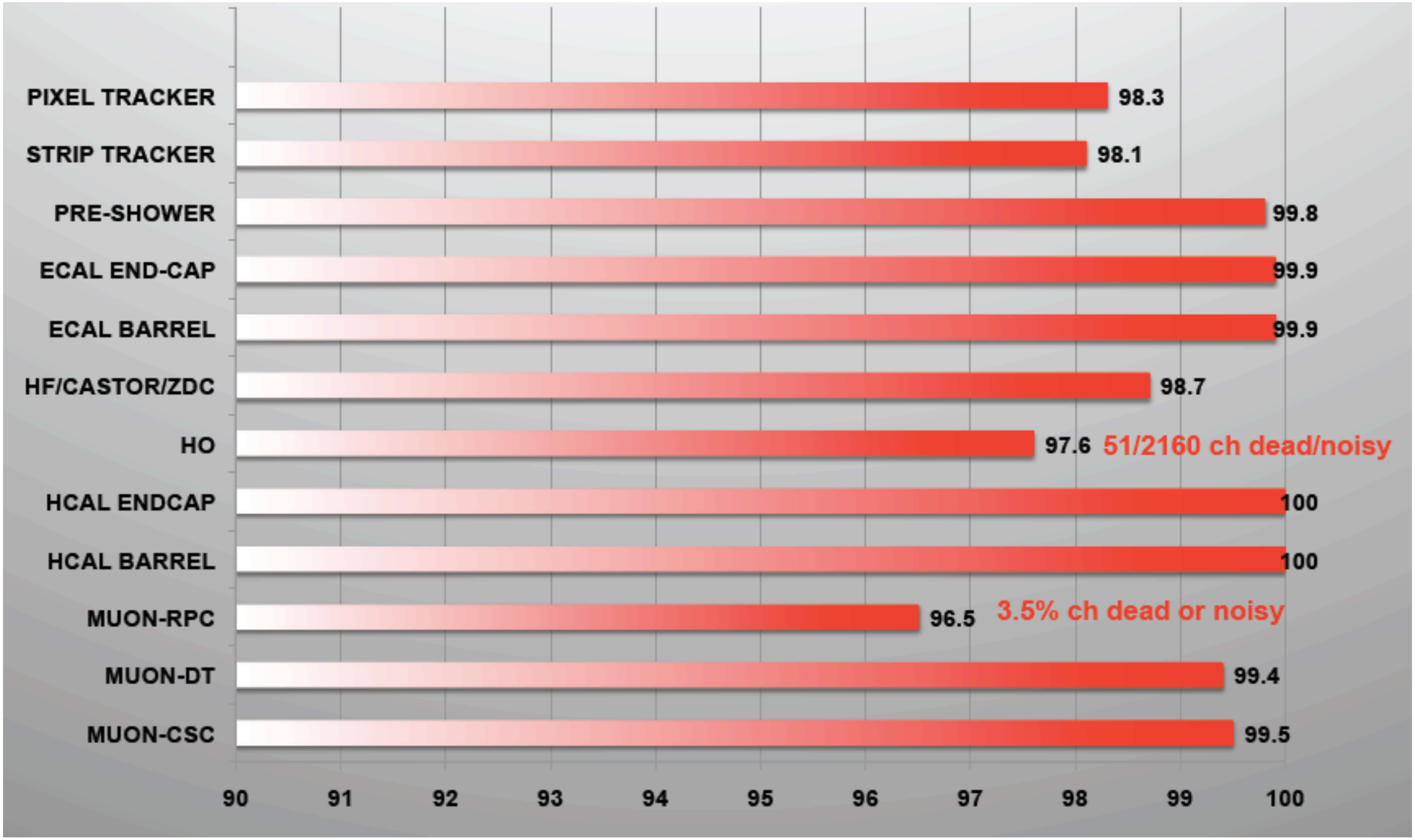
Il y a quelques instants à la CCC

May 1-2, 2010, squeezed, stable beams (30 hrs), $L > 1.1\times 10^{28}$ cm^{-2}s^{-1}

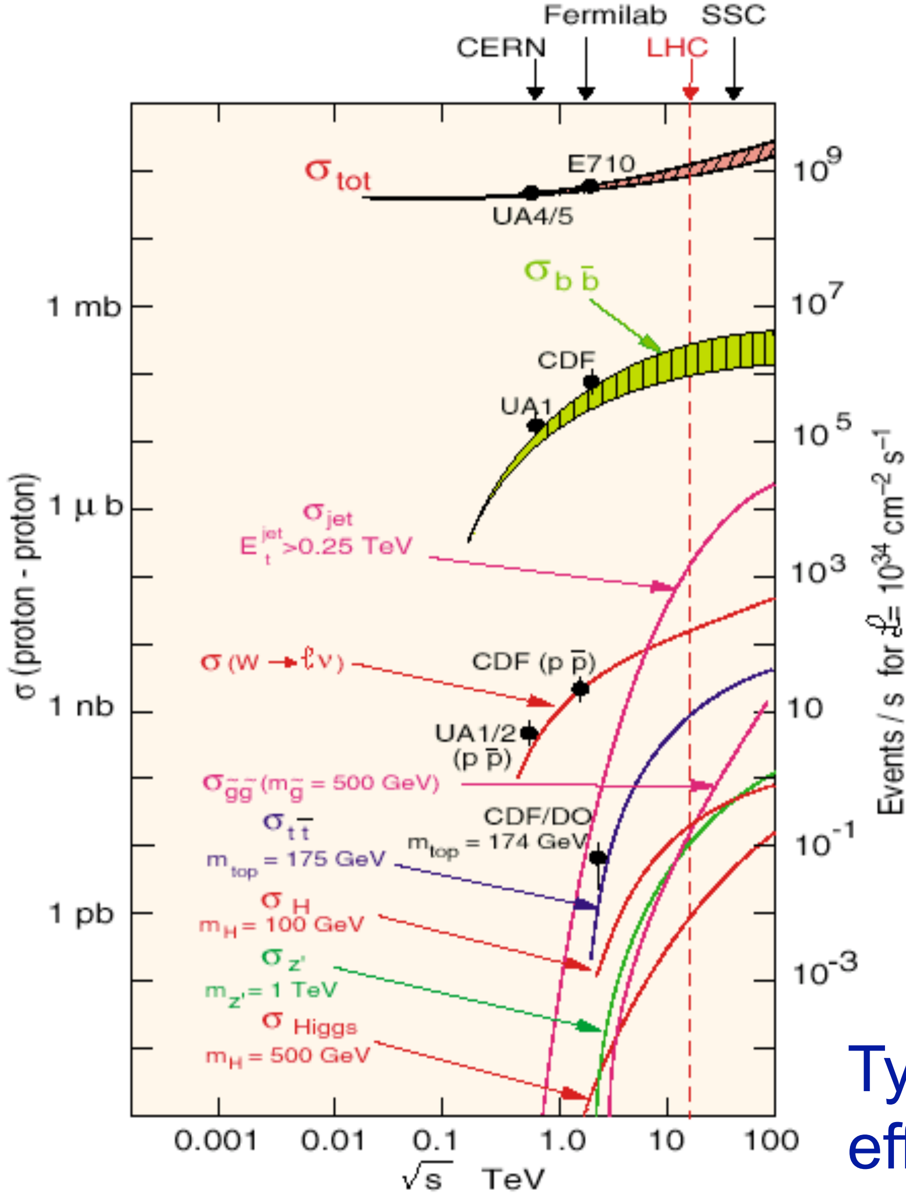


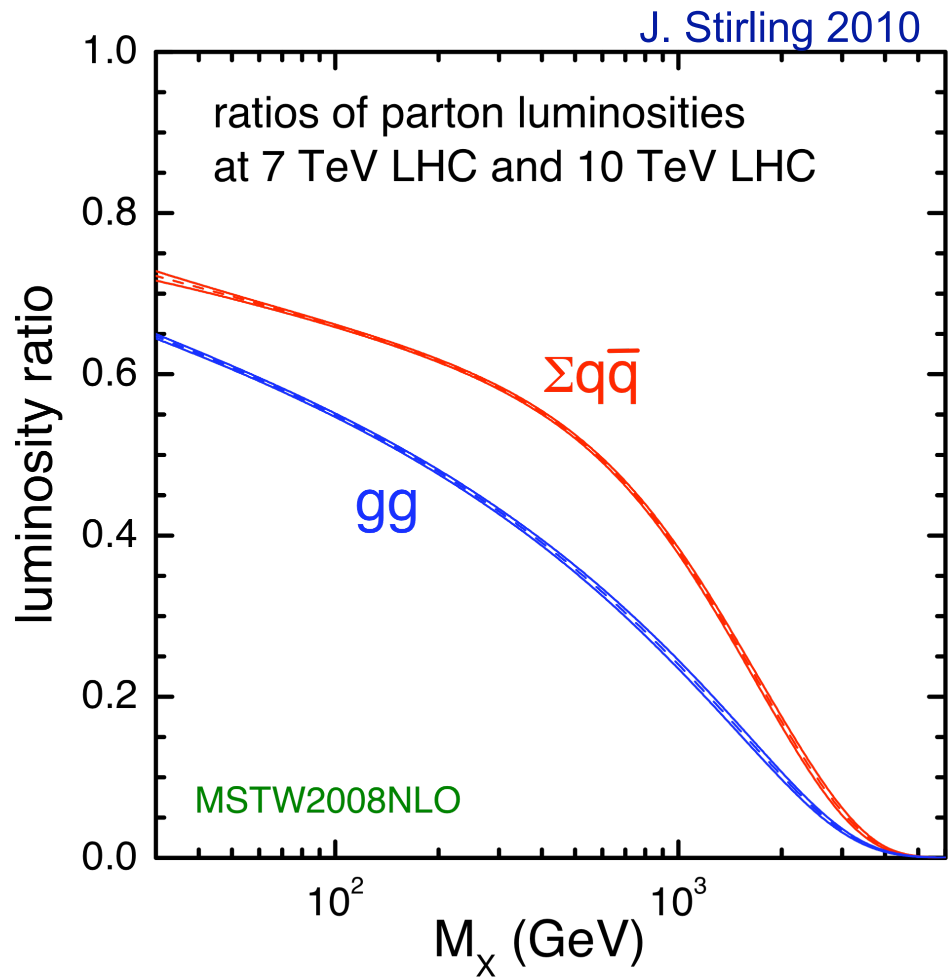
http://cdsweb.cern.ch/journal/CERNBulletin/2010/18/News%20Articles/1262593?ln=en

CMS Operations at 7 TeV



Cross sections for Key Processes





Typically lose about factor of 3-4 in effective luminosity from 10→7 TeV.

Comparison of Parton Luminosities at LHC and Tevatron

Use parton luminosities to illustrate the gain:

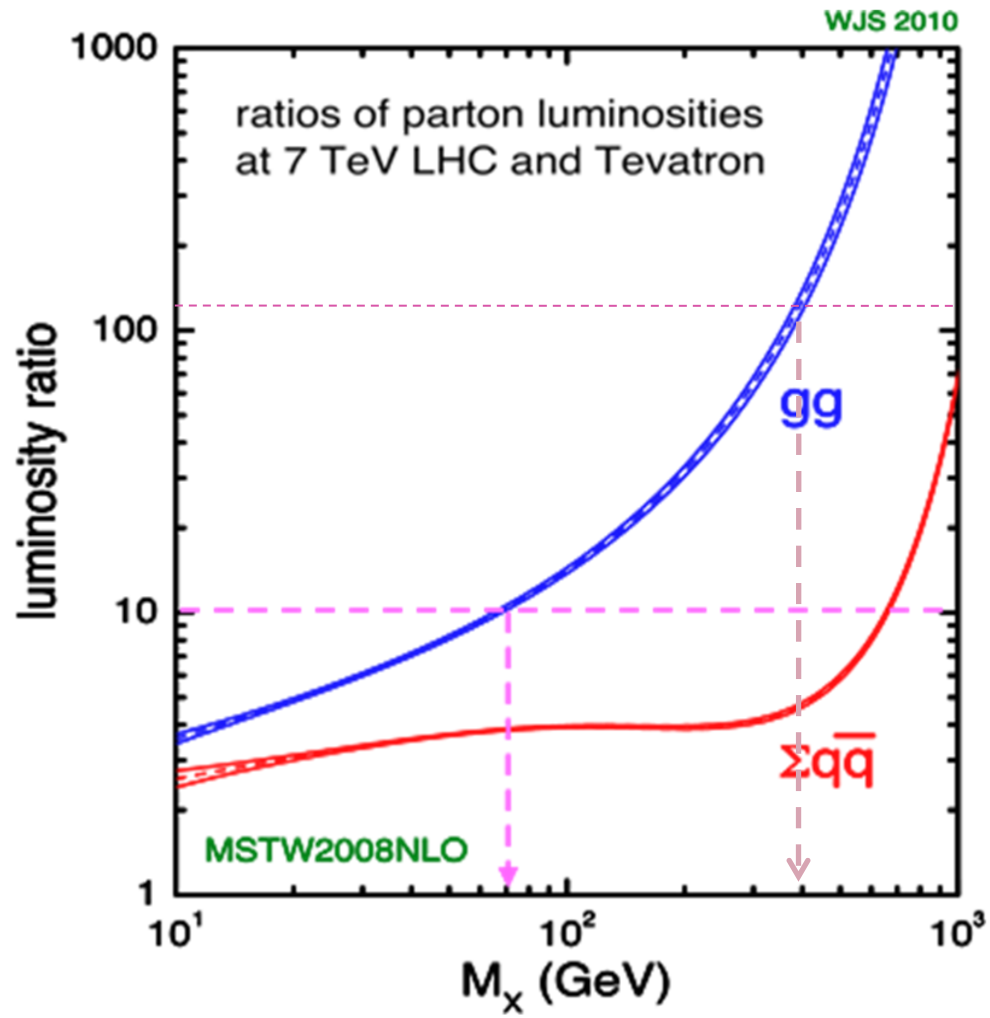
Example: mainly gg
Higgs: pp → H, H→WW and ZZ
Factor ~15

Example: gg and qq
Top: (85% qq, 15% gg at Tevatro
Factor: 0.85 x 5 + 0.15 x 100
➔ ~ 20

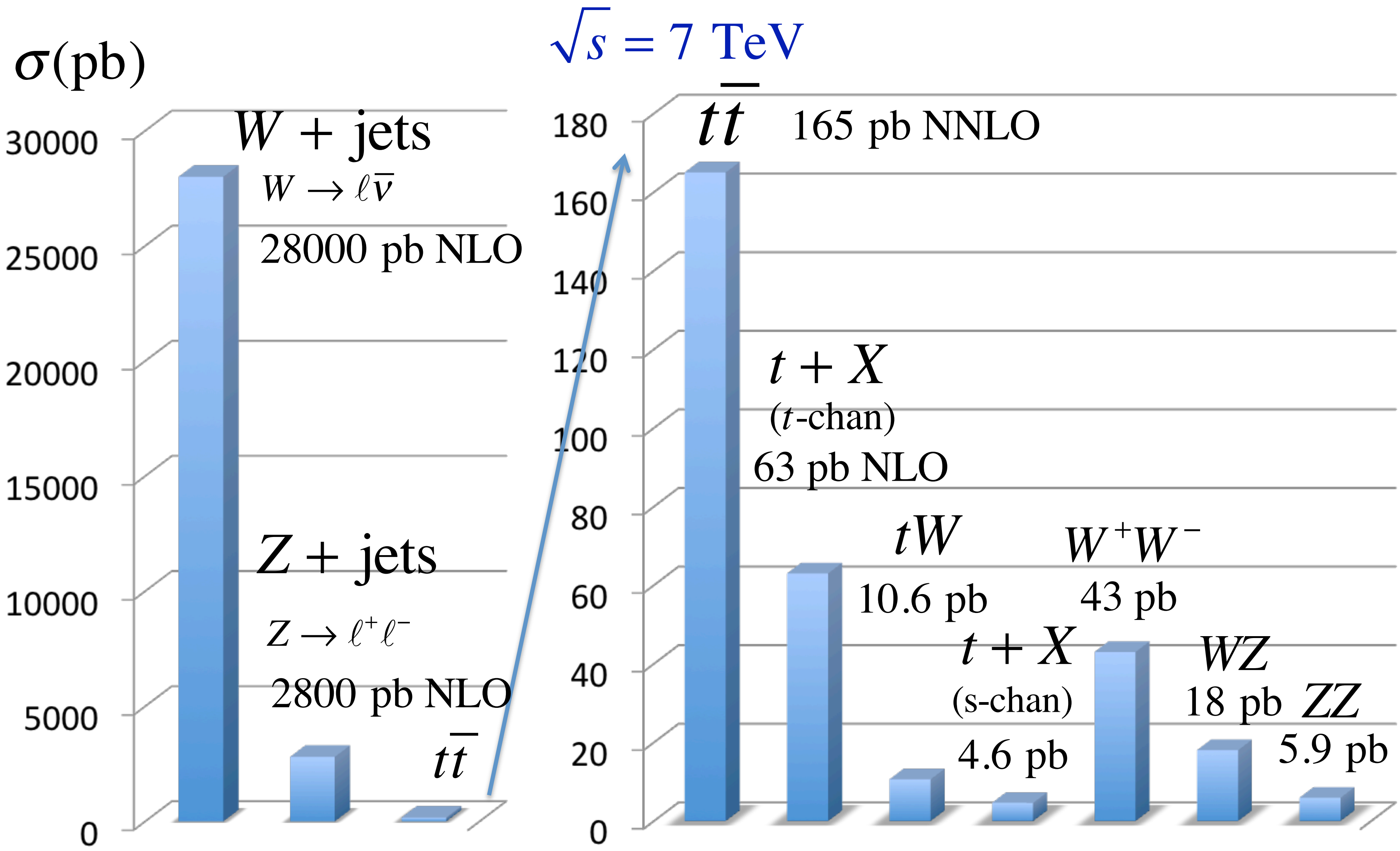
Squarks: ~350 GeV (assume top):
Factor: 0.85 x 10 + 0.15 x 1000
➔~ 150 to 200

Z': ~1 TeV (qq)
Factor: ~ 50 to 100

Courtesy Oliver Buchmuller, LHCC presentation
http://indico.cern.ch/conferenceDisplay.py?confId=92525

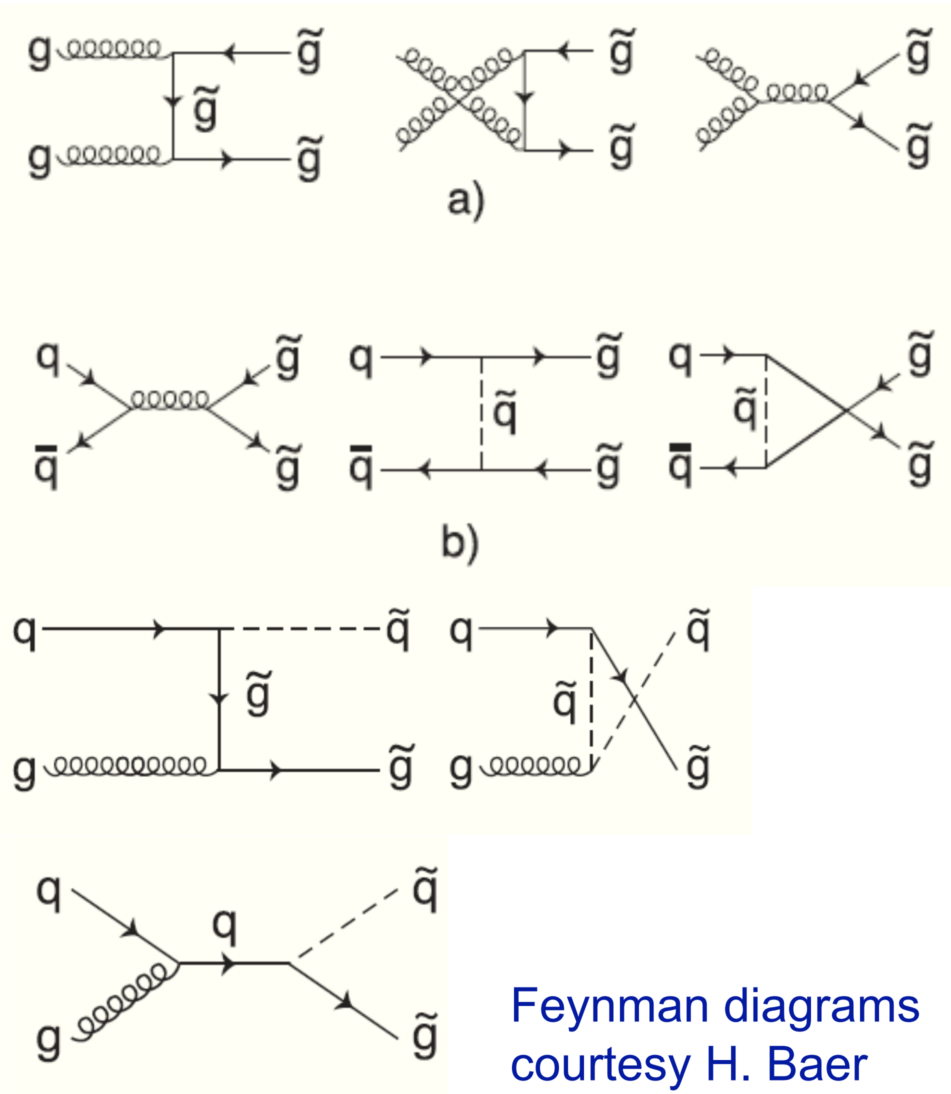


Cross Sections for Key SM Processes

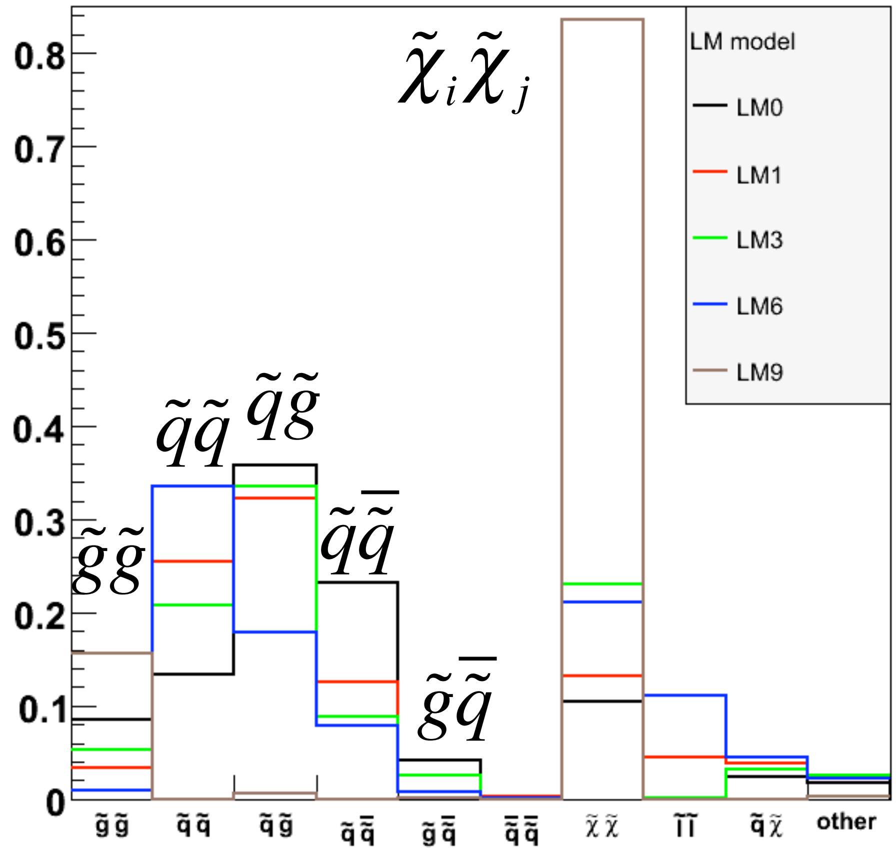


SUSY Production Mechanisms

Strong production usually dominates SUSY cross sections.



Fraction of production according to initial SUSY particle pair (CMS benchmark models).

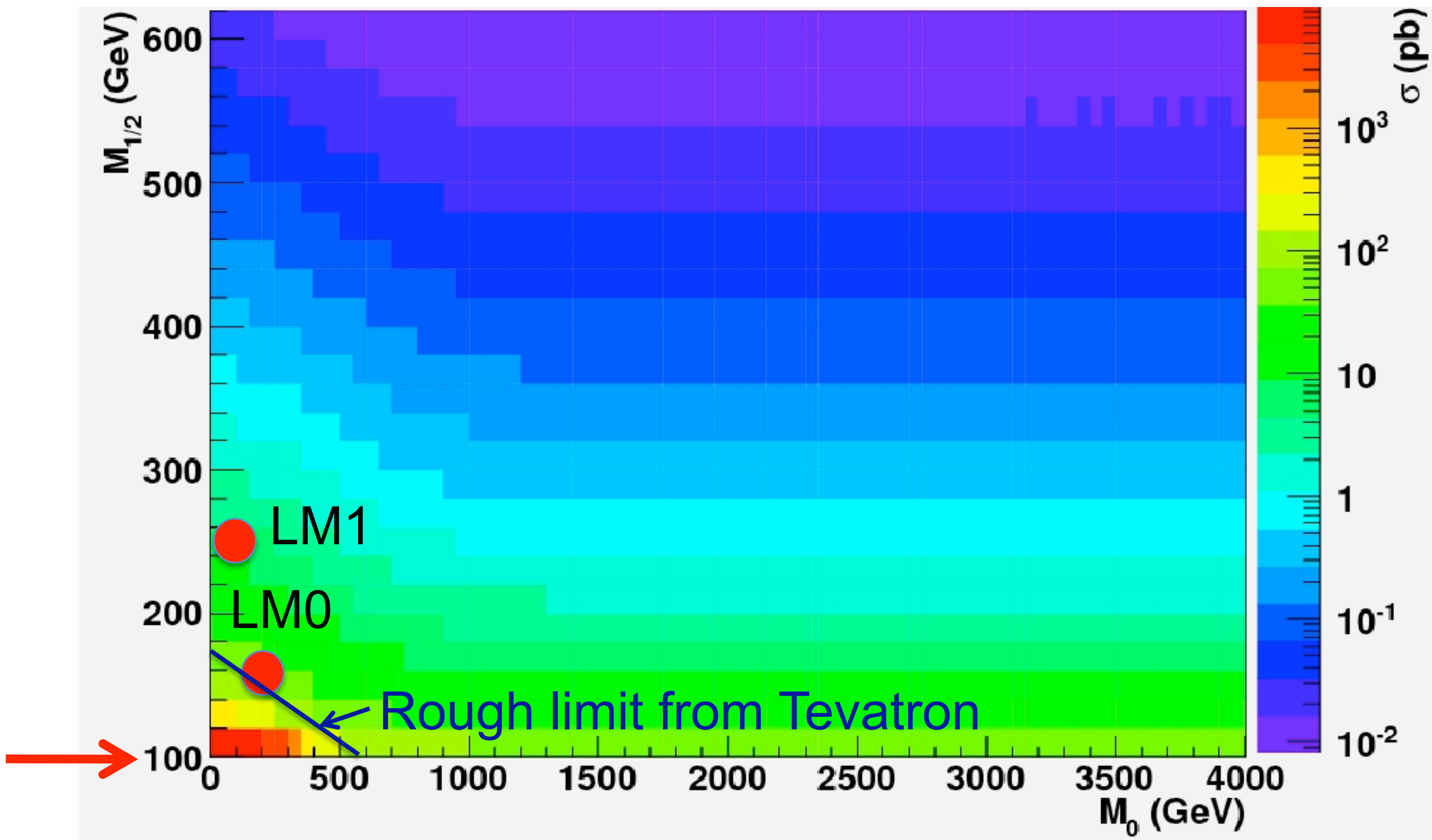


Feynman diagrams courtesy H. Baer

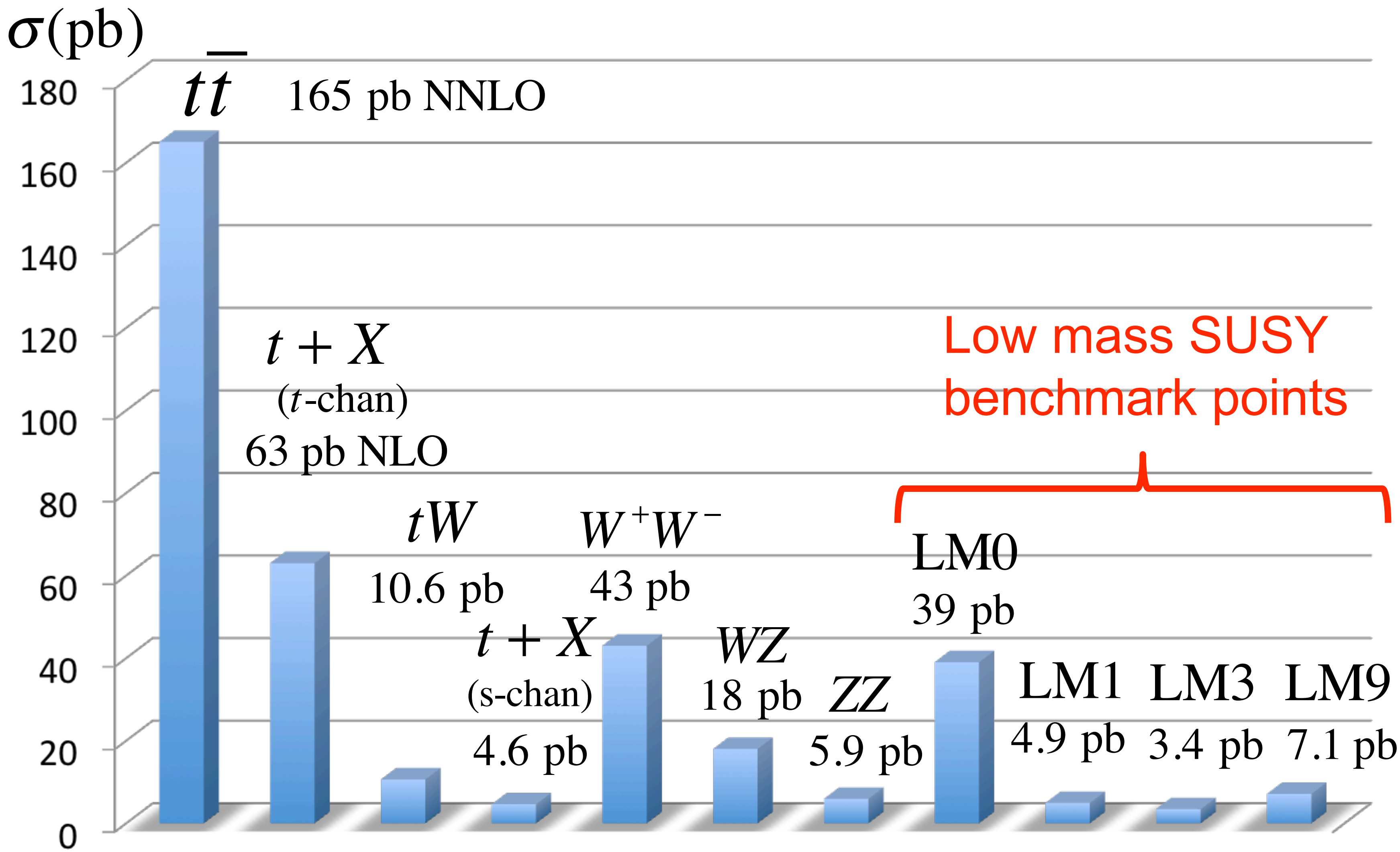
mSUGRA cross sections at 7 TeV

$\Delta m_0 = 50$ GeV $\Delta m_{1/2} = 20$ GeV

Leading order cross section $\tan\beta = 3,\ A_0 = 0,\ \mu > 0$

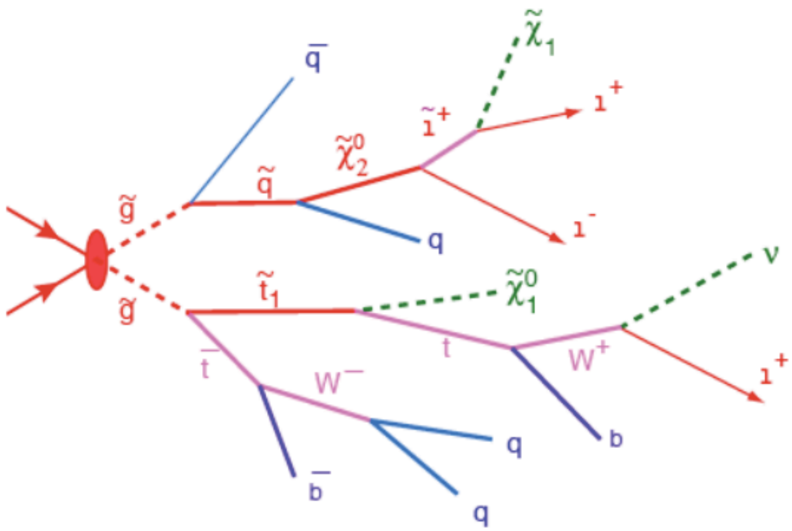


Cross Sections for SM vs. Low-mass SUSY benchmark points



Basic SUSY Search Topologies

Plan for first LHC physics run: coherent survey of simple, inclusive signatures involving MET. But also need to search for “exotic” signatures such as those arising from Split SUSY.



- Establish foundation for more complex searches. Signatures will expand to include b, τ, t.
- Data-driven background methods: pursue multiple approaches, <u>as many cross-checks as possible.</u>

<u>0 leptons</u>	<u>1 lepton</u>	<u>2 leptons</u>	<u>≥3 leptons</u>
• Exclusive jets • Inclusive Jets • Photons + Jets		• Like-sign • Opposite sign	

Experimentalists vs. Theorists

- Theorists ask…
  - How will we know if the New Physics is SUSY?
  - How will we determine mass scale…and the full spectrum?
  - How will we determine the underlying Lagrangian?
- What experimenters think about…
  - Is there a leak? Will the trigger work?
  - How much calorimeter noise is there?
  - How big is the QCD background?
  - How can we be confident it's not just the standard model + tails of experimental distributions?

Detector/Software Commissioning

A few examples of things you have to check…

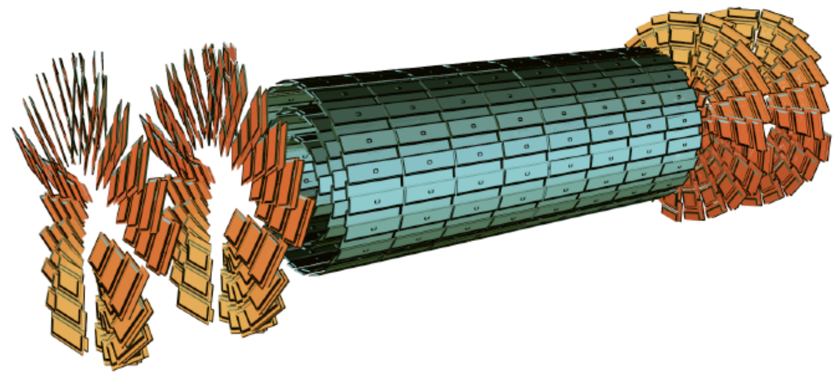
- Trigger rates and efficiencies
- Tracking system alignment, pattern recognition, resolution, efficiencies
- Calorimeter resolution, calibration, noise
- Jet energy scale corrections
- Photon, electron and muon ID algorithms
- Track isolation determination
- Missing energy resolution
- b- and τ-tagging algorithms

CMS Tracker Inner Region: Pixels

Inner part of all-silicon tracker
- Fast response to keep up with 25 ns beam xing interval (2 MHz)
- Pixels: 3 barrel layers, 2 pairs F/B

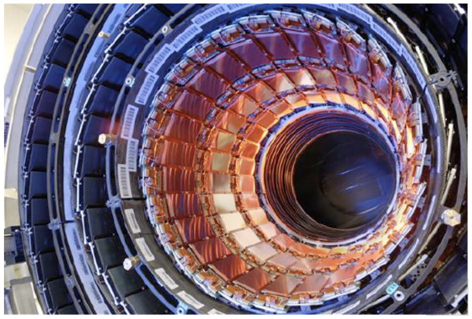
Pixel Detector Parameter	Value
Pixel Size	100 µm × 150 µm
Resolution	10 µm (rϕ)× 20 µm (z)
Number pixels	66 M
Sensor thickness	285 µm
Radii of barrel layers	4.3, 7.2, 11.0 cm
|z| of forward layers (disks)	34.5 cm, 46.5 cm (F and B)
Total sensor area	~1 m^2
Fraction operational	98.4%
Efficiency	97%

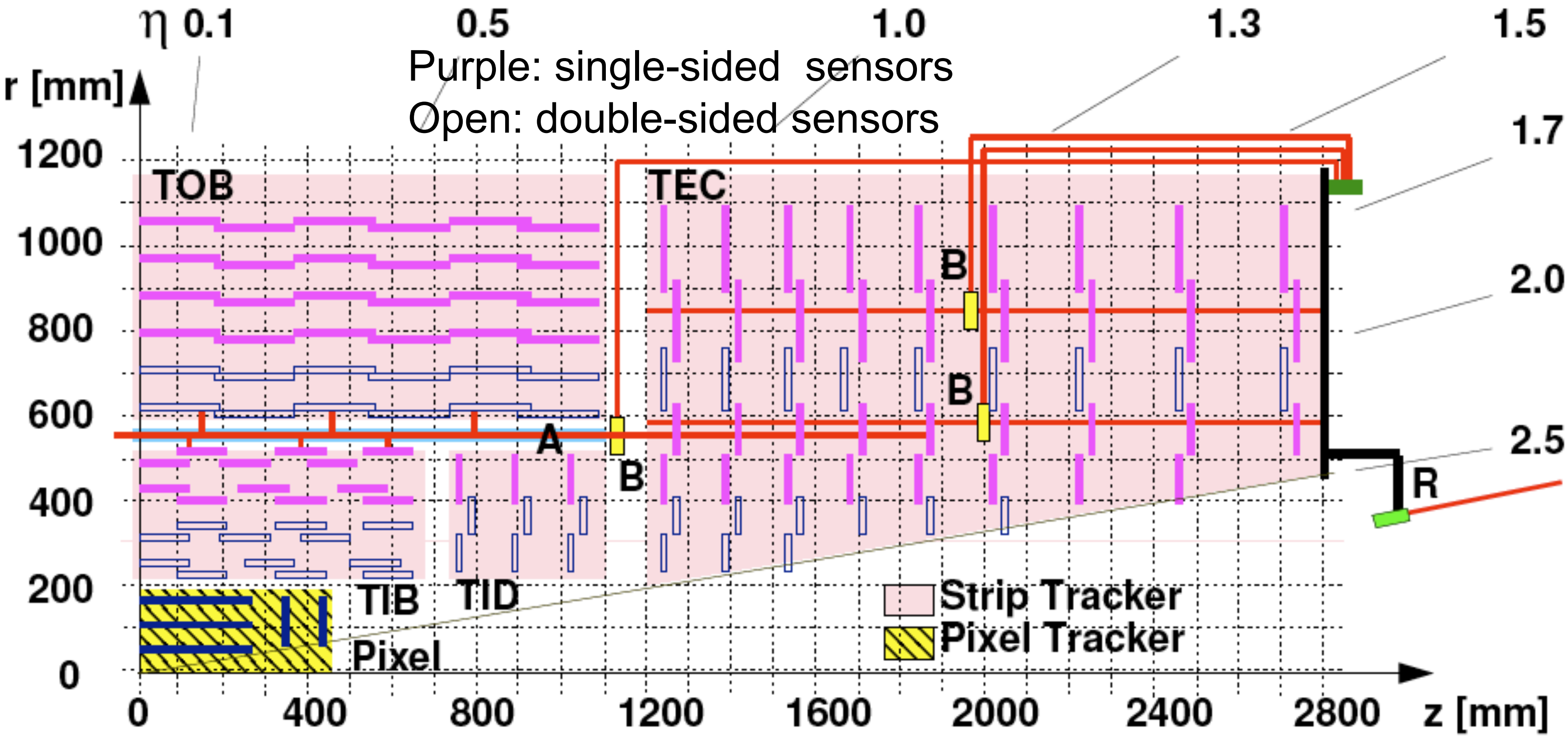
Pixel Detector Geometry



CMS Tracker: Silicon Strips

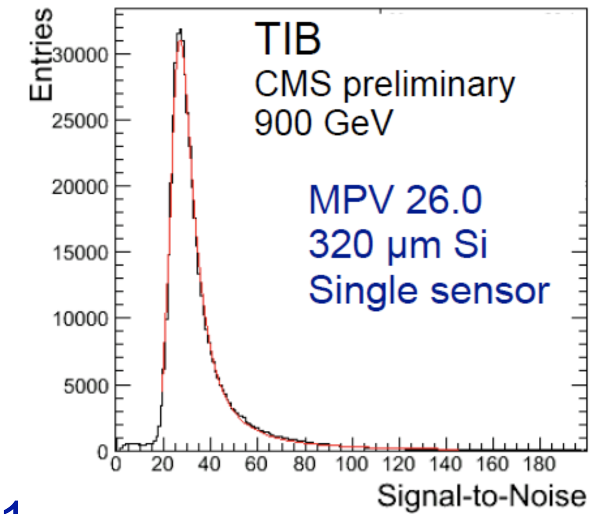
- Largest silicon tracker ever built: ~200 m^2
- Inner+outer barrel: 4+6 layers; 10-14 points
- 9.3 M strips, pitch 80-180 μm; 97.2% working
- Sensor thickness: 320 μm; 500 μm

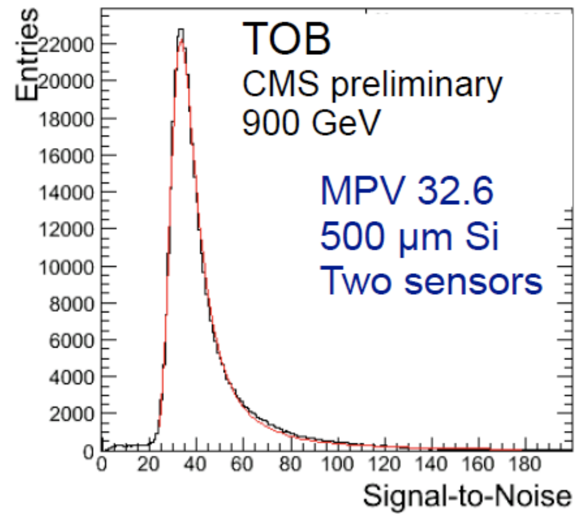




CMS Tracker Performance

- Si Strip S/N~30/1
- Agrees with expectation

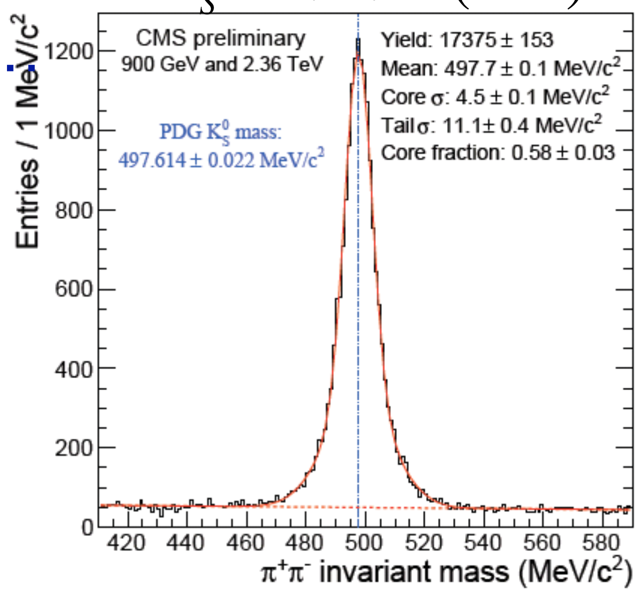




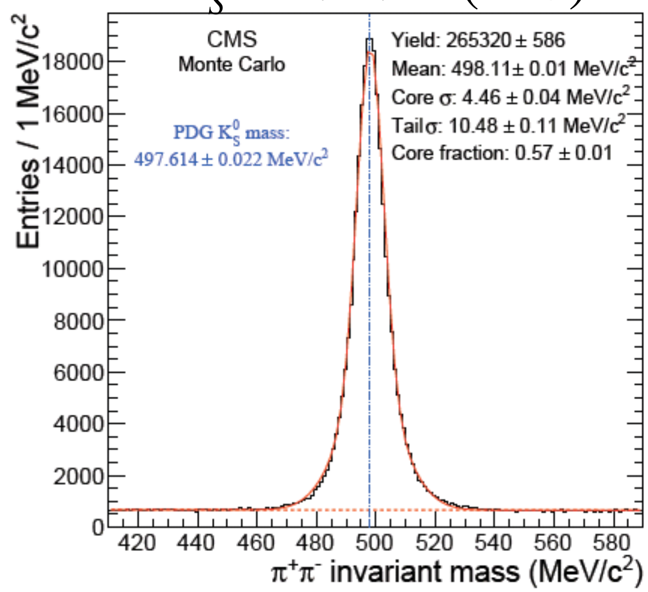
CMS PAS TRK-10-001

- Ks, ϕ, D*, Λ, Ξ, Ω,… observed & reconstructed at correct masses
- Good alignment, B-field map

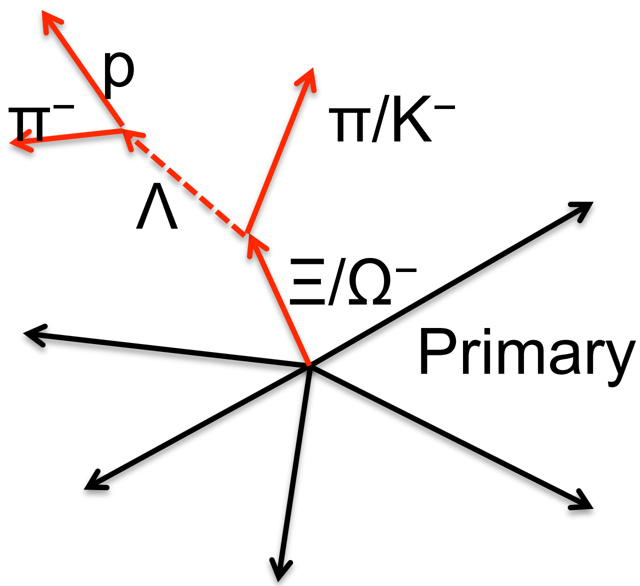
$K_S^0 \rightarrow \pi^+\pi^-$ (data)



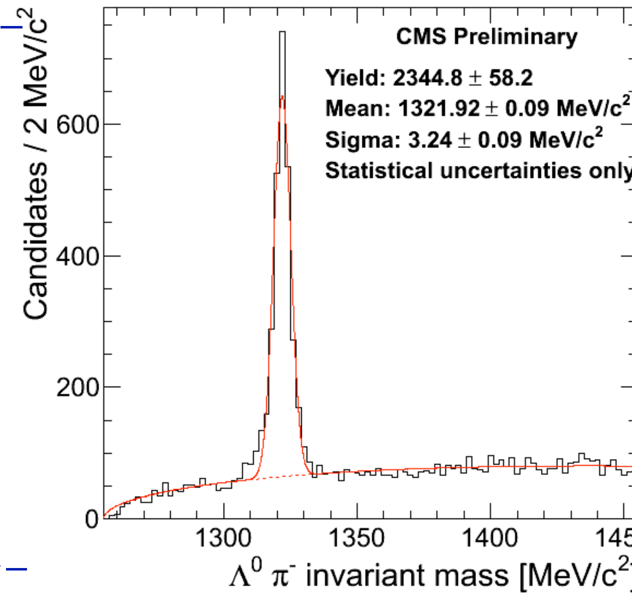
$K_S^0 \rightarrow \pi^+\pi^-$ (MC)



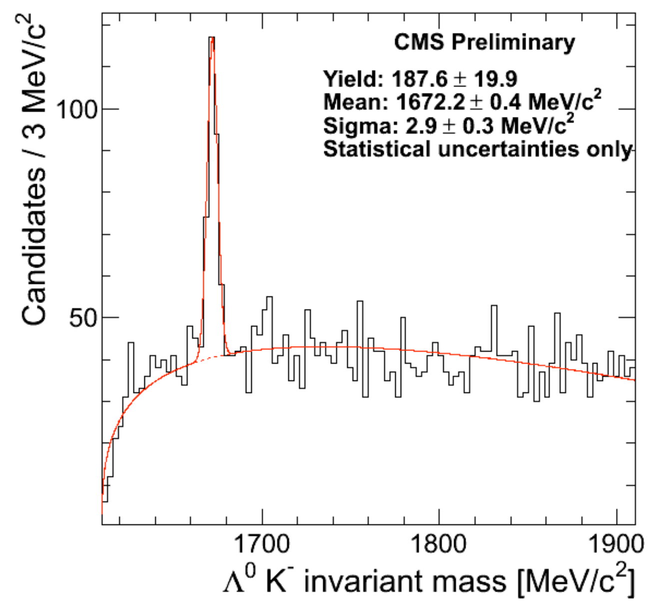
CMS Tracker Performance



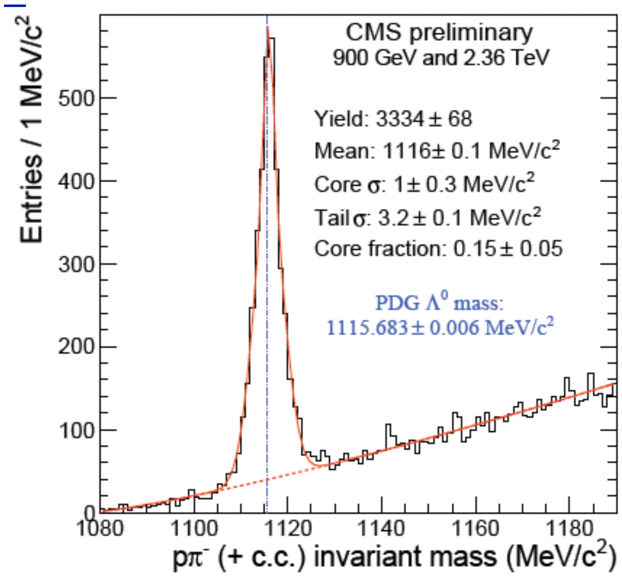
$\Xi^- \rightarrow \Lambda^0 \pi^-$



$\Omega^- \rightarrow \Lambda^0 K^-$

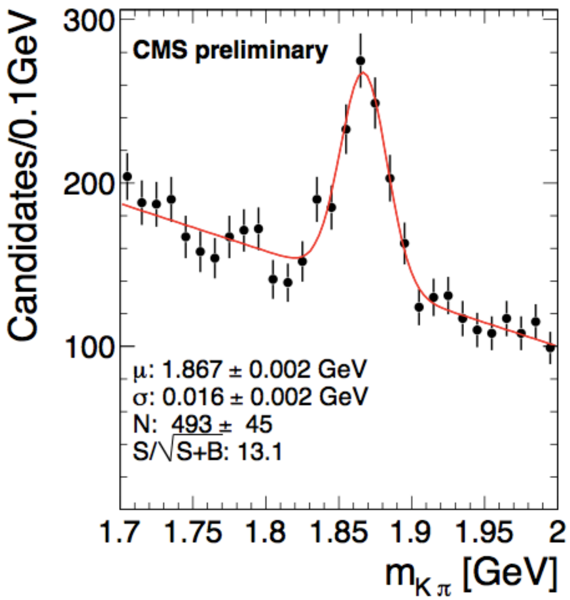


$\Lambda^0 \rightarrow p\pi^-$

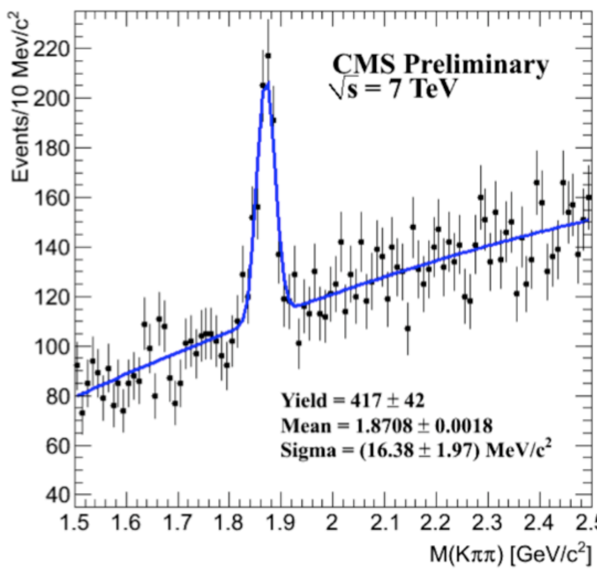


Charm Signals at 7 TeV

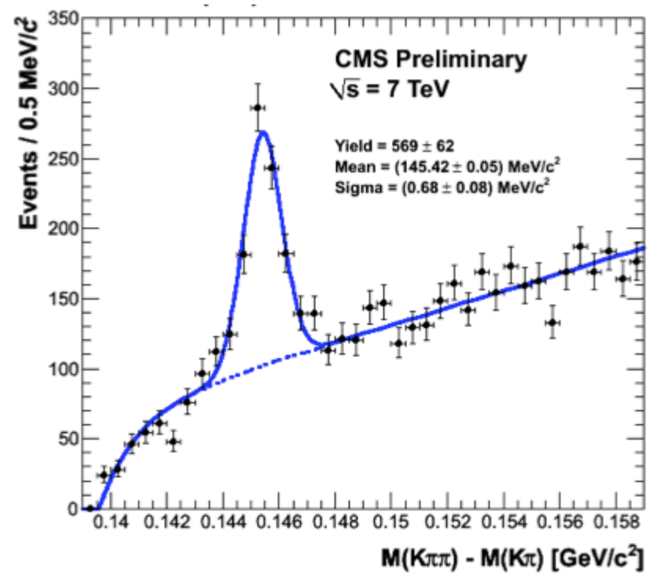
$D^0 \rightarrow K^- \pi^+$



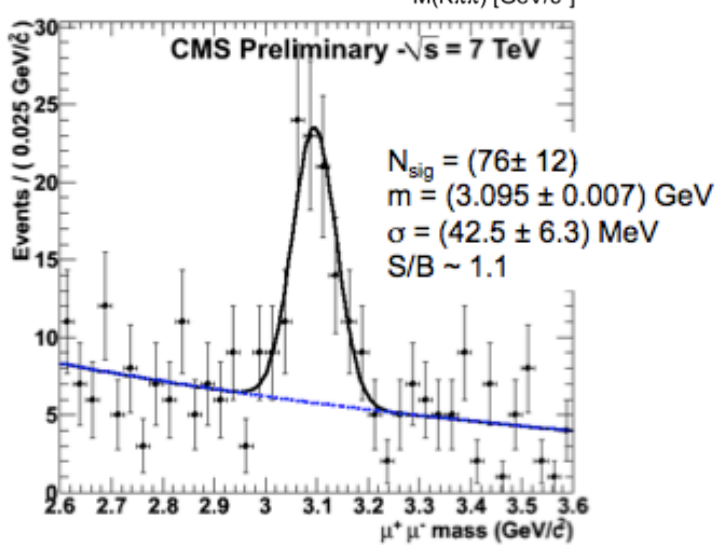
$D^+ \rightarrow K^- \pi^+ \pi^+$



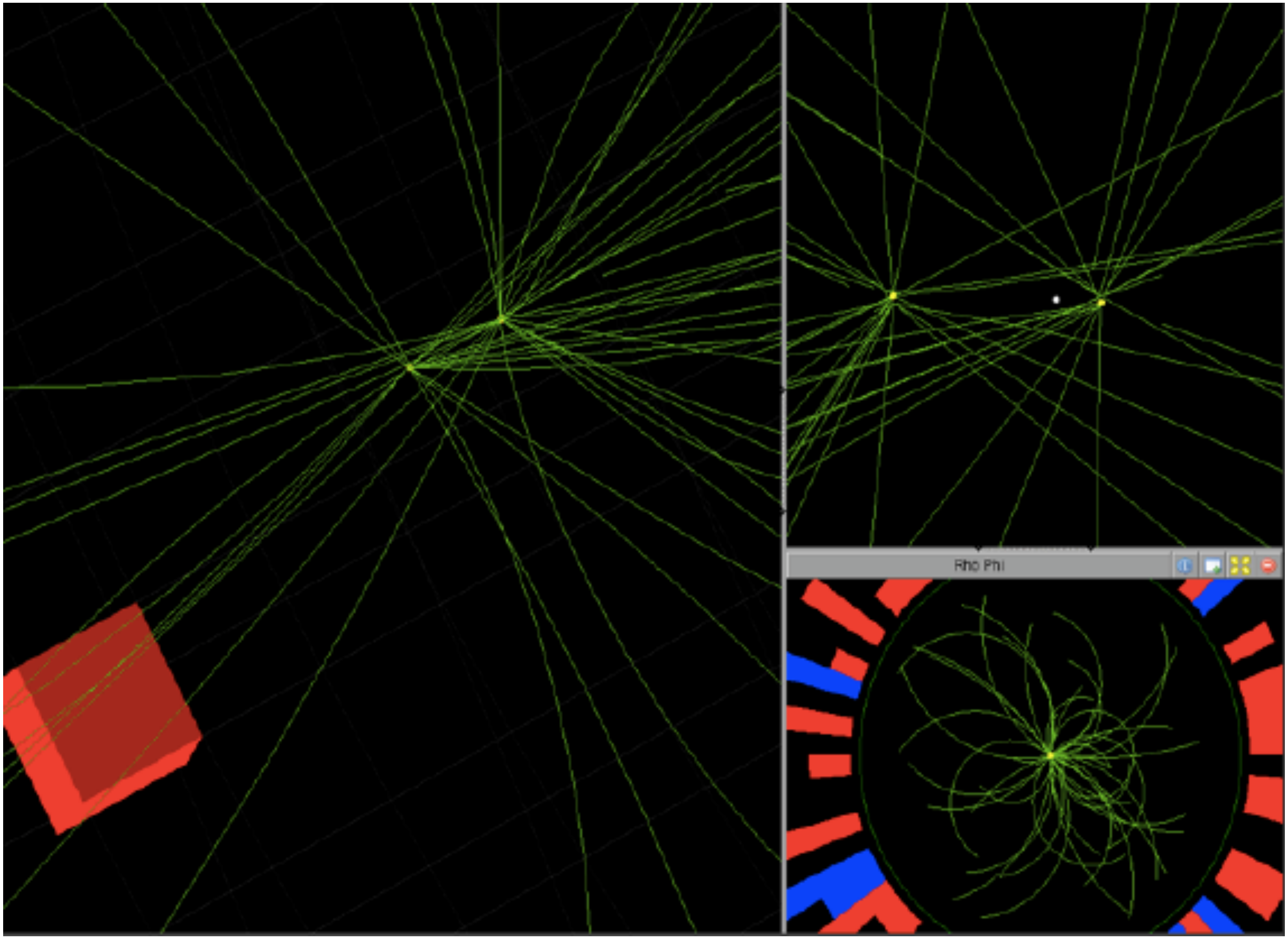
$D^{*+} \rightarrow D^0 (K^- \pi^+) \pi^+$



$J/\psi \rightarrow \mu^+ \mu^-$



Events with Two Primary Vertices

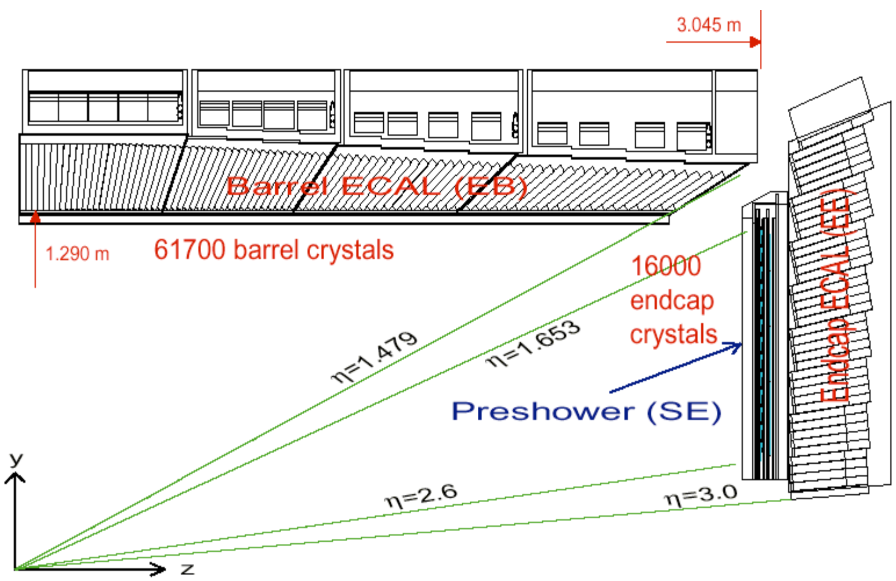


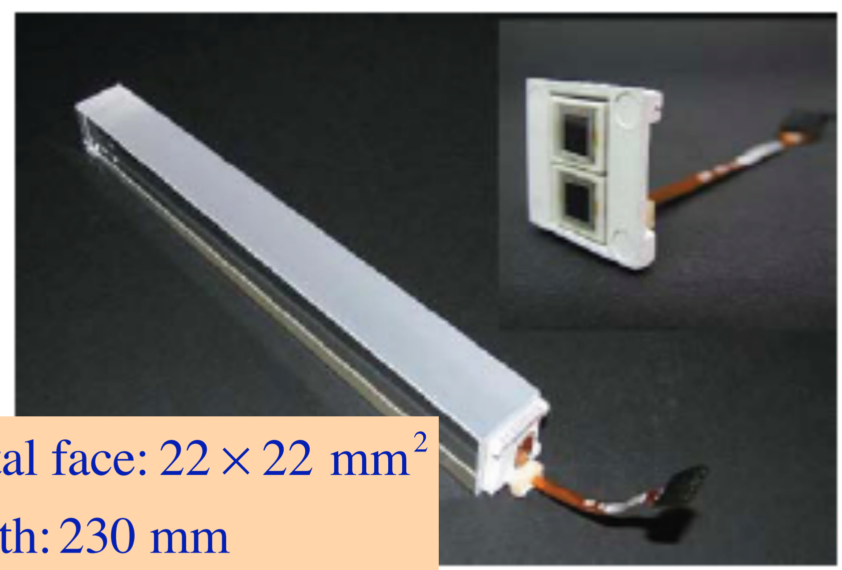
CMS Electromagnetic Calorimeter (ECAL)

- Barrel/Endcap: 61,200 / 2×7,324 $PbWO_4$ crystals
- Rad-hard, very fast (80% of light in 25 ns)
- 25.8 and 24.7 X_0; about 1 λ_0 (X_0 = 0.89 cm)
- Barrel inner radius: 129 cm (operates in B field!)
- Low light yield (30 γ/MeV); use avalanche photodiodes
- Coverage: |η|<1.479 (barrel), 1.479<|η|<3.0 (endcap)

$$\frac{\sigma_E}{E} \approx 0.8\% - 0.4\%$$

$(E \approx 25 - 200 \text{ GeV})$



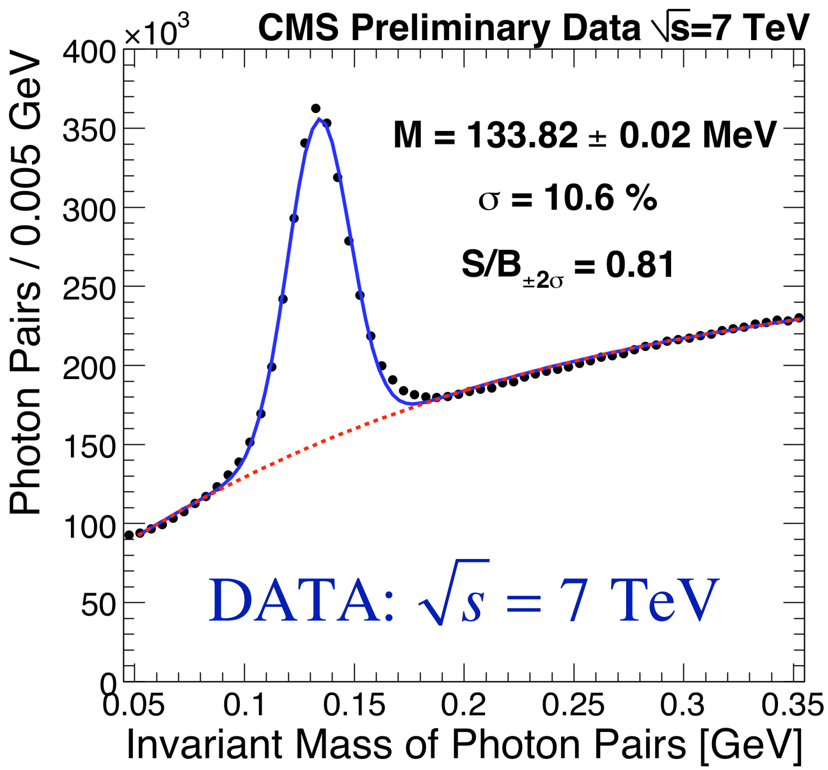


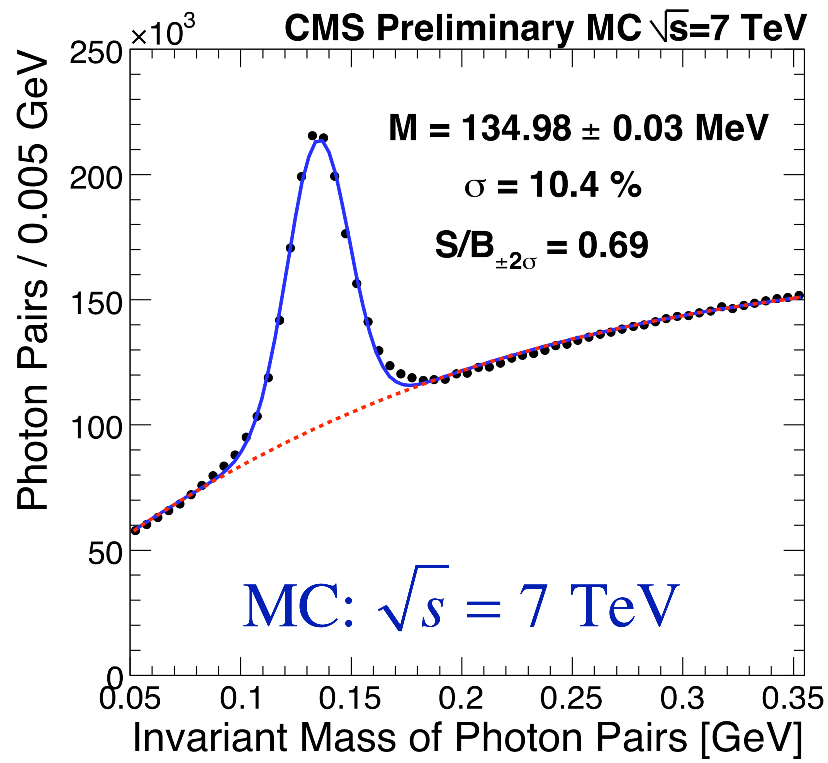
Crystal face: 22×22 mm^2

Length: 230 mm

CMS Electromagnetic Calorimeter Performance (I)

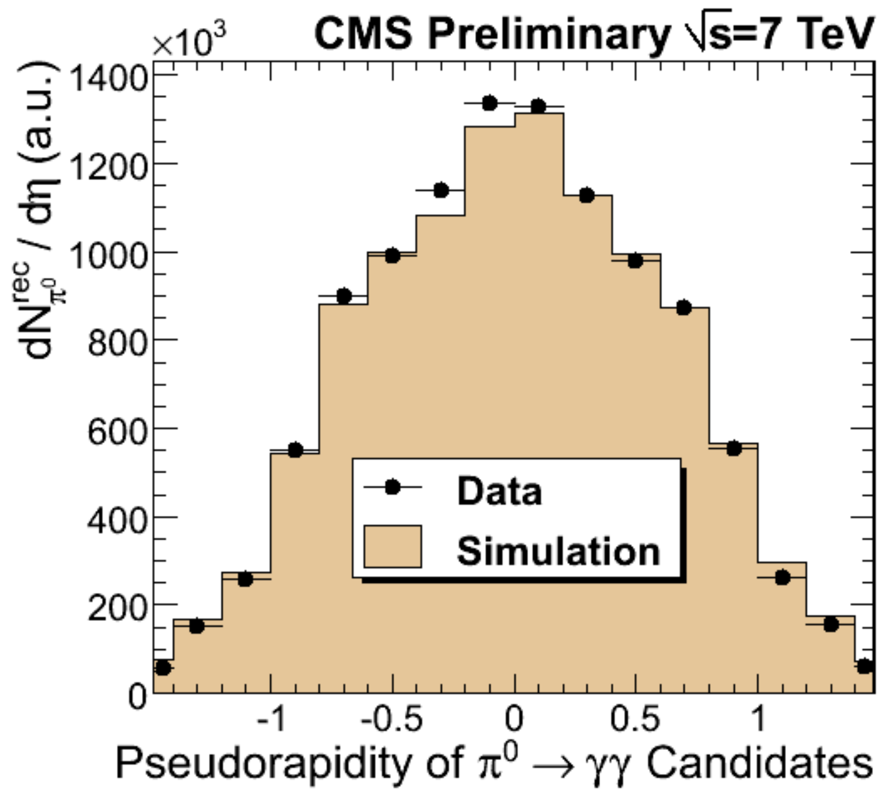
CMS PAS EGM-10-001

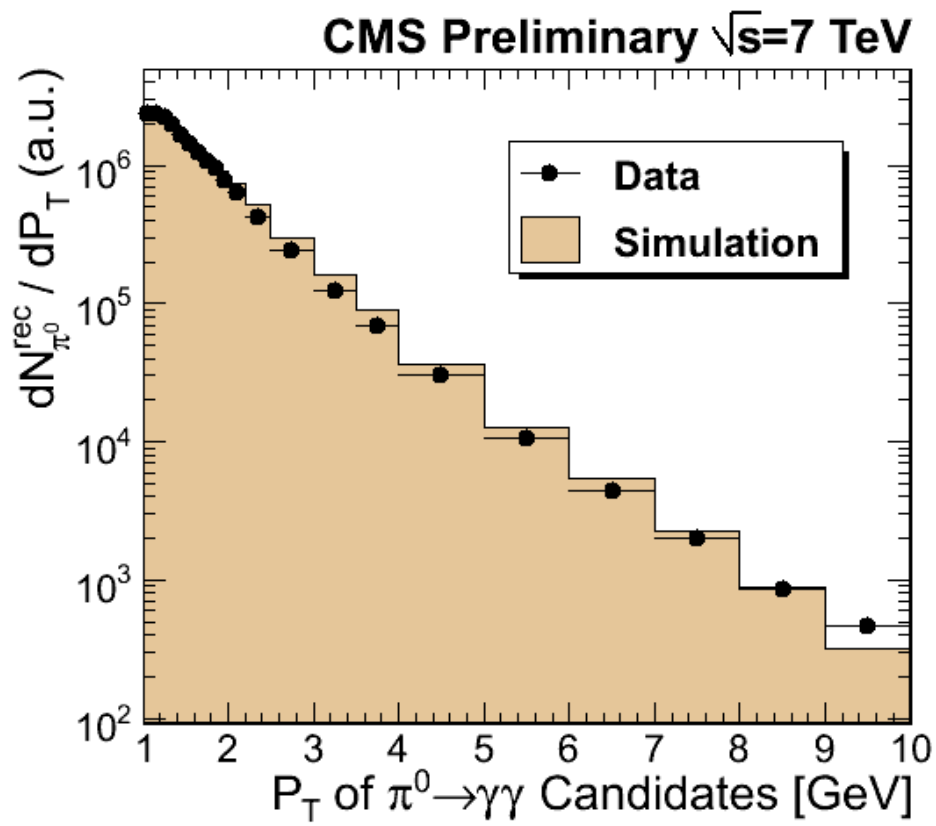




- $p_T(\gamma)$>0.4 GeV; $p_T(\gamma\gamma)$>1.0 GeV; S4/S9>0.83 both photons.
- Fitted mass agrees well with expected value.
- Fitted yield: $N(\pi^0 \rightarrow \gamma\gamma)$=1.46 M

CMS Electromagnetic Calorimeter Performance (II)





- |η| and P_T distributions of π^0 candidates agree between data and MC.

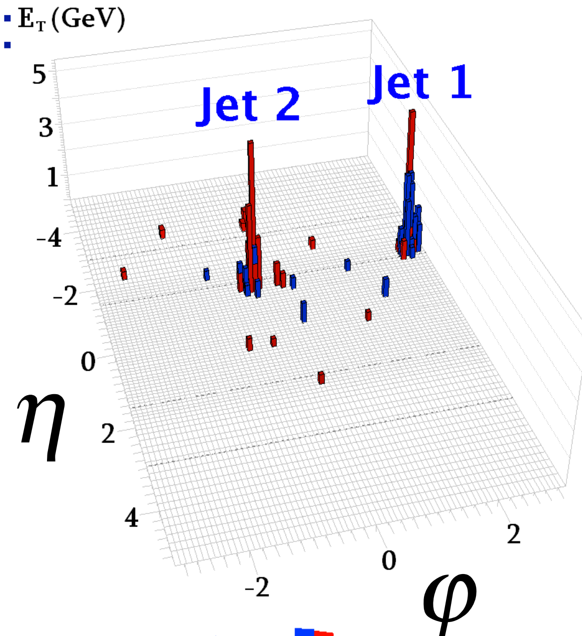
Studies of Jets and MET in 2009 Data

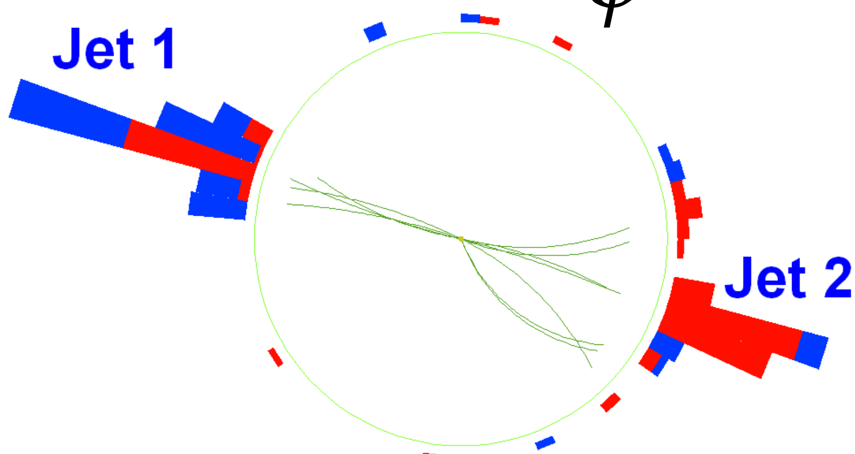
CMS PAS JME-10-001

In barrel region: calo tower (projective):
5X5 ECAL crystals + 1 HCAL cell

Dijet event candidate from 0.9 TeV run
- ECAL energy deposits (red)
- HCAL energy deposits (blue)
- E_T>0.3 GeV in calo tower
- Silicon tracks with p_T>1 GeV (green)

Transverse energy





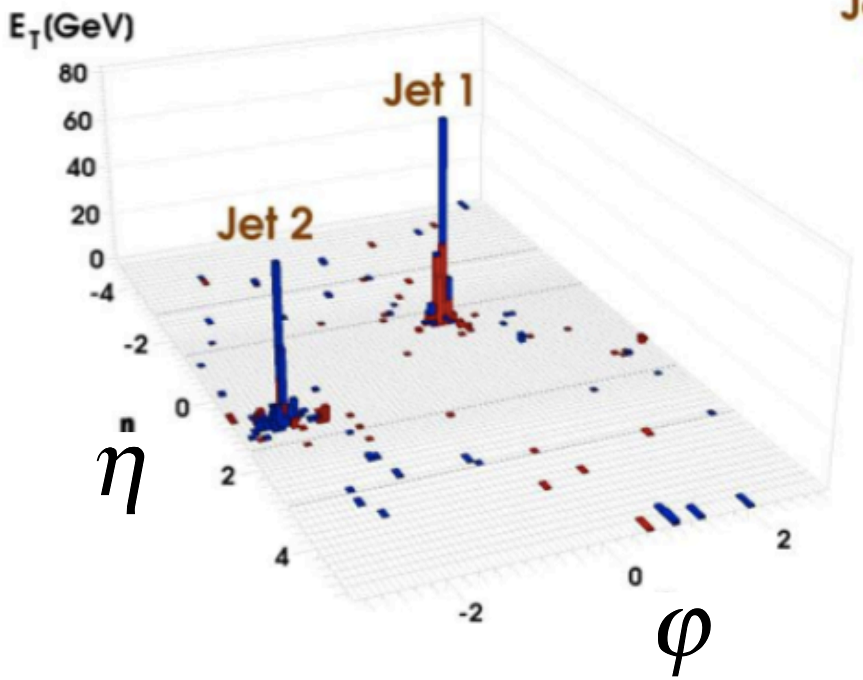
Algorithm	Jet ET values
Calorimeter only information	45 GeV, 37 GeV
Calorimeter + tracker	39 GeV, 33 GeV
Particle Flow	39 GeV, 31 GeV

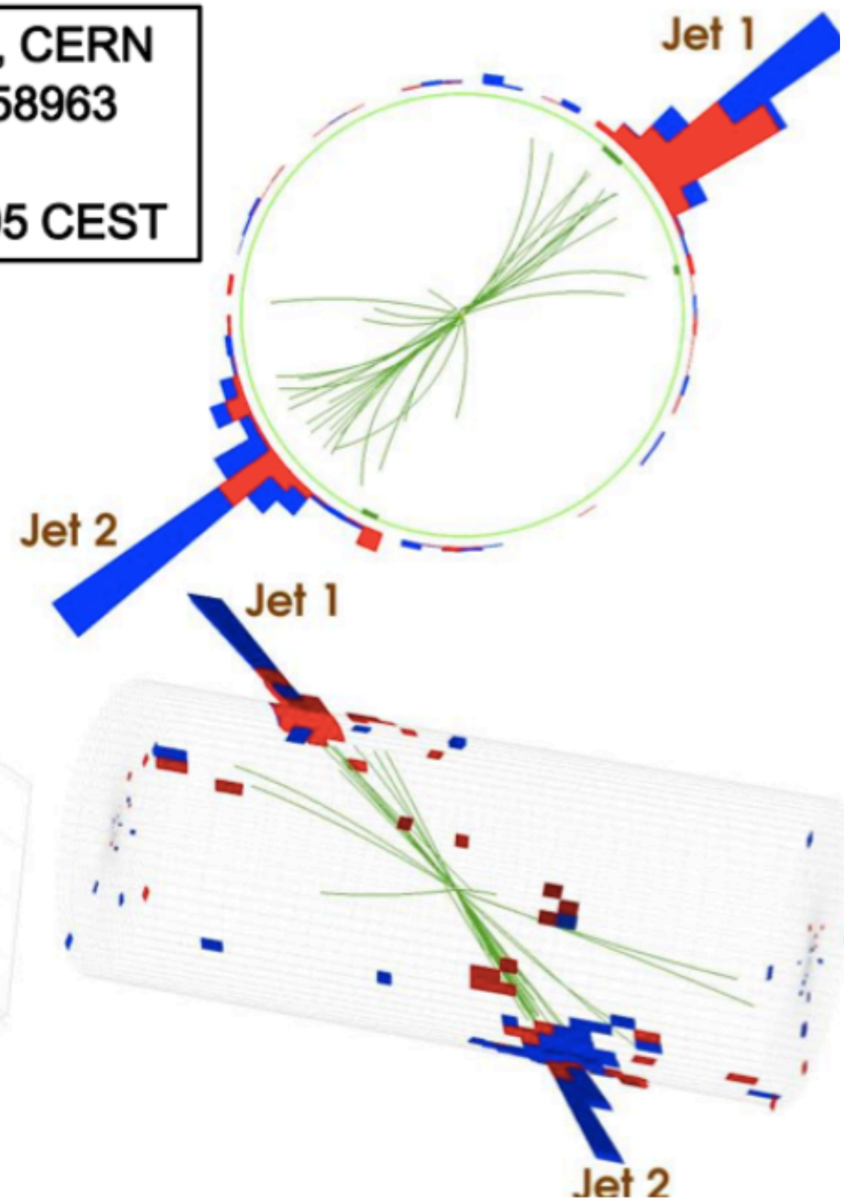
Dijet Event at 7 TeV

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

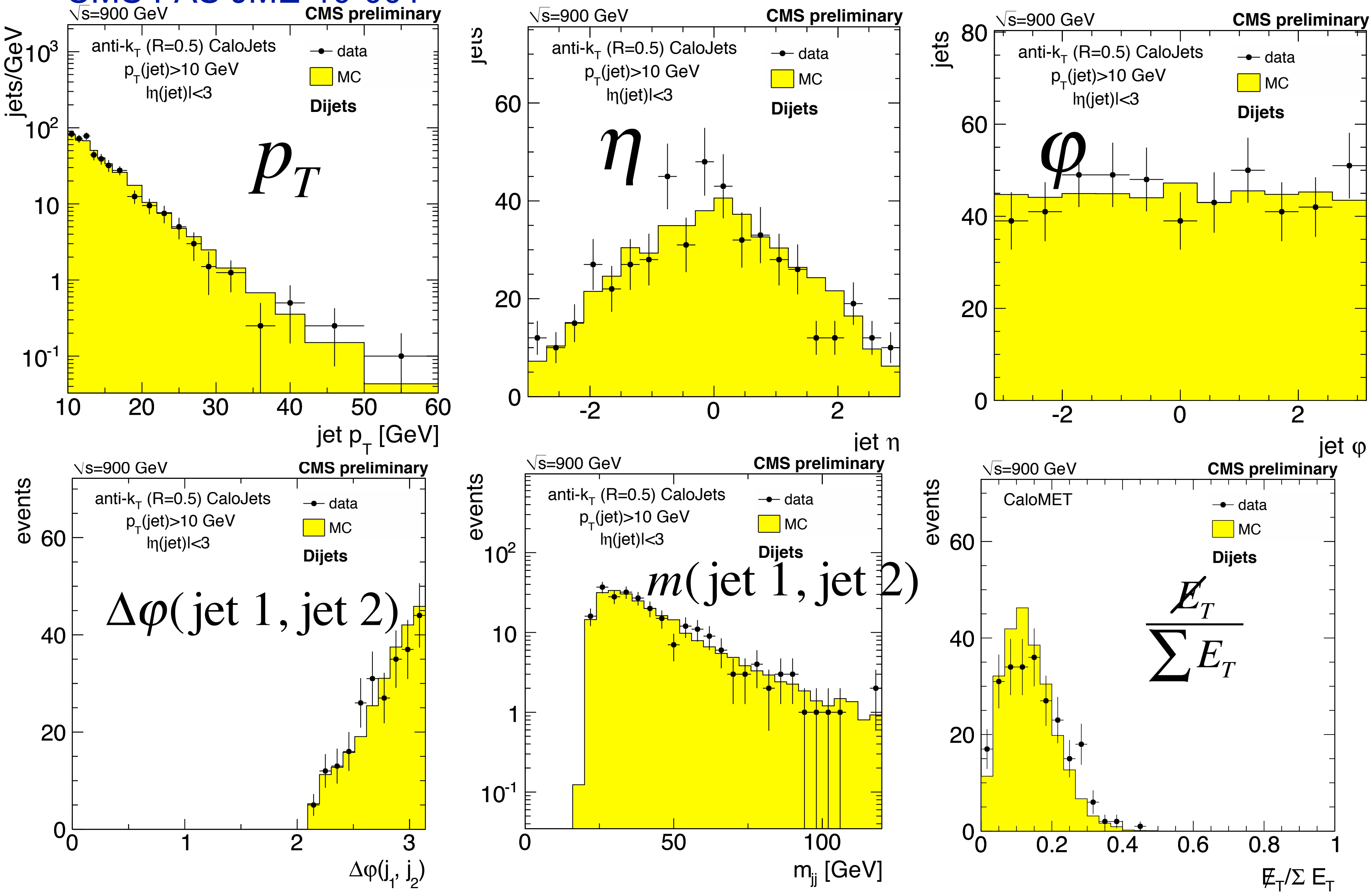
Di-jet mass = 764 GeV





CMS Di-jet Distributions √s=0.9 TeV

CMS PAS JME-10-001

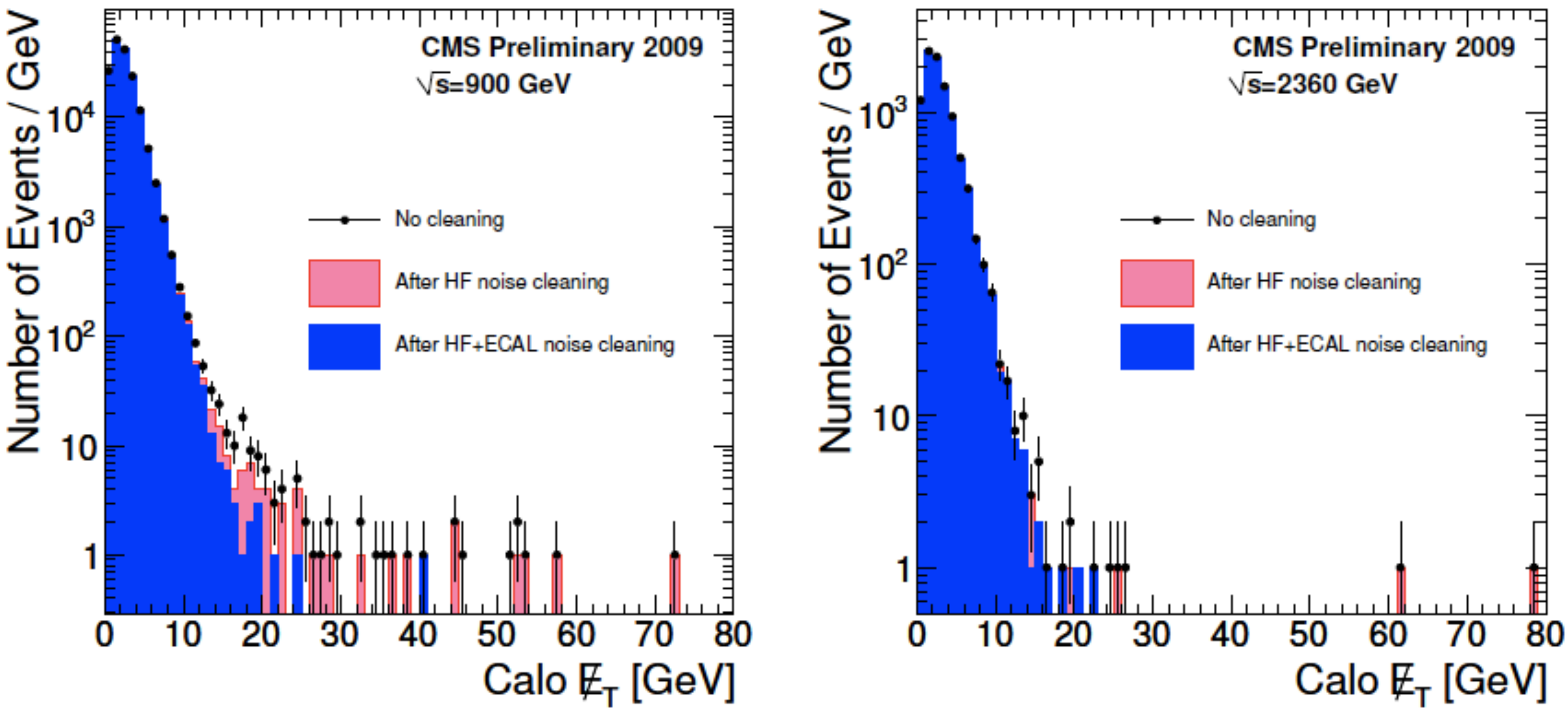


Calorimeter Performance: MET

CMS PAS JME-10-002

Identification and cleanup of noise hits in HF and ECAL.

DATA 0.9 TeV　　　　DATA 2.36 TeV



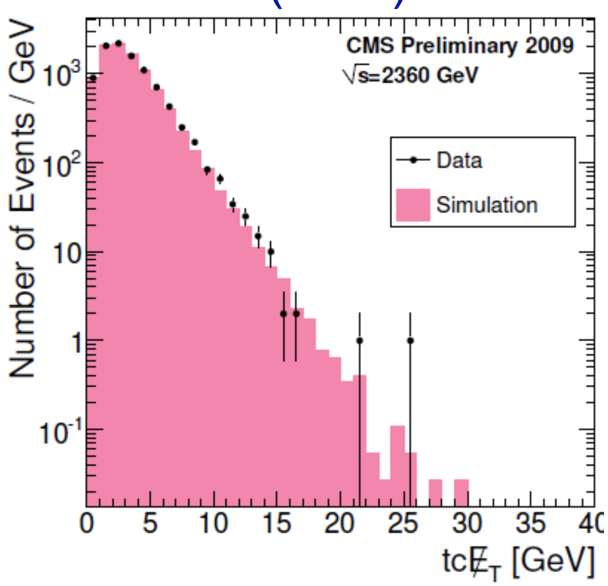
HF "noise" may be due to particles directly hitting the window of HF PMT; removed using redundant readout system.

Calorimeter Performance: MET

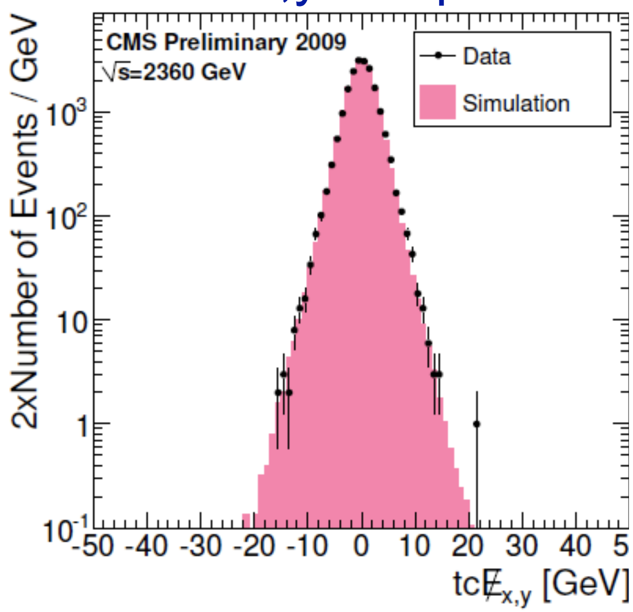
CMS PAS JME-10-002

Track-corrected MET (tcMET) after application of clean-up procedure identifying anomalous noise.

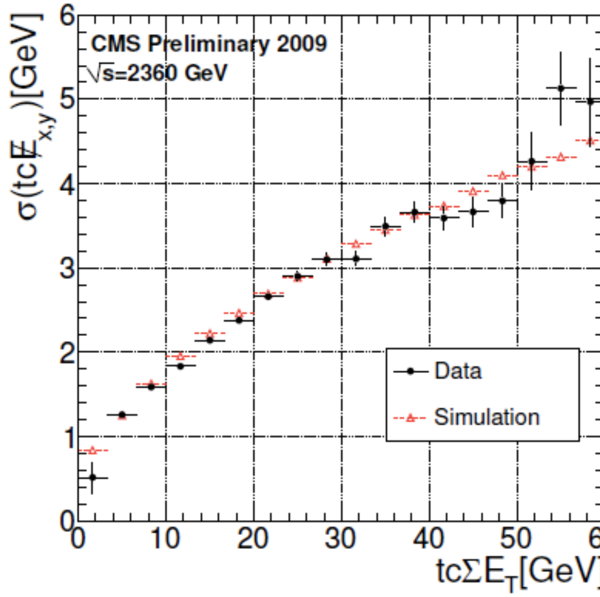
tcMET (GeV)



tcMET: x,y components



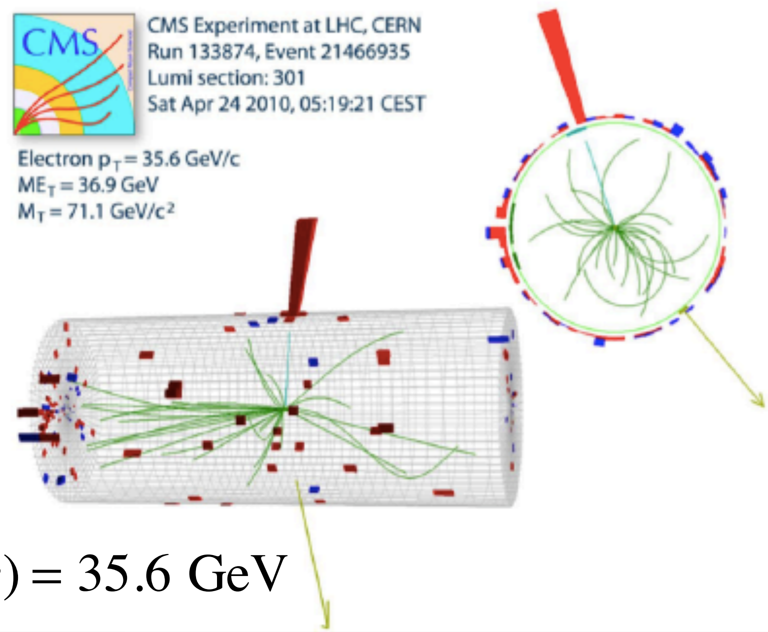
Resolution vs. ΣtcMET



W and Z Boson Candidates

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

W→eν: three candidates found

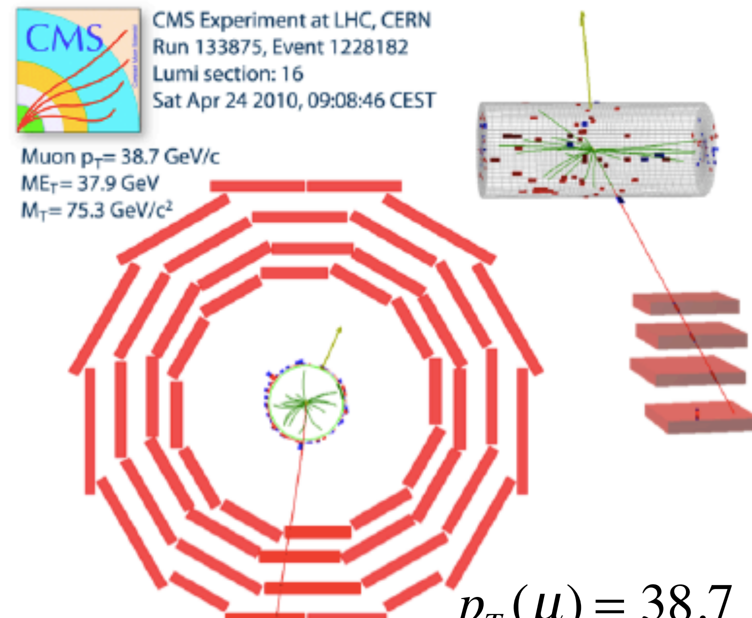


$p_T(e) = 35.6$ GeV

MET = 36.9 GeV

$m_T \quad = 71.1$ GeV

W→μν: three candidates found



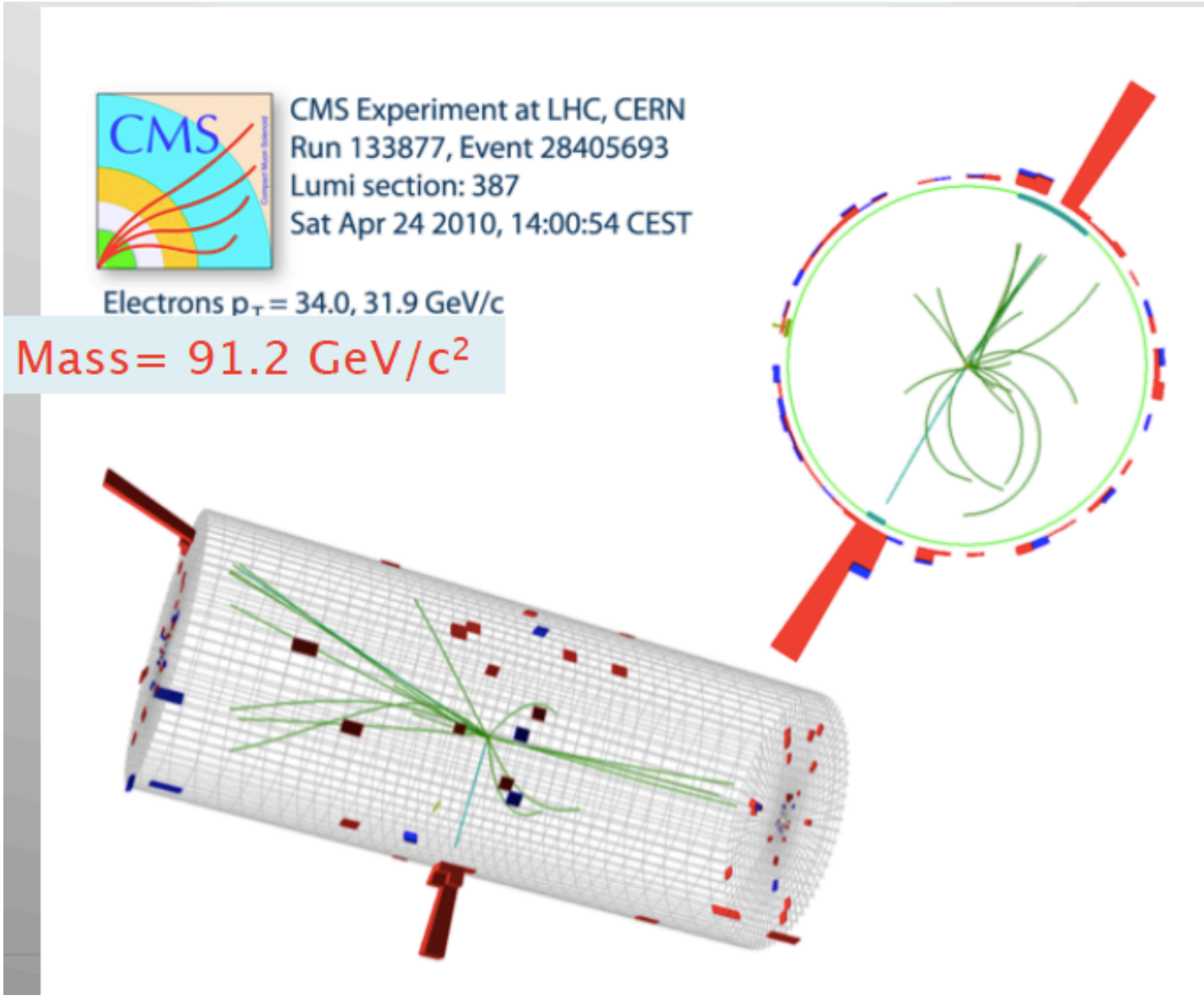
$p_T(\mu) = 38.7$ GeV

MET = 37.9 GeV

$m_T \quad = 75.3$ GeV

- 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.

Z Boson Candidate



Luminosity progression of 7 TeV Run

Summer 2010	End of 2010	Fall 2011
$\sim 1\ \mathrm{pb}^{-1}$	$\sim 100\ \mathrm{pb}^{-1}$	$\sim 1000\ \mathrm{pb}^{-1} = 1\ \mathrm{fb}^{-1}$

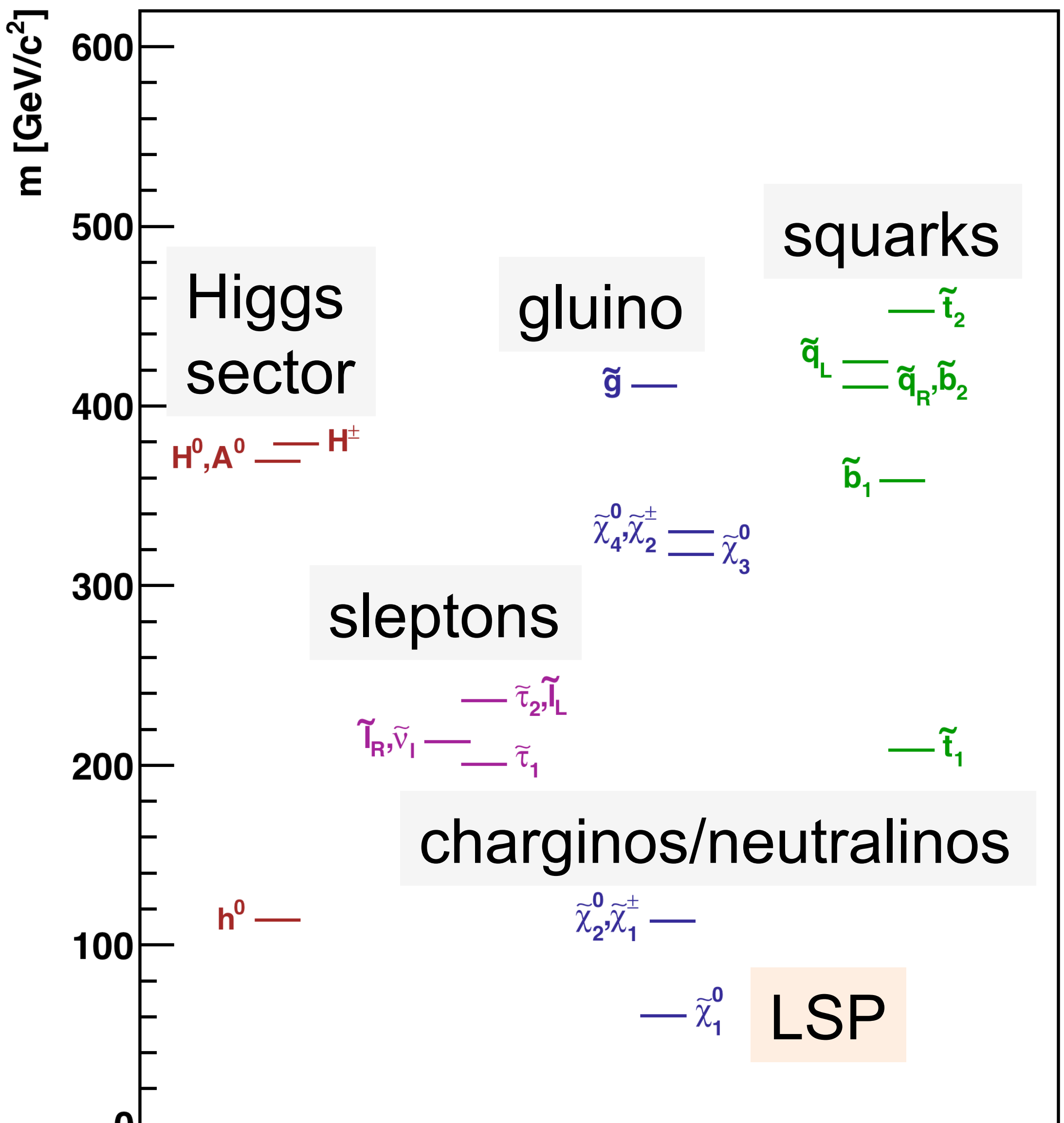
- QCD, b measurements
- W, Z cross sections
- Electroweak program
- Early ttbar observation
- Early searches, mainly Exotica

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

- \+ Higgs program

<u>Early SM studies are critical for laying the foundation for searches.</u>

mSUGRA benchmarks: LM0



- Light gluino, squarks

$$m(\tilde{g}) = 409\ \mathrm{GeV}$$

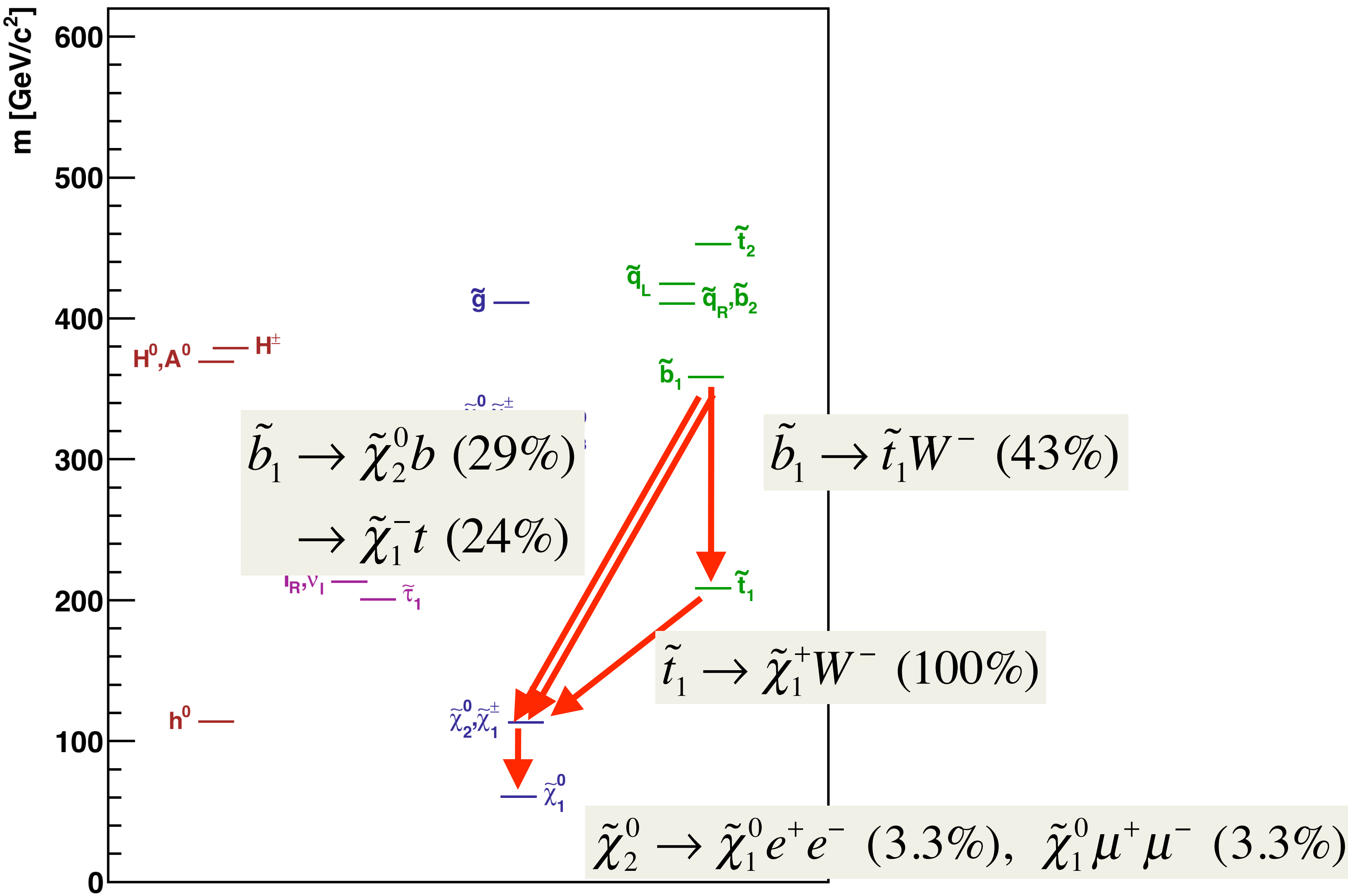
- "Large" cross sec., even at 7 TeV.

$$\sigma_{LO}(7\ \mathrm{TeV}) = 38.9\ \mathrm{pb}$$

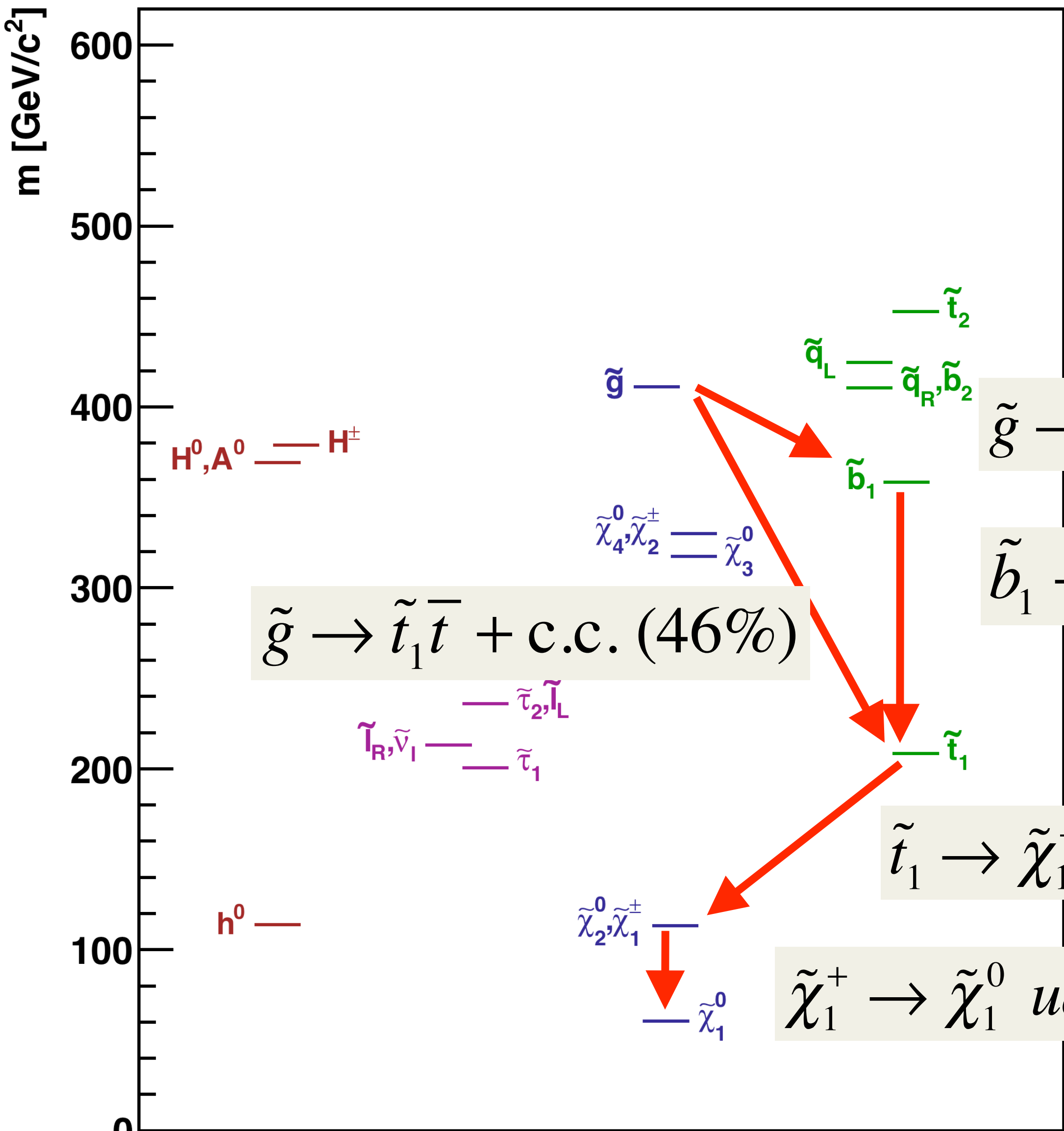
$$\frac{\sigma_{\mathrm{NLO}}}{\sigma_{\mathrm{LO}}} = k_{\mathrm{Prospino}} \simeq 1.4$$

- Roughly marks edge of current Tevatron exclusion results.

Typical decay patterns in LM0



Typical decay patterns in LM0



$$\tilde{g} \rightarrow \tilde{b}_1 \bar{b} + \text{c.c.}\ (54\%)$$

$$\tilde{b}_1 \rightarrow \tilde{t}_1 W^-\ (43\%)$$

$$\tilde{g} \rightarrow \tilde{t}_1 \bar{t} + \text{c.c.}\ (46\%)$$

$$\tilde{t}_1 \rightarrow \tilde{\chi}_1^+ W^-\ (100\%)$$

$$\tilde{\chi}_1^+ \rightarrow \tilde{\chi}_1^0\ u\bar{d},\ \tilde{\chi}_1^0\ c\bar{s}\ (66\%)$$

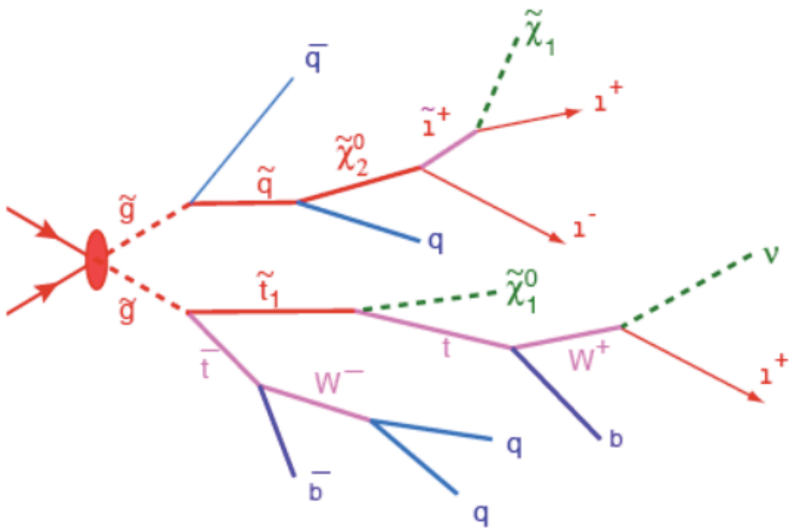
CMS mSUGRA benchmark points

Benchmark	σ(LO) [7/10/14 TeV] (pb)	M($\tilde{g}$) GeV	M($\tilde{b}_1$) GeV	M($\tilde{\chi}_1^0$) GeV	m_1/2 GeV	m_0 GeV
LM0	39/110	409	356	60	160	200
LM1	4.9/16/43	603	510	96	250	60
LM2	0.60/2.4/7.3	827	671	141	350	185
LM3	3.4/12/34	597	548	94	240	330
LM4	1.9/6.7/19.4	687	598	112	285	210
LM5	0.47/1.9/6.0	851	734	144	360	230
LM6	0.31/1.3/3.8	932	785	161	400	85
LM7	1.2/2.9/3.8	637	2450	94	230	3000
LM8	0.73/2.9/8.8	738	710	120	300	500
LM9	7.1/11.6/23.3	488	1008	65	175	1450

LM0 has tanβ=10, sign(μ)=+1, A_0=-400

Basic SUSY Search Topologies

Plan for first LHC physics run: coherent survey of simple, inclusive signatures involving MET. But also need to search for “exotic” signatures such as those arising from Split SUSY.



- Establish foundation for more complex searches. Signatures will expand to include b, τ, t.
- Data-driven background methods: pursue multiple approaches, <u>as many cross-checks as possible.</u>

<u>0 leptons</u>	<u>1 lepton</u>	<u>2 leptons</u>	<u>≥3 leptons</u>
• Exclusive jets • Inclusive Jets • Photons + Jets		• Like-sign • Opposite sign	

Analysis issues and approaches

- For many background measurements, we (mostly) do not want to rely on
  - Predicted cross sections (especially for QCD)
  - Predicted kinematical distributions
- Major emphasis on “Data-driven background determinations”
  - Rely on control samples in the data, sometimes with some assistance from Monte Carlo
  - May suffer from limitations (statistical or systematic) that reduce the precision of the measurement. Will evolve rapidly w/more data.

All hadronic exclusive Jets + MET

CMS PAS SUS-09-001

L. Randall and D. Tucker-Smith, "Dijet Searches for Supersymmetry at the LHC," Phys. Rev. Lett. **101 (2008) 221803.**

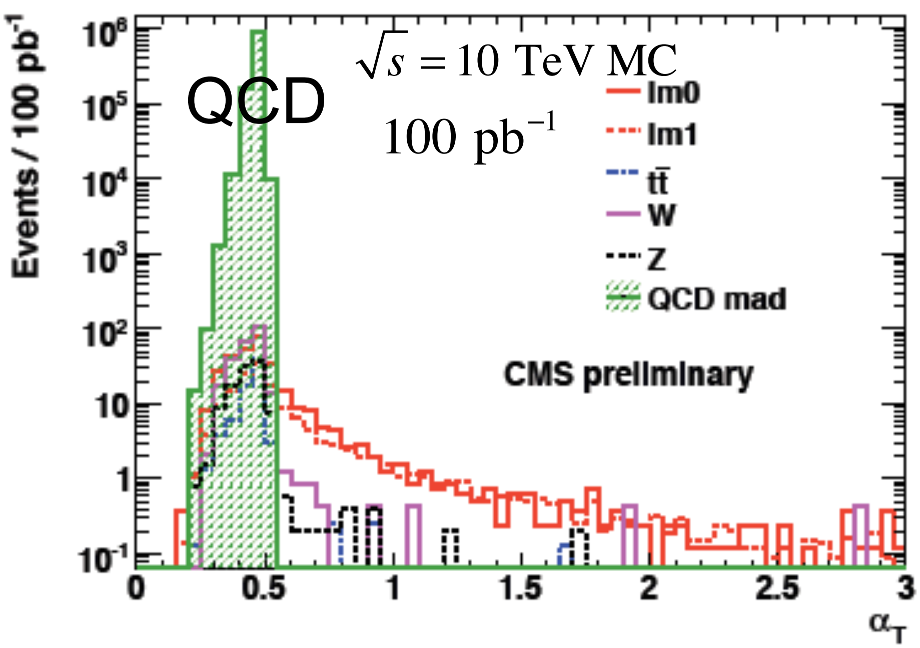
- Dijet analysis

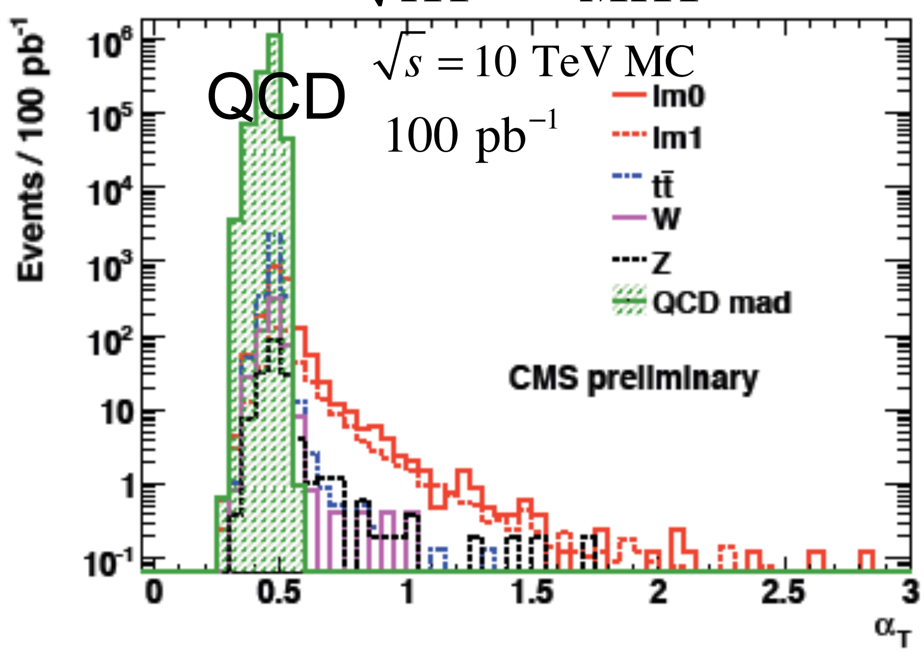
$$\alpha_T \equiv E_T^{j_2} / M_T(j_1 j_2) = \frac{\sqrt{E_T^{j_2} / E_T^{j_1}}}{\sqrt{2(1-\cos\Delta\varphi)}}$$

- N=3-6 jets: form two pseudo-jets
- minimize

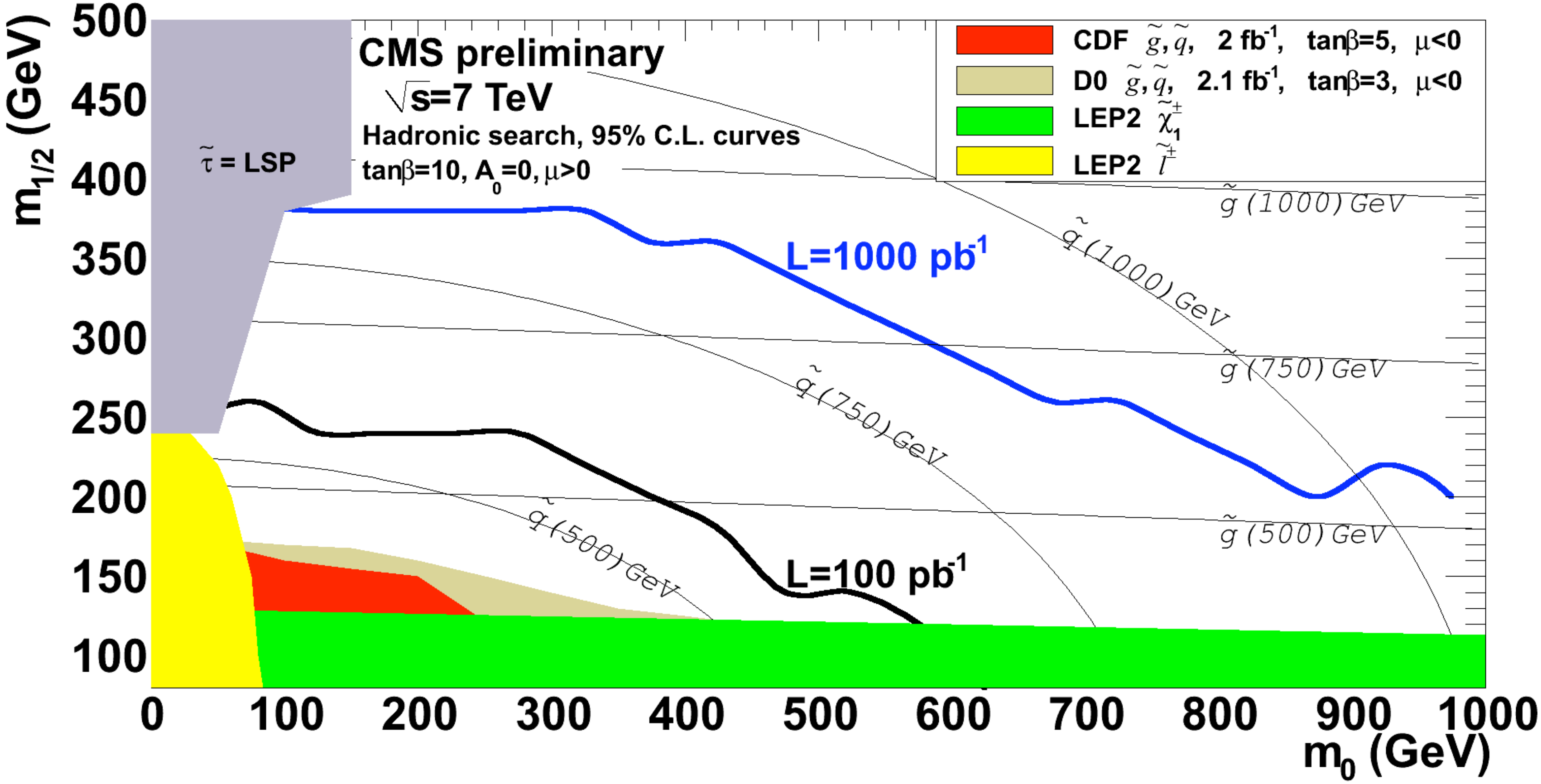
$$\Delta HT = E_T^{pj1} - E_T^{pj2}$$

$$\alpha_T \equiv \frac{1}{2}\frac{HT - \Delta HT}{\sqrt{HT^2 - MHT^2}}$$





Estimated Sensitivity of Inclusive All-Hadronic SUSY Search: tanβ=10



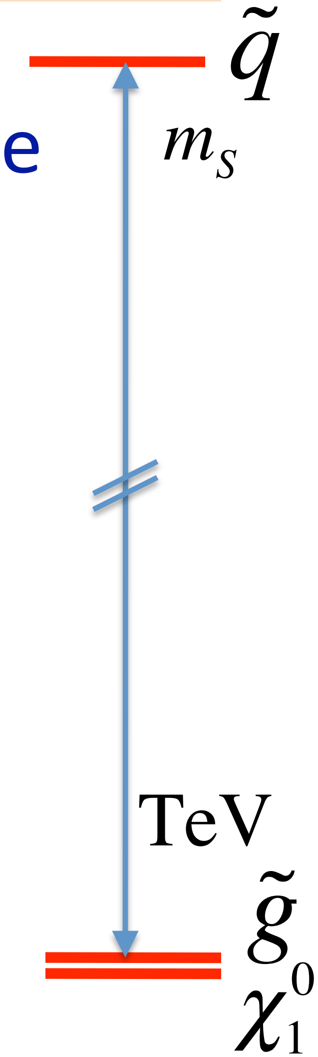
Systematic uncertainty assumed to be 50% overall.

Separate tight selections for 100 pb^{-1} and 1 fb^{-1}.

Search for Stopped Gluinos

CMS PAS EXO-09-001

See N. Arkani-Hamed, S. Dimopoulos, arXiv:hep-th/0405159v2



- In Split SUSY, the masses of the scalars are at a very high SUSY breaking scale, while the gluino can be vastly lighter

  $\tilde{g} \to \tilde{q}^* \overline{q}; \;\; \tilde{q}^* \to q\chi_1^0$ (3 body decay)

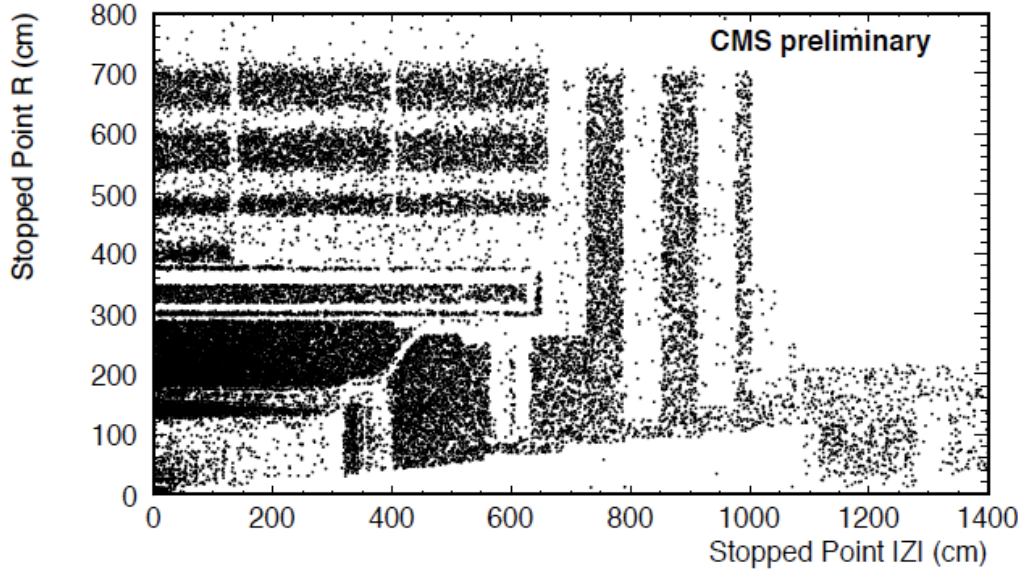
- Motivates search for long-lived particles (gluinos) that stop in the detector and decay well after the pp collision time.
- Gluinos fragment into R-hadrons, which could stop in the detector and decay seconds, days, or weeks later! $\Delta_{\tilde{g}}^{++} \to \tilde{g}u(uu) \to g\chi_1^0 u(uu)$

Search for Stopped Gluinos: Method (I)

CMS PAS EXO-09-001

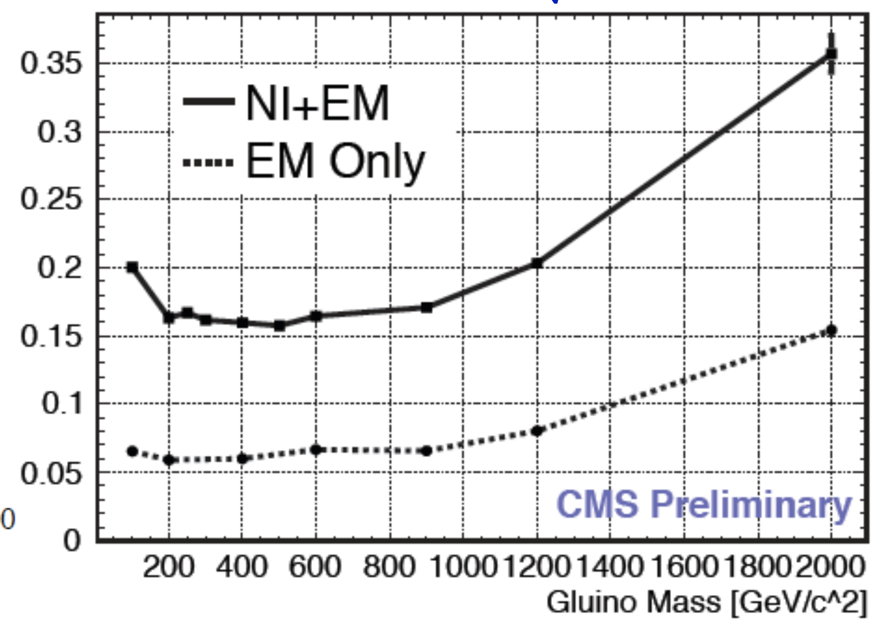
Where do R-hadrons stop?

Cloud model: R. Mackeprang & A. Rizzi
Eur. Phys. J C50 (2007) 055007, arXiv:hep-ph/0612161



R-hadron stopping efficiency

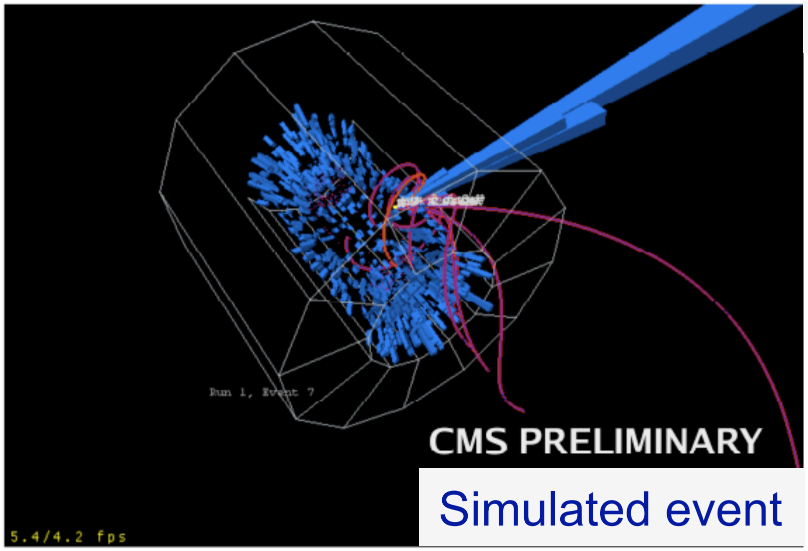
$\sqrt{s} = 10$ TeV



- Offline analysis based on hadronic calorimeter (HCAL) energy deposit, shower shape, and pulse shape.
- Trigger efficiency: 31.8%. Efficiency after all cuts: 16.4% of stopped gluinos. $\sqrt{s} = 10\ \text{TeV}, m(\tilde{g}) = 300\ \text{GeV}, m(\chi_1^0) = 50\ \text{GeV}$

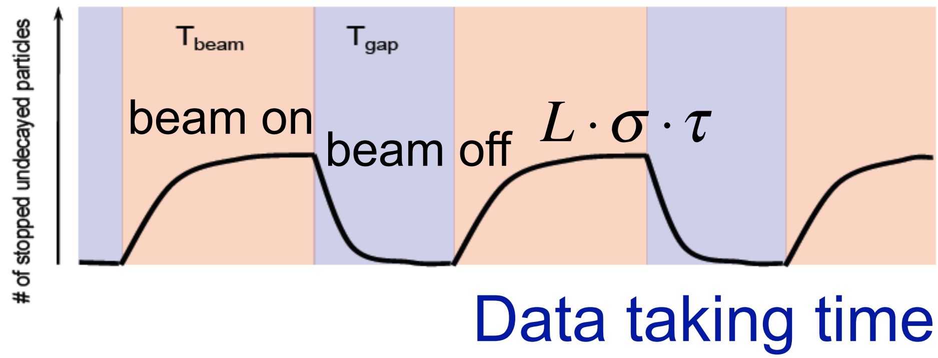
Search for Stopped Gluinos: Method (II)

CMS PAS EXO-09-001



Simulated event

Num stopped undecayed particles

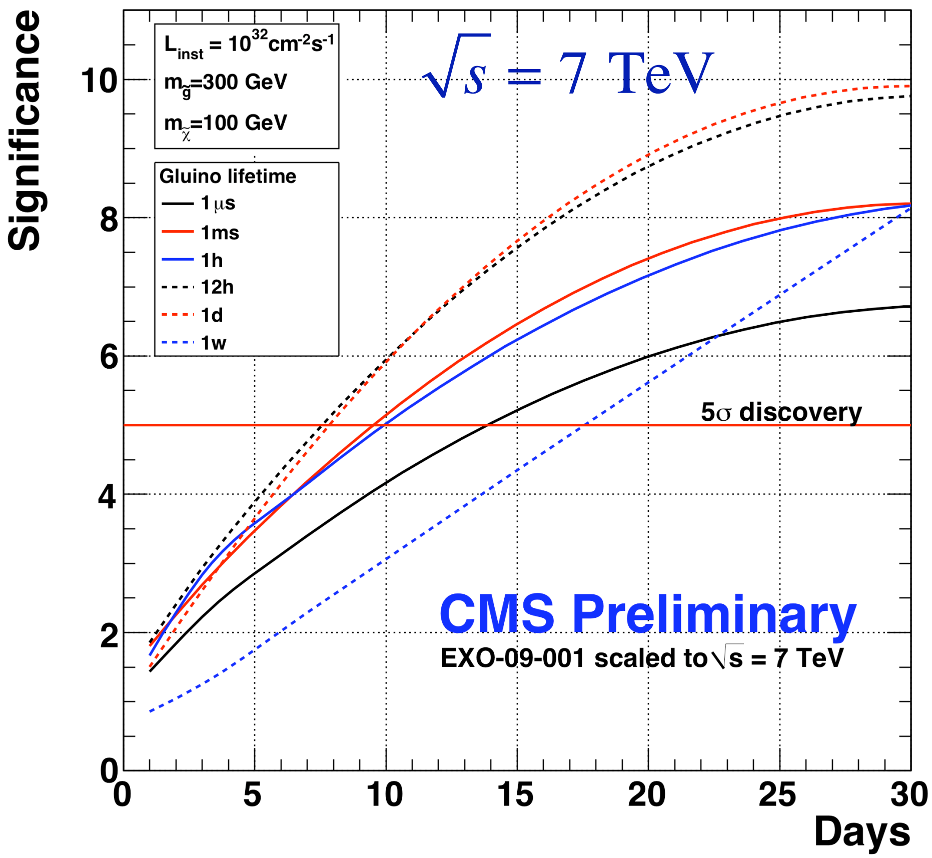


$$\frac{S}{\sqrt{B}} \propto \frac{L \cdot t}{\sqrt{t}} \propto L\sqrt{t} \qquad t_{5\sigma} \propto L^2$$

- Trigger: calorimeter (HCAL) energy + out of LHC collision times (beam gaps+interfill periods). Use coincidence of beam pick-up monitors upstream of CMS to veto pp.
- Dominant background: cosmic rays+instrumental noise (both studied during extensive CMS cosmic ray running in 2008-2009). $R_{background} \approx 4\times10^{-4}$ Hz.

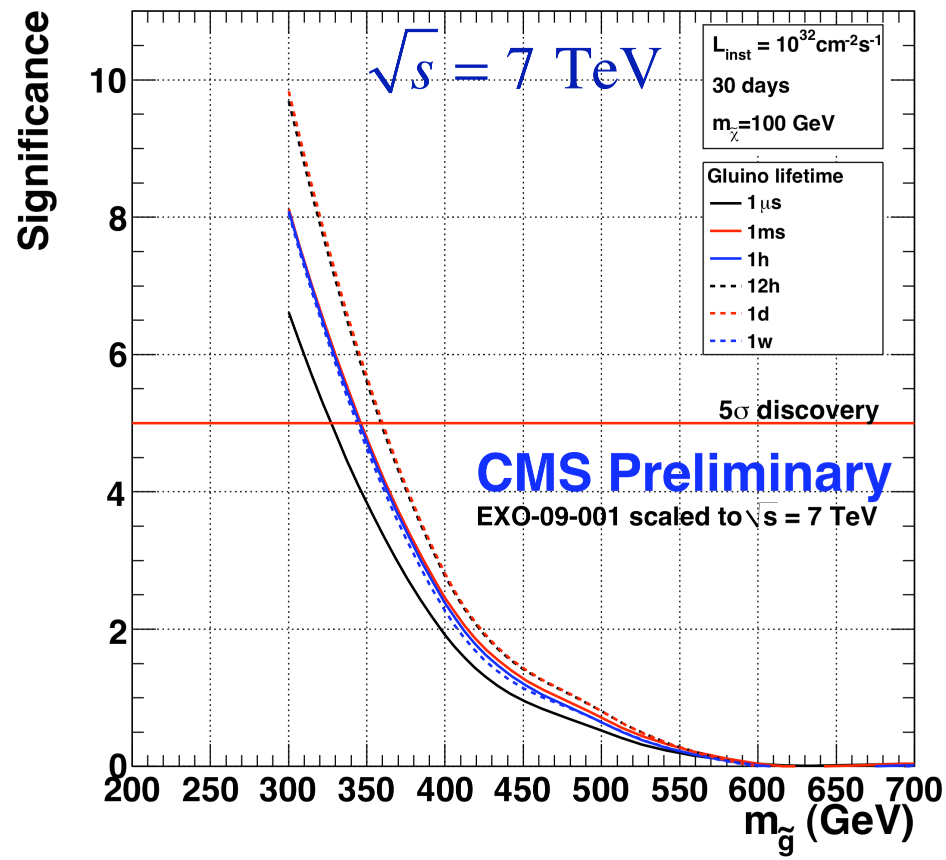
Search for Stopped Gluinos: Sensitivity

Significance vs. running time for various gluino lifetimes



CMS PAS EXO-09-001 scaled from 10 TeV → 7 TeV

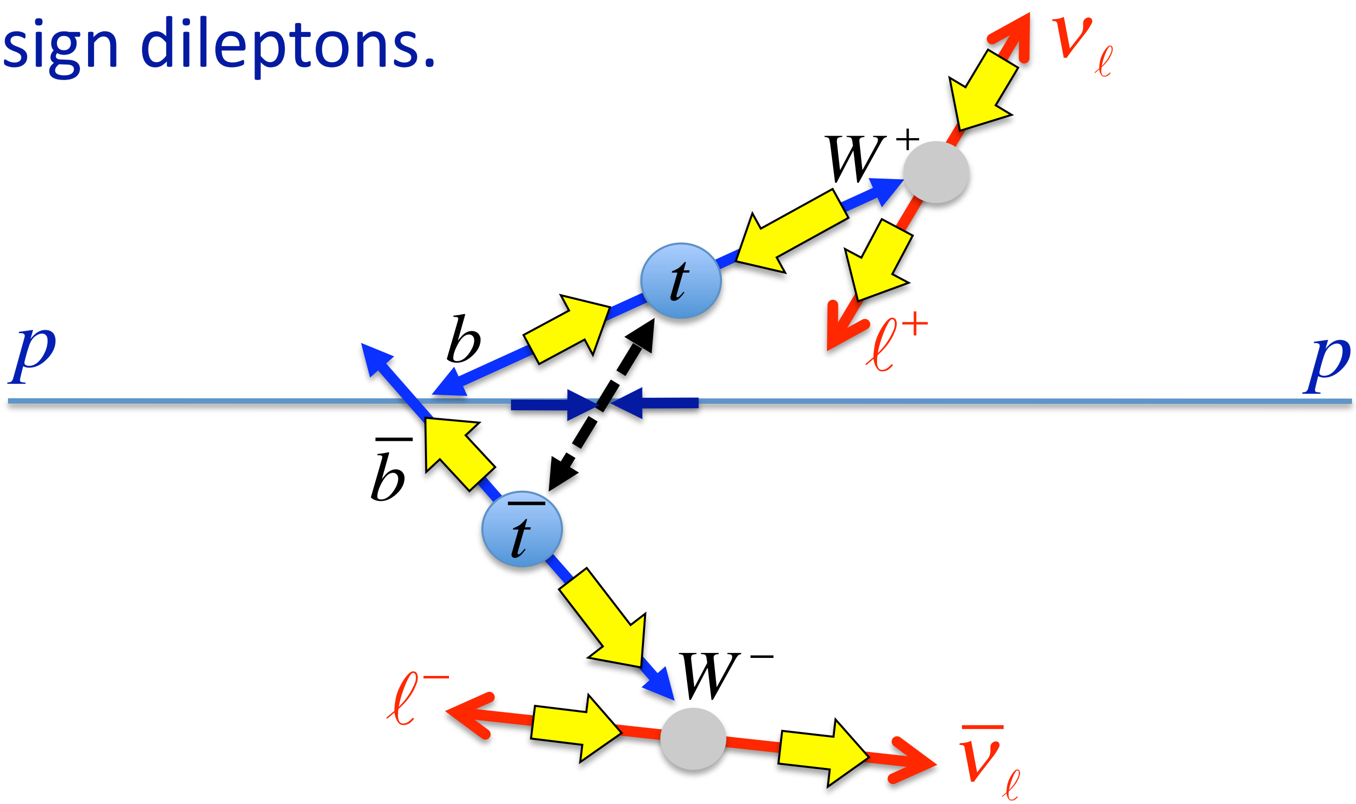
Significance vs. gluino mass



Beamgap exp't: τ≈1μs→hours; interfill exp't: τ≈hours→weeks

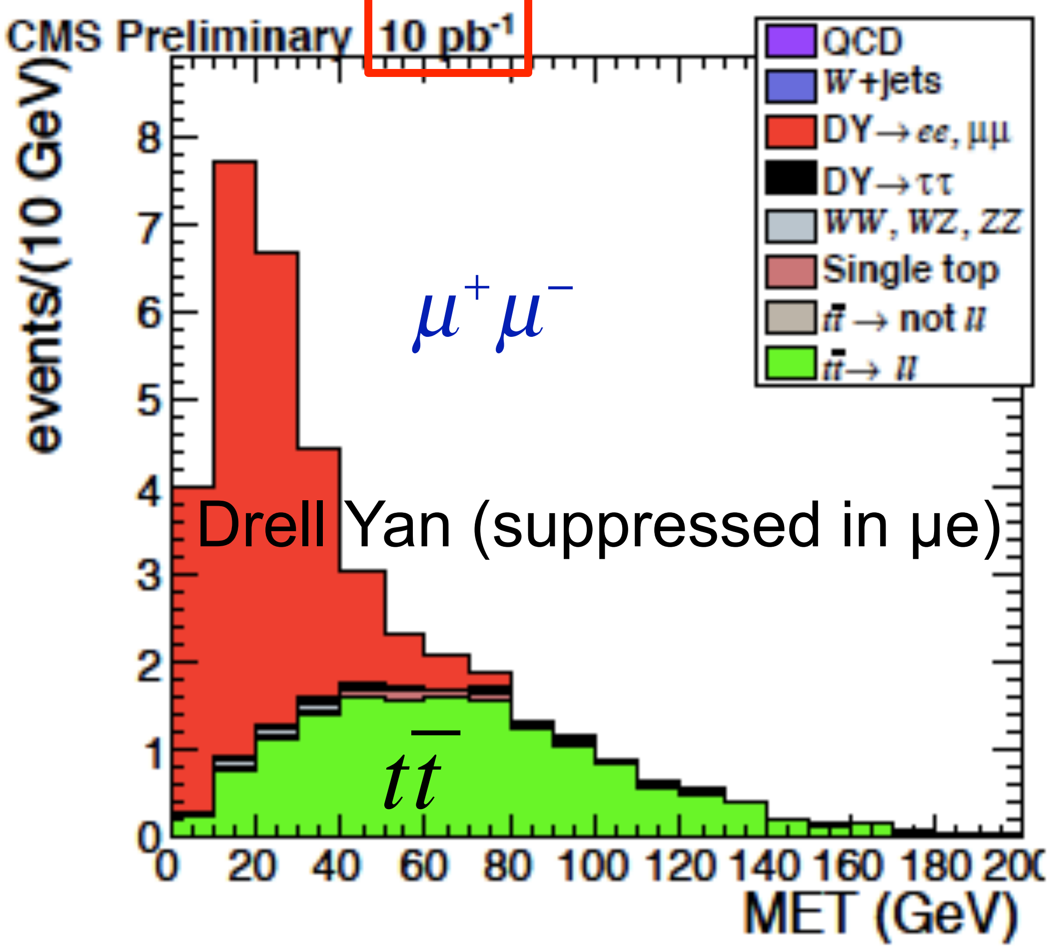
$pp \rightarrow t\bar{t} + X$ in the dilepton channel

- Key SM benchmark process
- In channels with leptons, have substantial p_T^{miss}.
- Topology is SUSY-like: multiple jets + p_T^{miss} + leptons.
- Is a key background in nearly all SUSY searches, even like-sign dileptons.



$pp \to t\bar{t} + X$ in the dilepton channel

CMS PAS TOP-09-002 $\sqrt{s} = 10$ TeV Monte Carlo

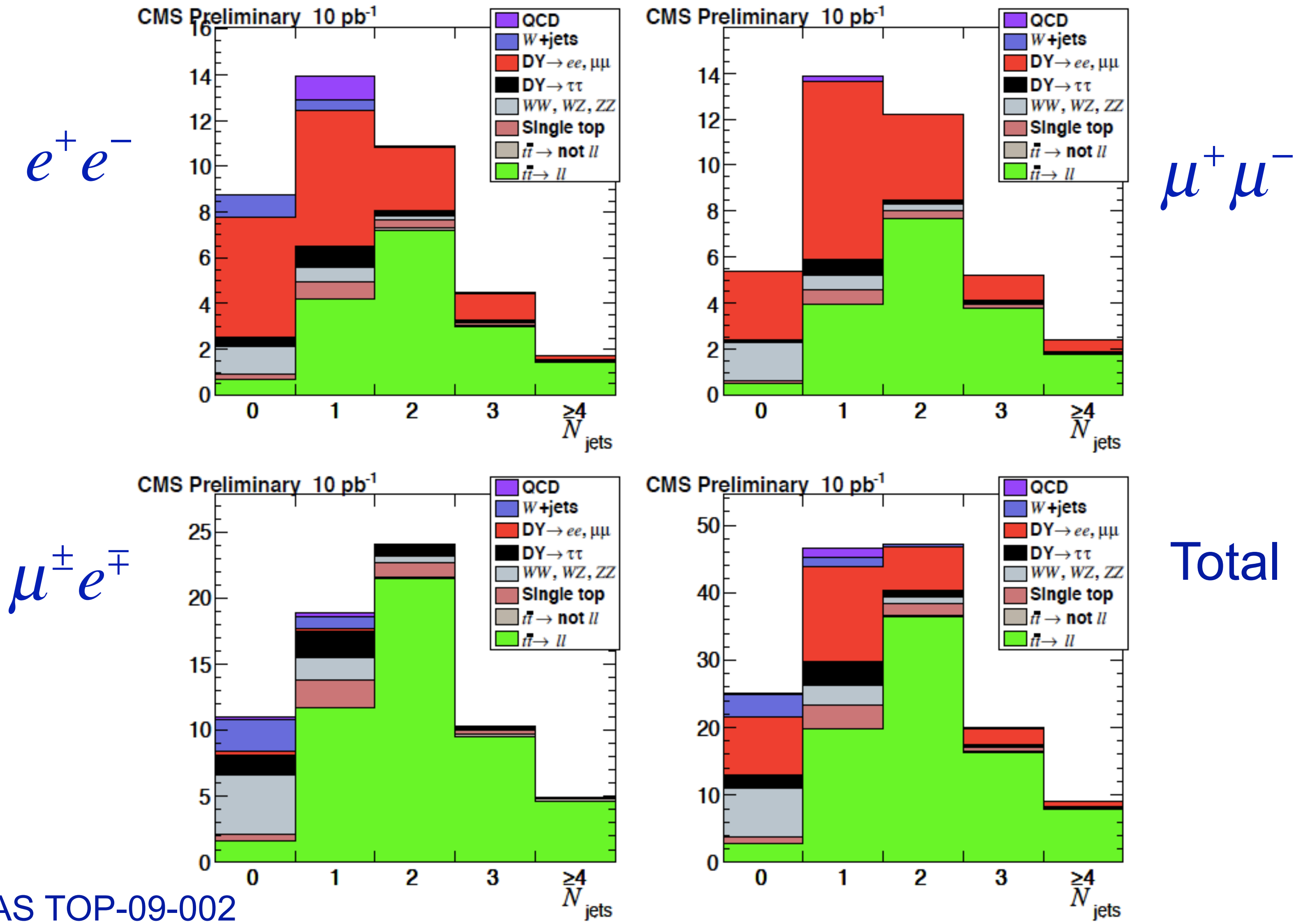


Baseline $t\bar{t}$ selection:

- Trigger: 1μ (9 GeV) or 1e (15 GeV) trigger
- Two opp sign, isolated leptons, p_T>20 GeV
- μμ, μe, ee channels
- ≥2 jets p_T>30 GeV
- Z mass veto (±15 GeV)

Background level & composition is very sensitive to Njets required and to whether the lepton flavors are the same.

pp→tt+X dileptons: jet multiplicities



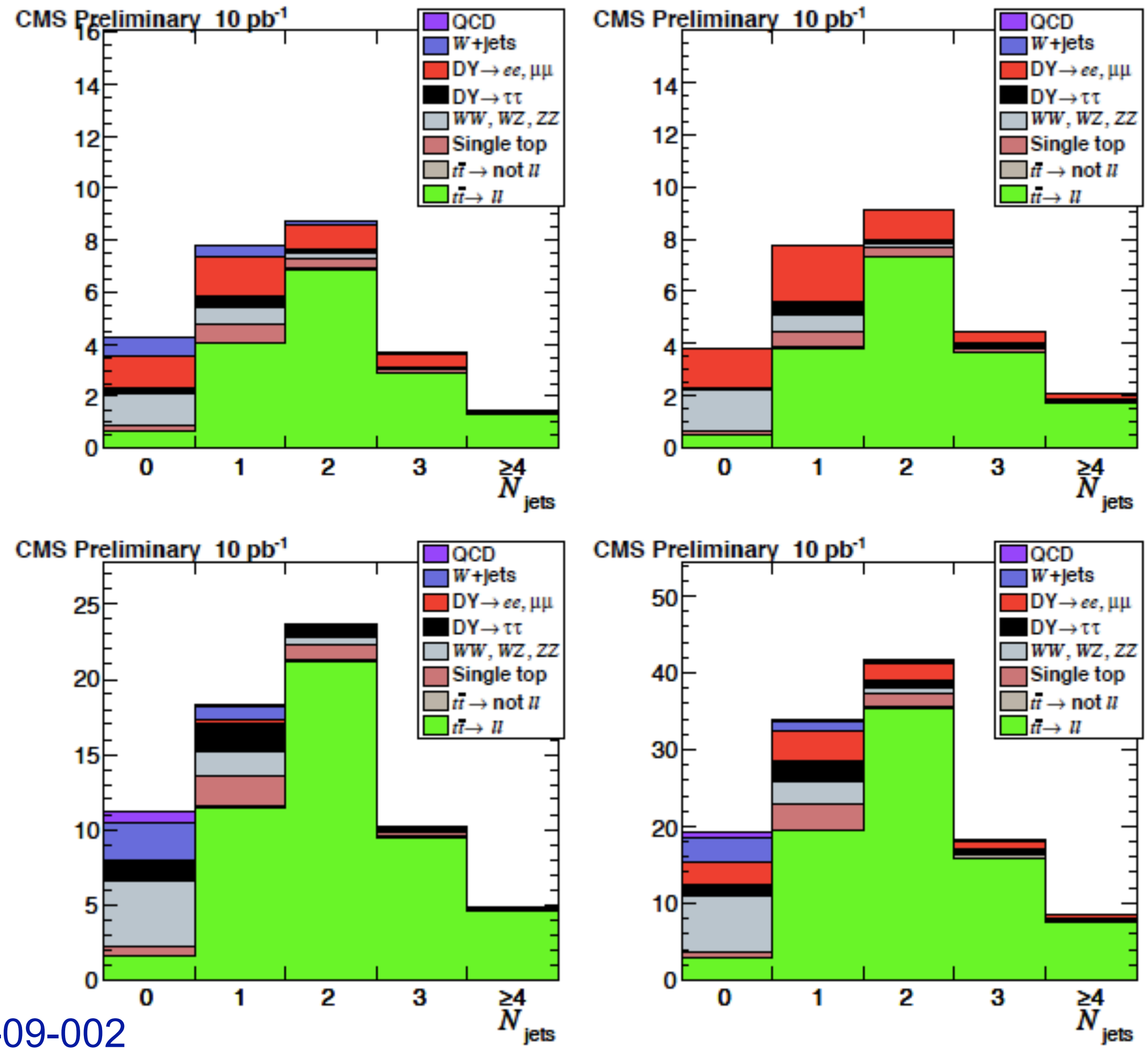
CMS PAS TOP-09-002

Signal purity highly dependent on N_{jets}; so far no MET requirement.

pp → tt+X dileptons: apply MET cuts

e^+e^- $\mu^+\mu^-$

$\mu^\pm e^\mp$ Total

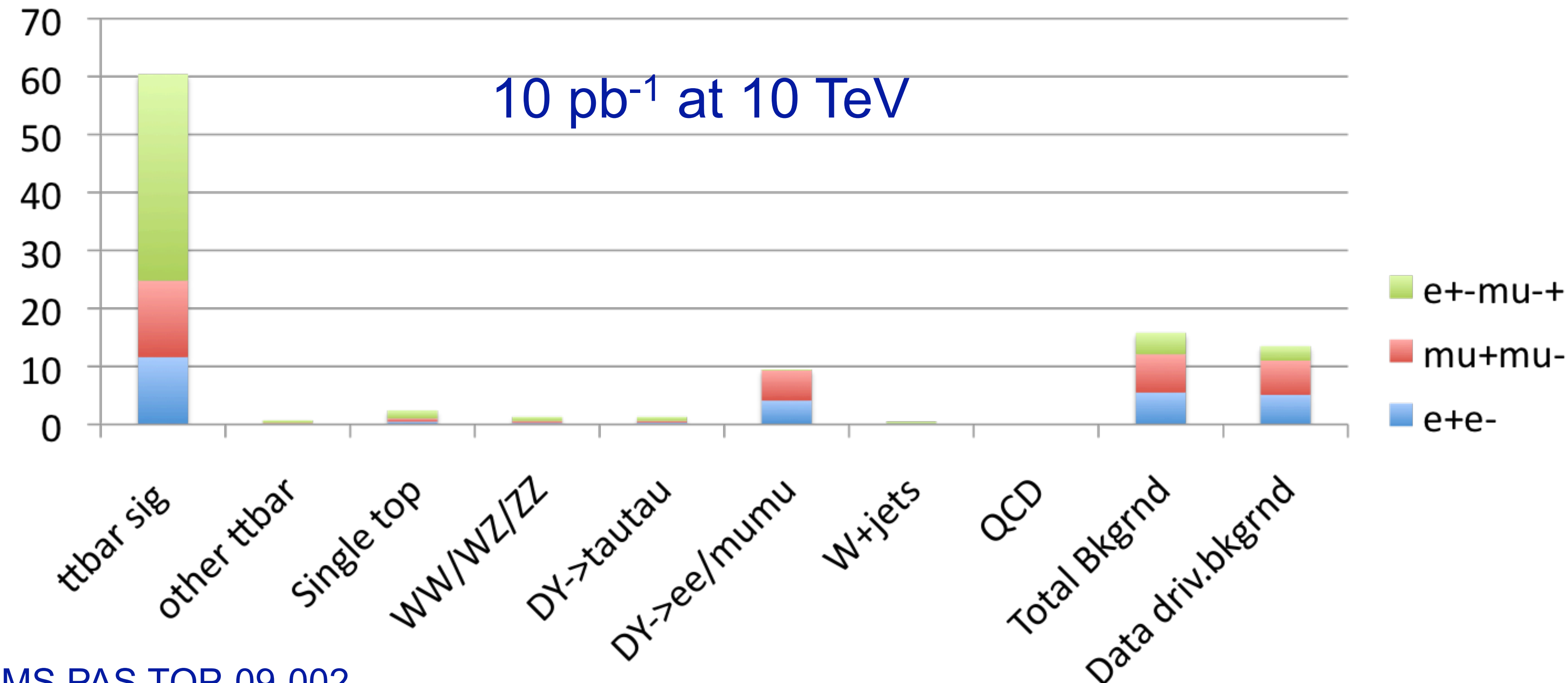


CMS PAS TOP-09-002

MET requirement suppresses Drell Yan, bkgnd is small for Njets≥2

pp→ tt+X dileptons: expectations

- Drell-Yan estimated from Z control sample (MET)+ +Monte Carlo R(Zoff/Zon).
- S/B=9/1 in emu mode, which dominates precision. 10 pb^{-1}→15% stat error all modes



CMS PAS TOP-09-002

SUSY in Opposite-Sign Dileptons

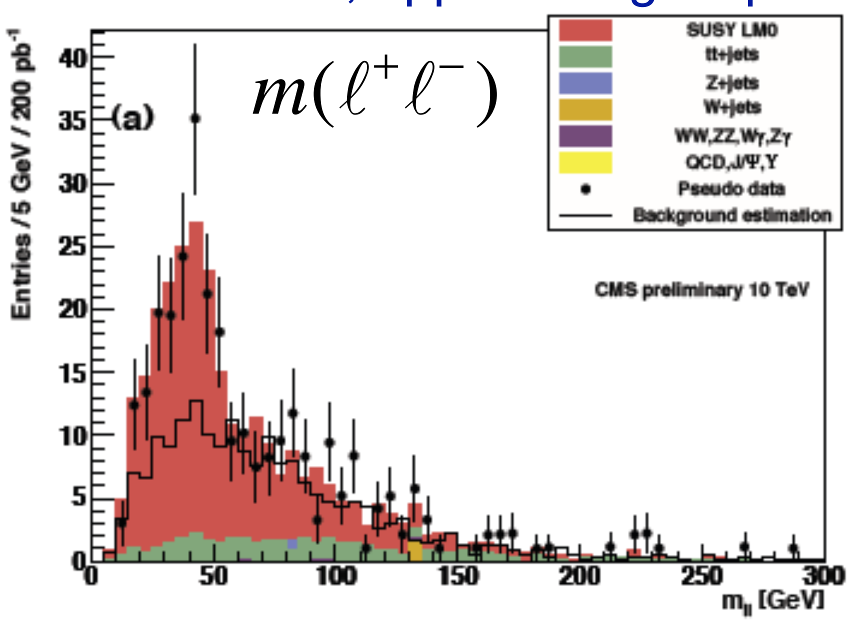
- Traditional approach: search for opp. sign, same flavor leptons from correlated SUSY production:

$$\tilde{\chi}_2^0 \rightarrow \ell^+ \tilde{\ell}^-; \quad \tilde{\ell}^- \rightarrow \ell^- \tilde{\chi}_1^0$$

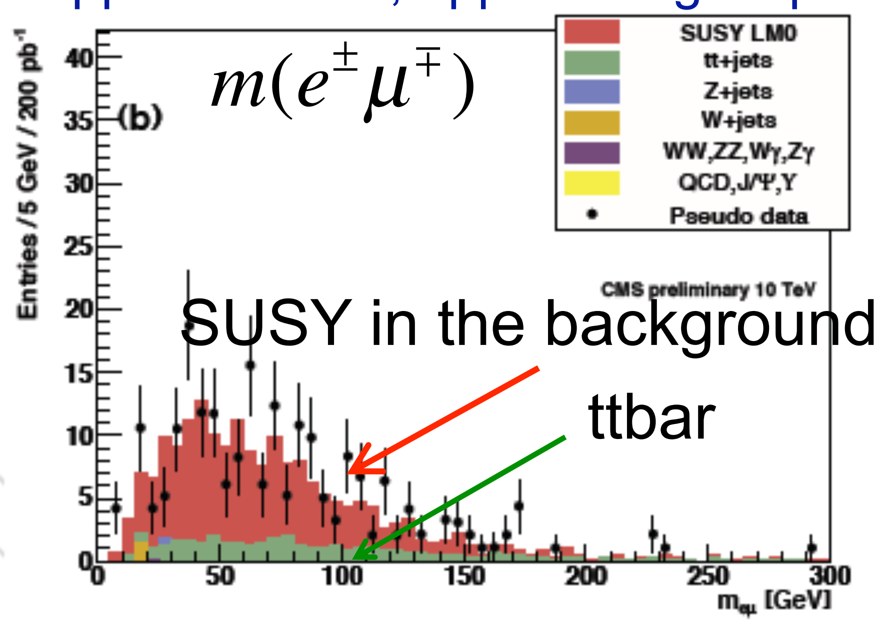
slepton on-shell: seq. 2-body decays
slepton off-shell: 3-body decay

- Background estimations from eμ control sample.

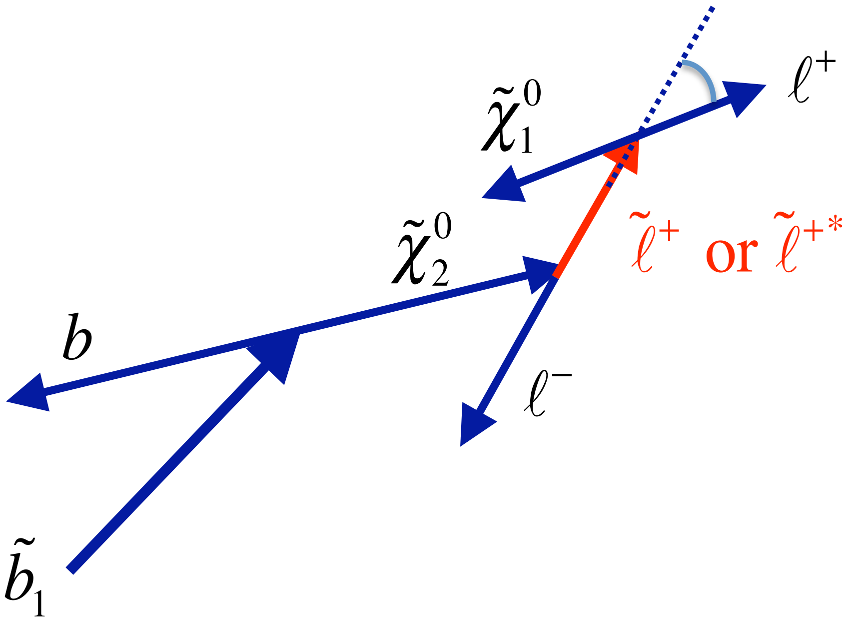
Same flavor; opposite sign leptons



Opposite flavor; opposite sign leptons



Opposite Sign Dileptons: Kinematics



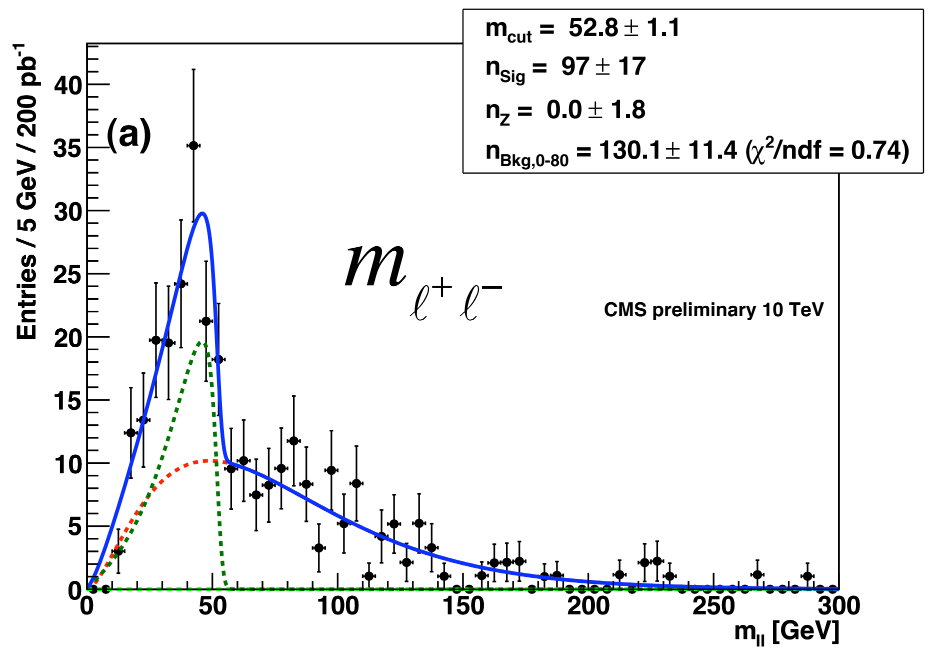
Sequential 2-body decay

$$m_{\ell^+\ell^-,\max} = \sqrt{\left(1-\frac{m_{\tilde{\ell}}^2}{m_{\tilde{\chi}_2^0}^2}\right)\left(1-\frac{m_{\tilde{\chi}_1^0}^2}{m_{\tilde{\ell}}^2}\right)} \cdot m_{\tilde{\chi}_2^0}$$

3-body decay

$$m_{\ell^+\ell^-,\max} = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$$

$\sqrt{s} = 10$ TeV 200 pb^{-1} LM0 MC signal

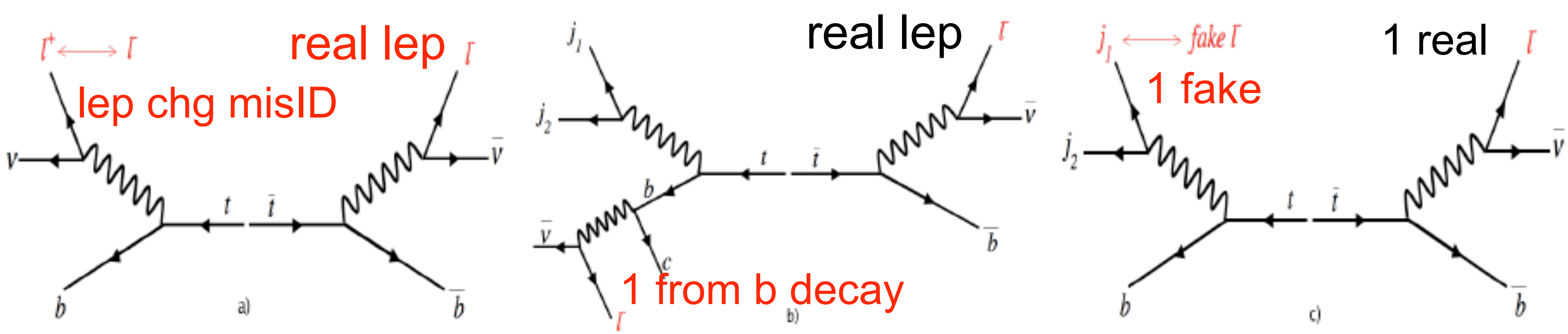


•Can extract endpoint of spectrum
with good precision.

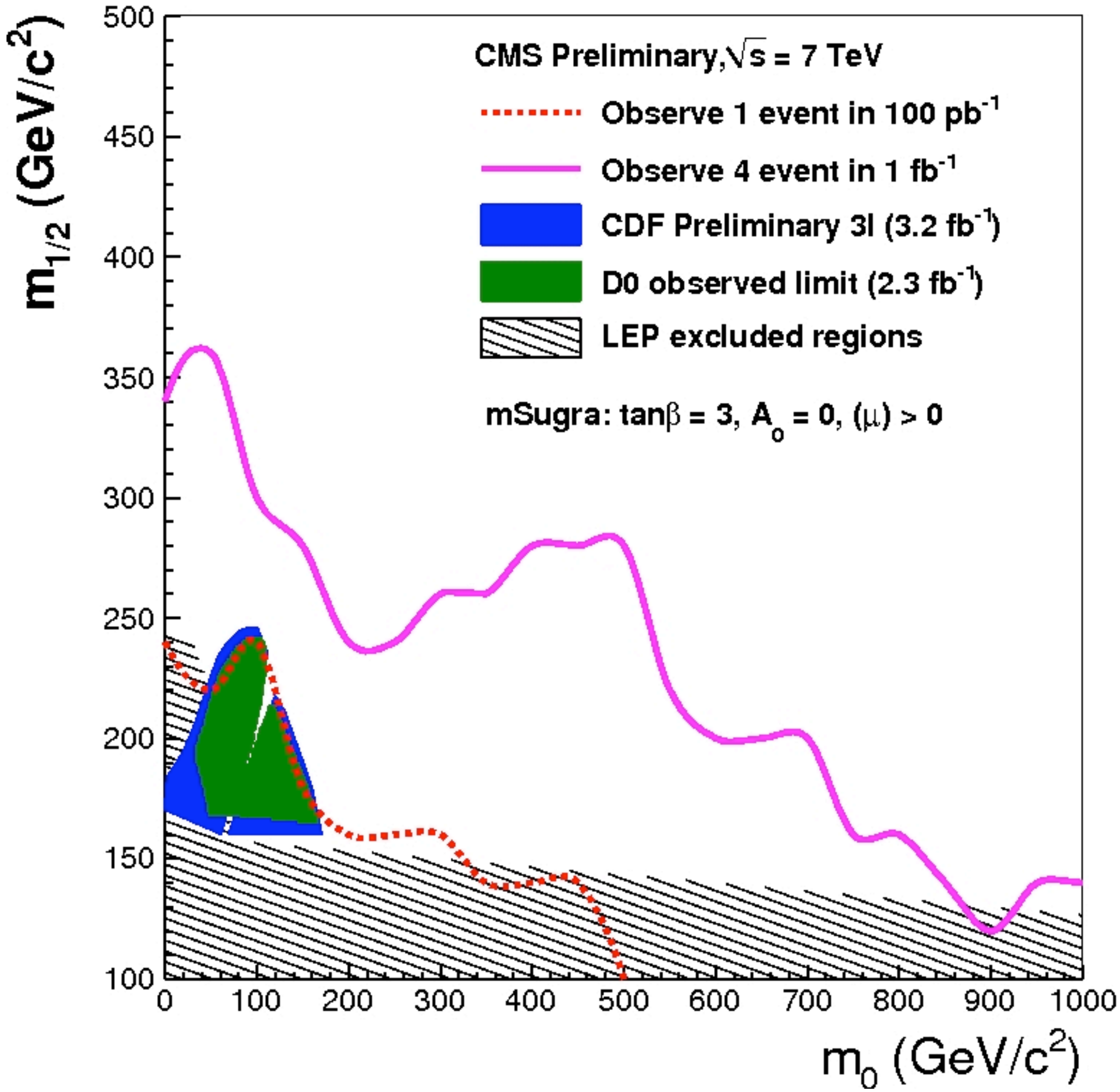
Not easy to distinguish between 2- and 3-body spectra w/this size data sample.

Search for Like-Sign Dileptons

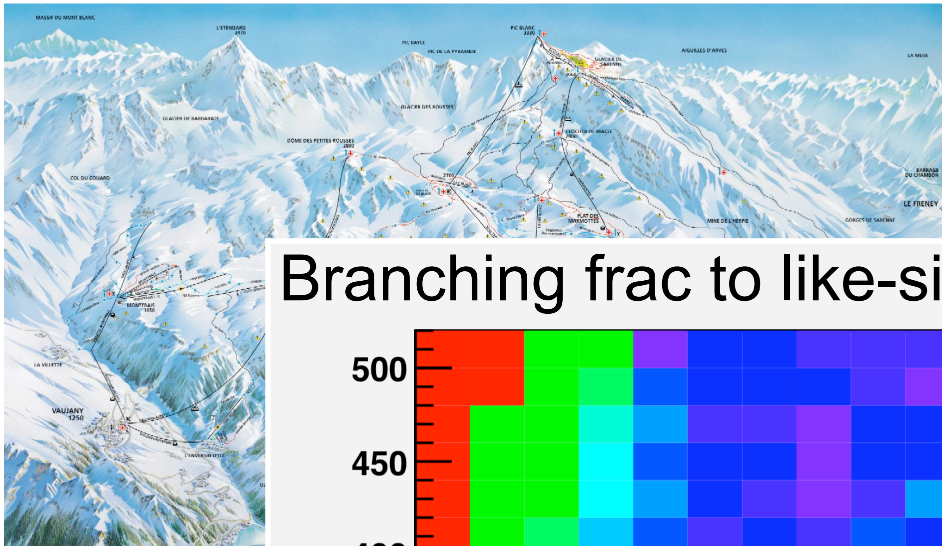
- Classic SUSY signature; very low SM background.
- Reliable data-driven background estimate is critical.
- Basic cuts ee/eμ/μμ with pT>10, pT>20 GeV; Z veto; ≥3 jets ET>30; SumET(jets)>200 GeV, ETmiss>80 GeV
- Key issues: fake leptons & electron charge misID
- Largest background: ttbar

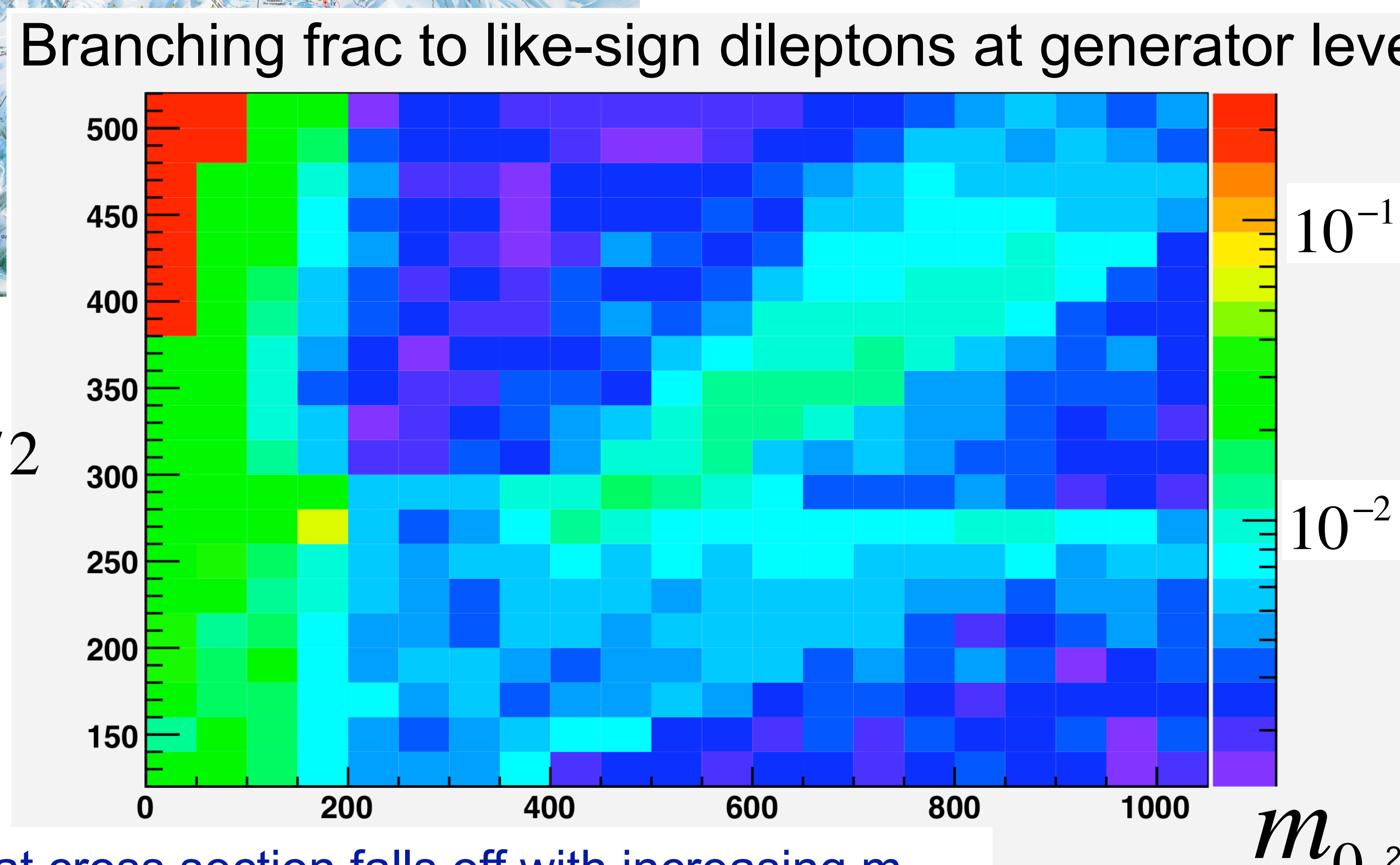


Estimated Sensitivity of Like-Sign Dilepton Search



Is the `Alpe d'Huez' structure understood?



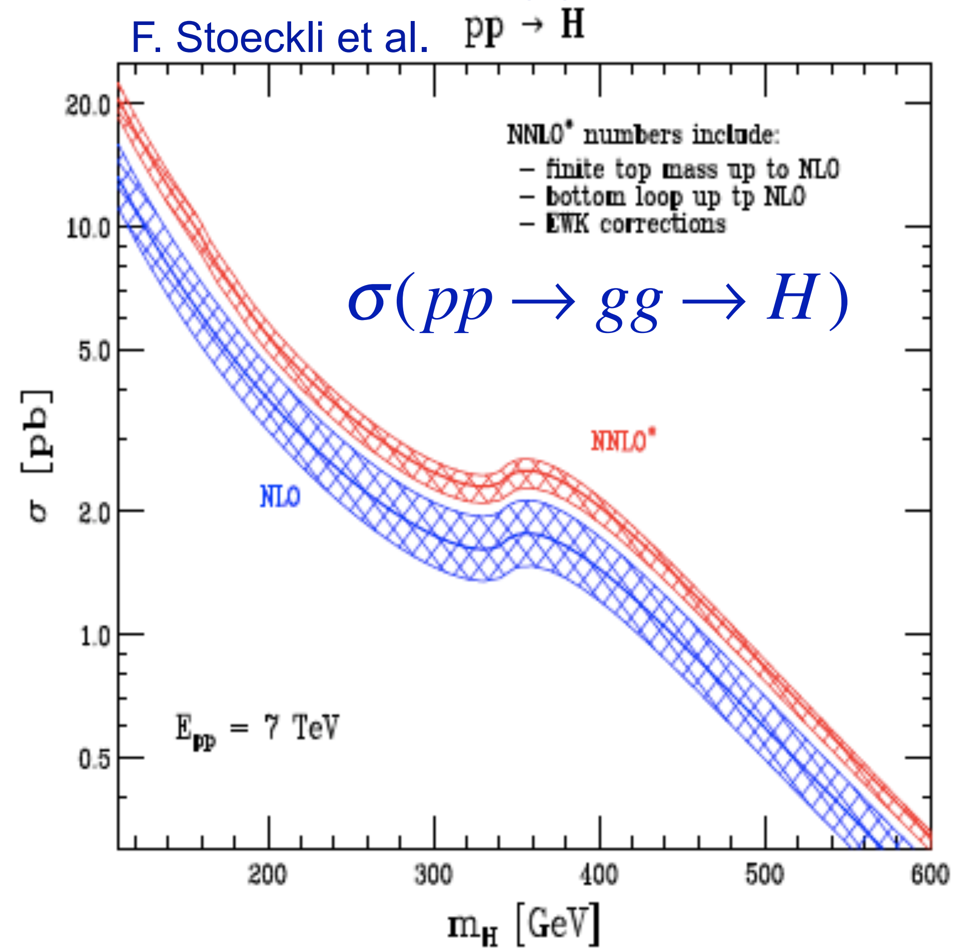


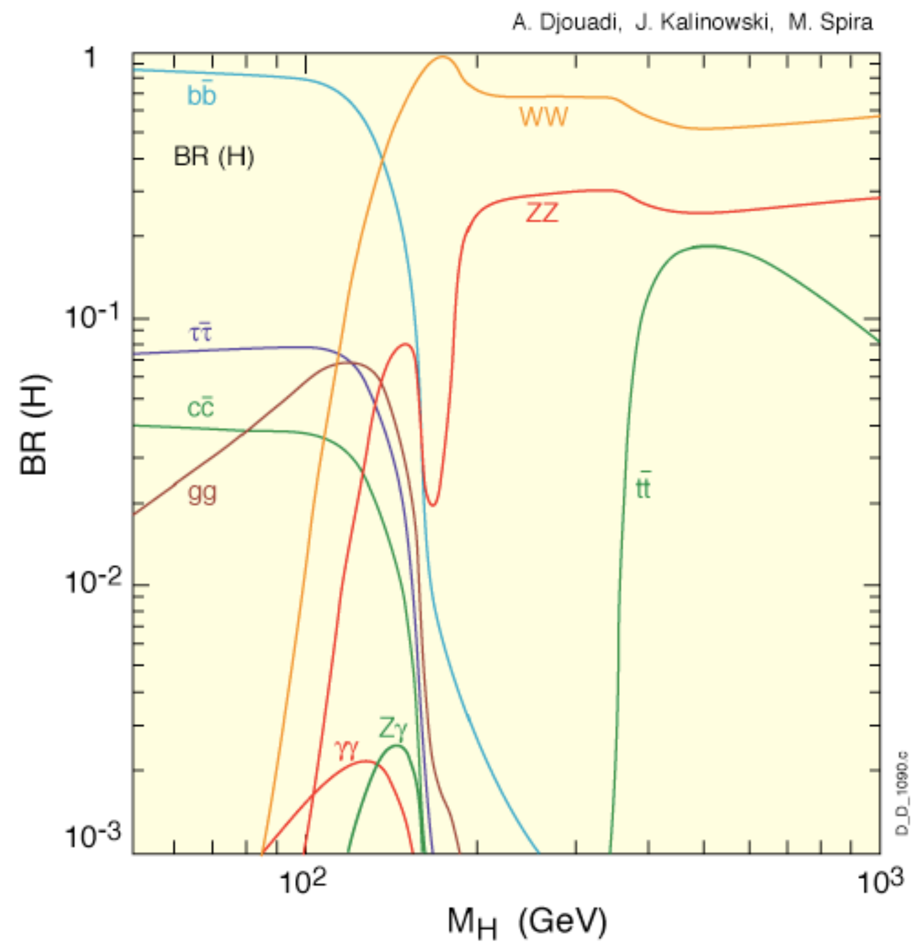
Remember that cross section falls off with increasing $m_{1/2}$.

Higgs Production and Decays

- Best sensitivity for H at $\sqrt{s}$=7 TeV is from $H \rightarrow W^+W^-$
- Dominant production via $gg \rightarrow H$
- Low mass Higgs via $H \rightarrow \gamma\gamma$ requires O(10 fb^{-1}) at 14 TeV

F. Stoeckli et al.



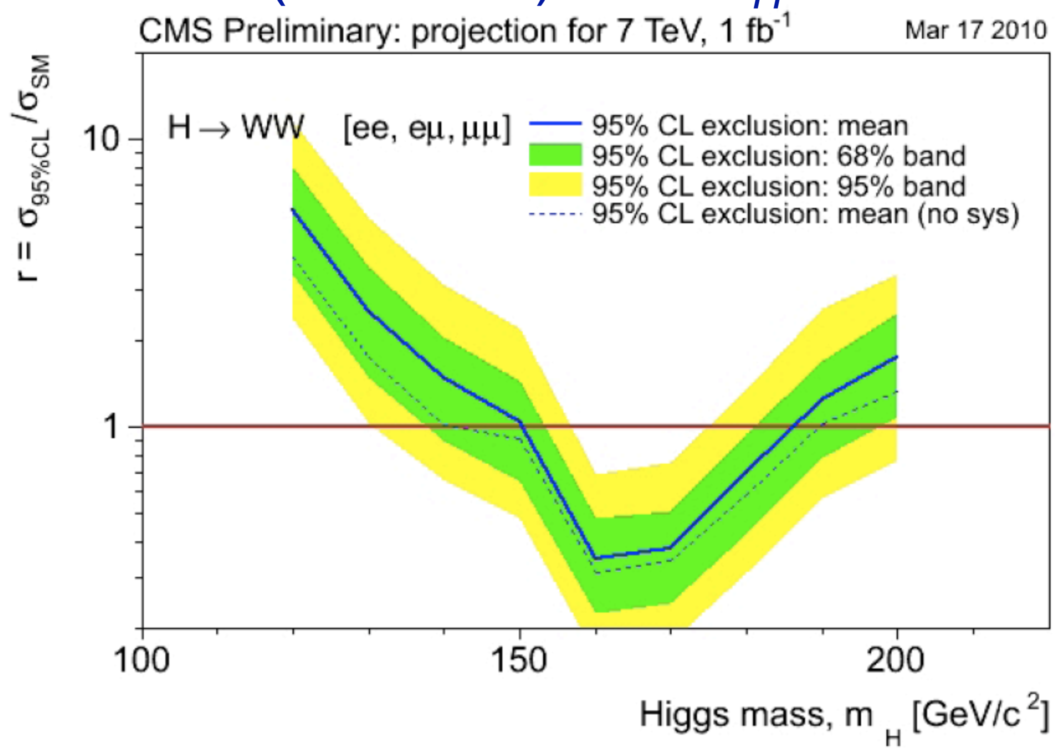


Higgs boson sensitivity: $H \to W^+W^-$

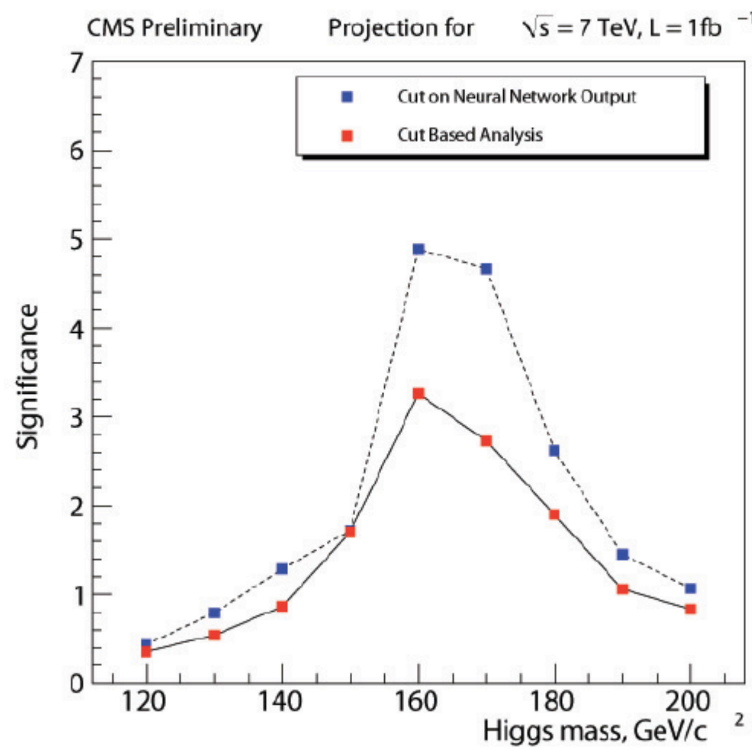
Andrey Korytov http://www.ippp.dur.ac.uk/export/sites/IPPP/Workshops/10/Th-Exp-LHC/Andrey_Korytov.pdf
Guillelmo Gomez-Ceballos http://indico.cern.ch/getFile.py/access?contribId=2&sessionId=0&resId=0&materialId=slides&confId=86819

- Estimate sensitivities by rescaling previous results from 14 TeV
- Gluon-gluon fusion (NNLO),vector-boson fusion (NLO), *WH* and *ZH* contributions at NLO

Exclude (95% C.L) $150 < m_H < 185$ GeV



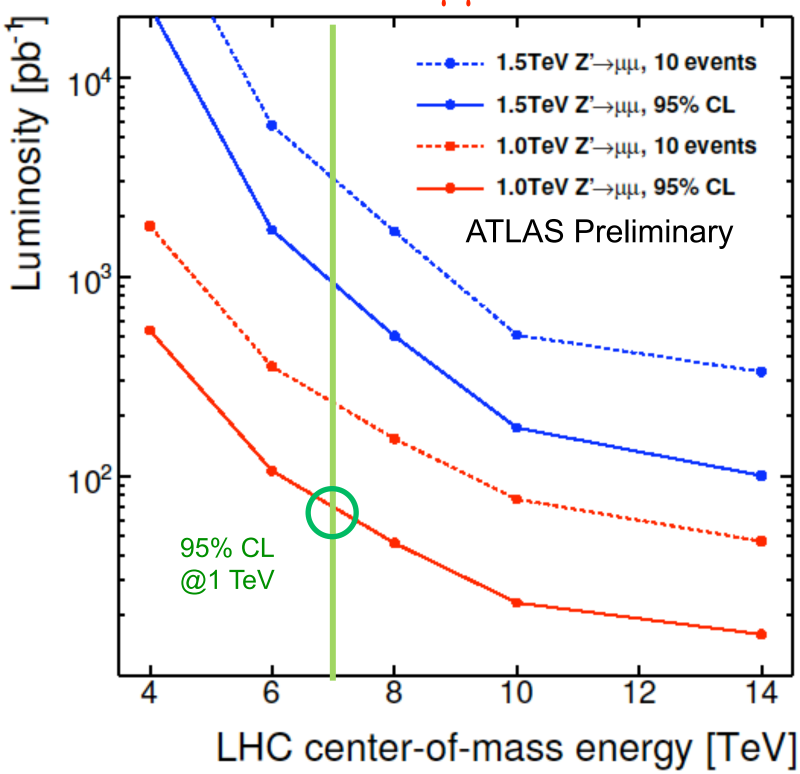
Discovery level sensitivity for $160 < m_H < 170$ GeV



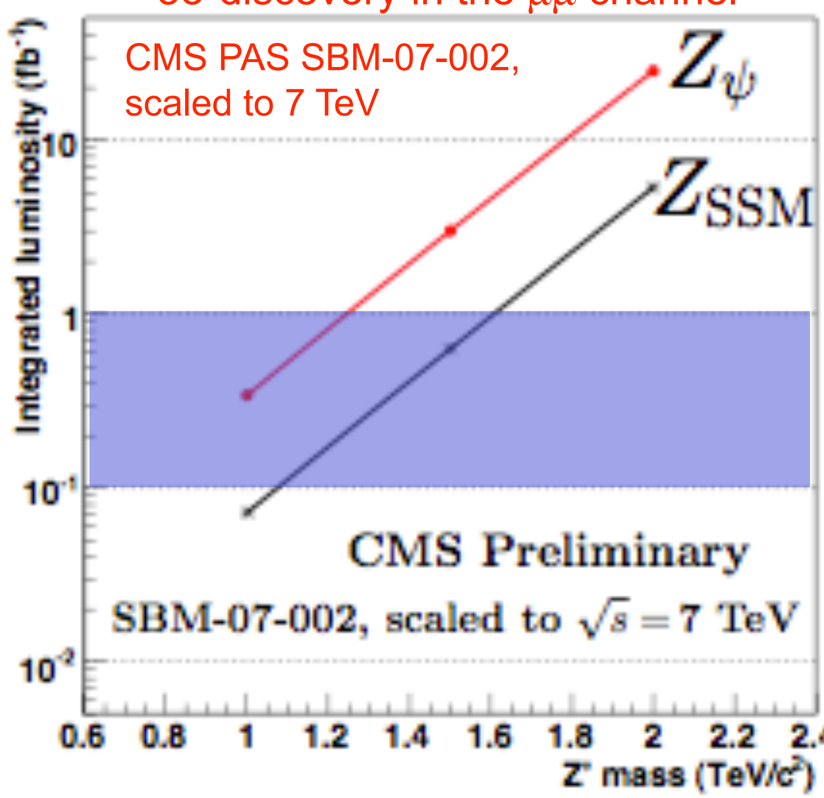
Dilepton Resonances (Example Z')

- Predicted in many SM extensions (Extra Dimensions, Technicolour, Little Higgs)
- Low, well understood background dominated by DY
- 95% CL exclusion O(100/pb) at 1 TeV
- Sensitivity beyond the Tevatron (1 TeV SSM Z') with ~100 pb^{-1}

95% exclusion in μμ



5σ discovery in the μμ channel



From Steve Myers LHC Status Report
5 May 2010

http://indico.cern.ch/getFile.py/access?contribId=6&resId=1&materialId=slides&confId=92525

Strategy for Increasing the Beam Intensity

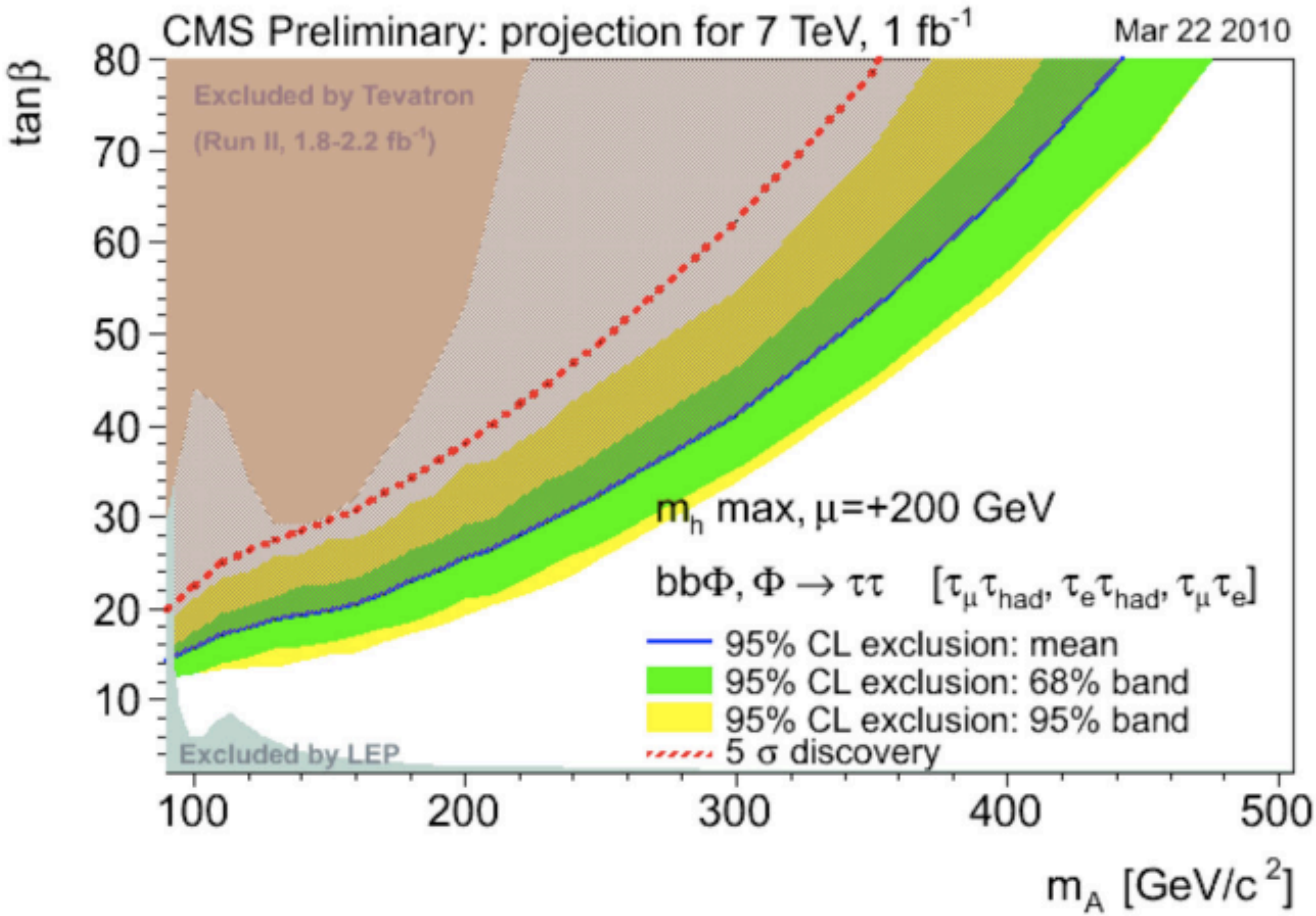
- The magic **number for 2010/11 is 1 fb^{-1}**. To achieve this, the LHC must run flat out at $1\text{-}2 \times 10^{32}\ cm^{-2}s^{-1}$ in 2011,
  - Correspond to 8e10 ppb, 700 bunches, with a stored energy of 35 MJ (with $\beta^*=2$ m and nominal emittance).

Conclusions

- The LHC physics program has finally begun.
- The run at 7 TeV will provide sensitivity to new physics beyond current Tevatron limits.
- ATLAS and CMS are working extremely well.
- The physics program will advance through many different eras due to large successive increases in the luminosity.
- The range of cross sections relevant for new physics is enormous—each era will allow us to address new questions.

Backup Slides

Higgs Sensitivity



CDF Jet-MET search (2 fb^{-1})

http://www-cdf.fnal.gov/physics/exotic/r2a/20080214.squark_gluino/cdf9229_squark_gluino_2fb.ps (public document)

CDF, PRL, 102, 121801 (2009) http://arXiv.org/pdf/0811.2512