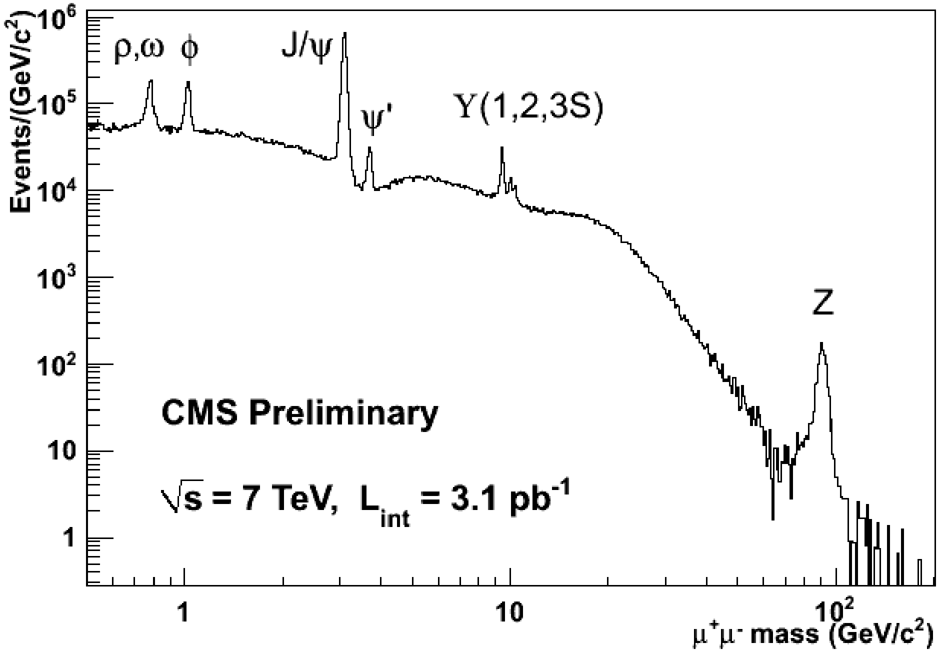


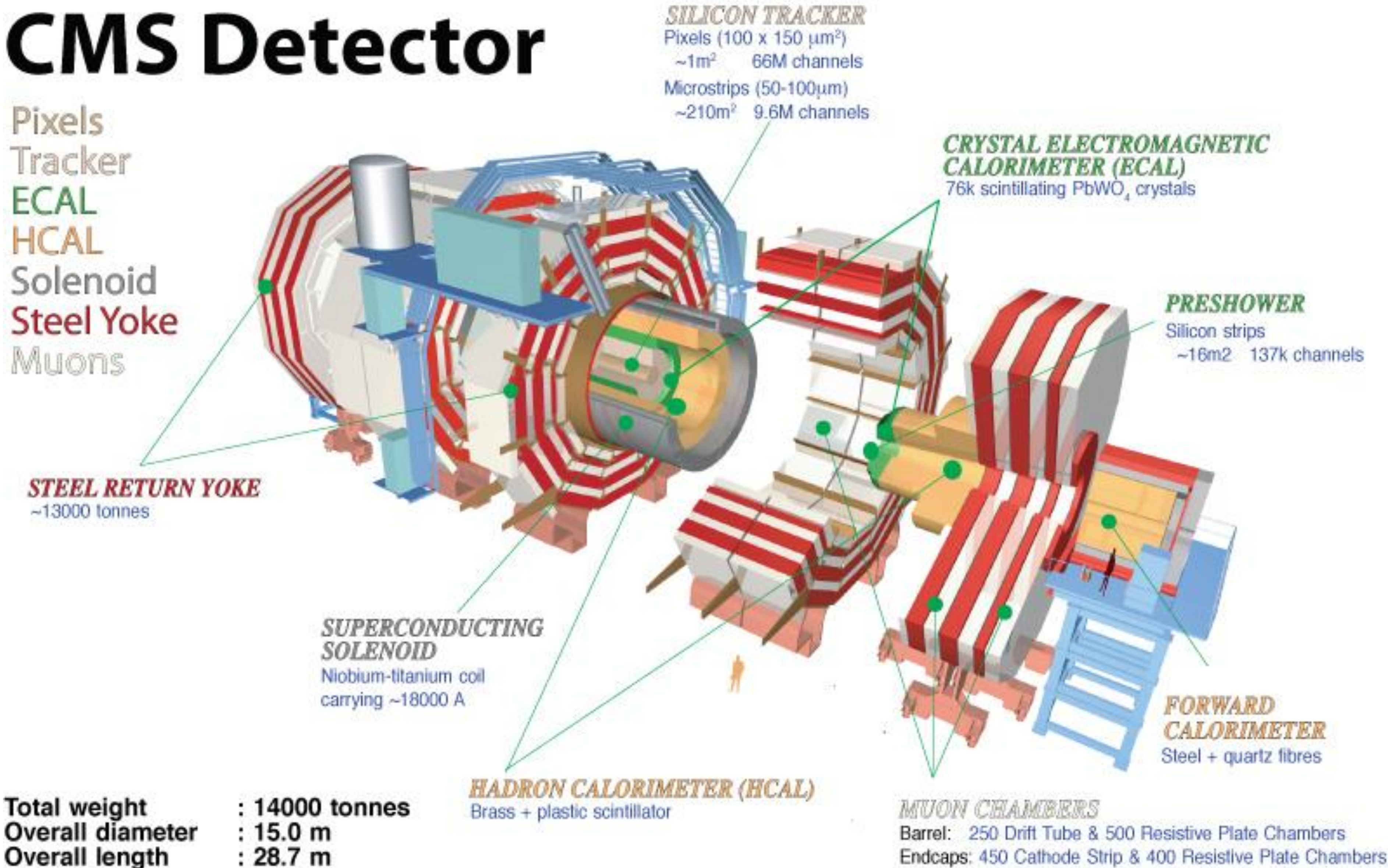
Status of CMS

A. Nikitenko, Imperial College

H^+ Workshop 27-30th September 2010

Uppsala

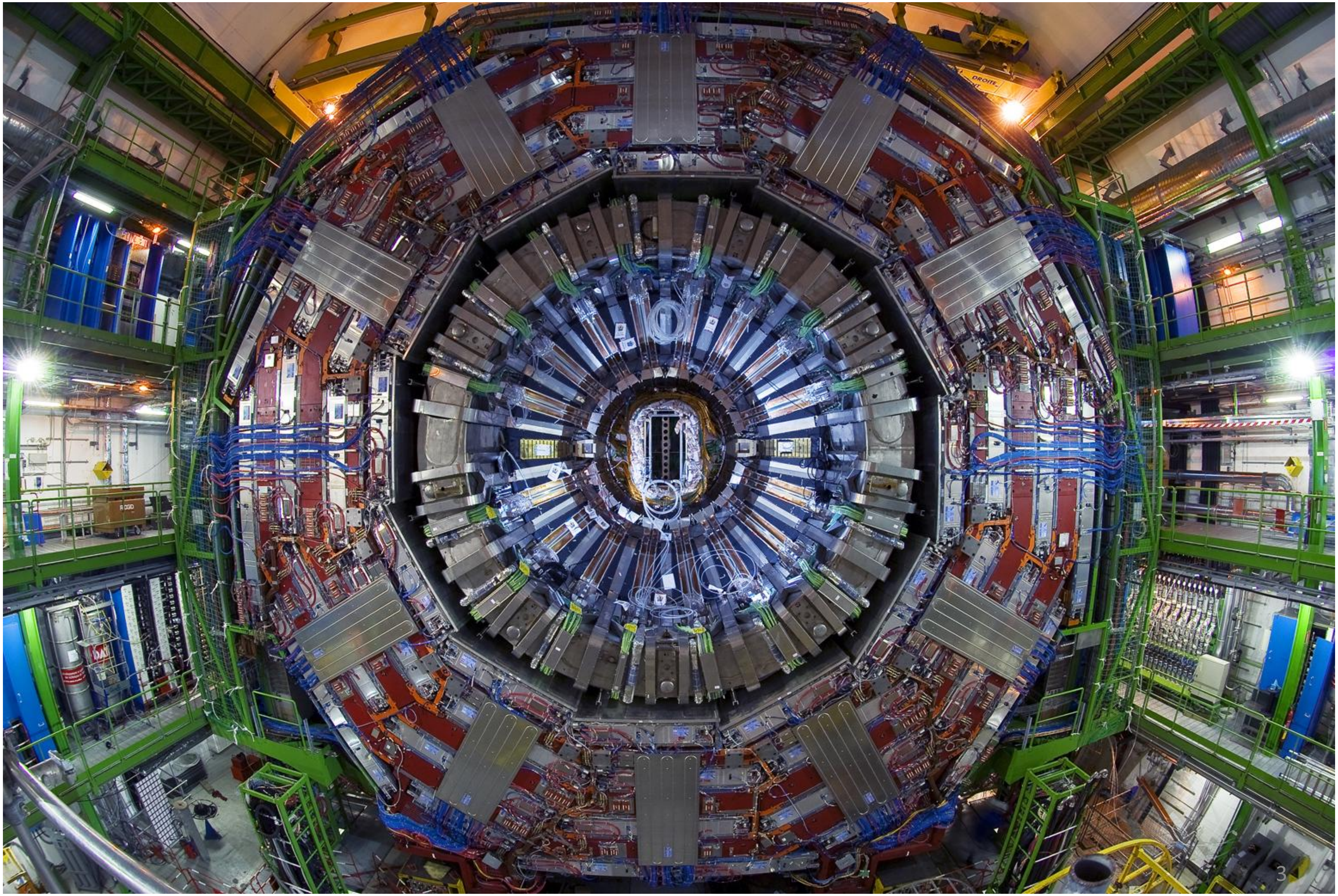
CMS Detector



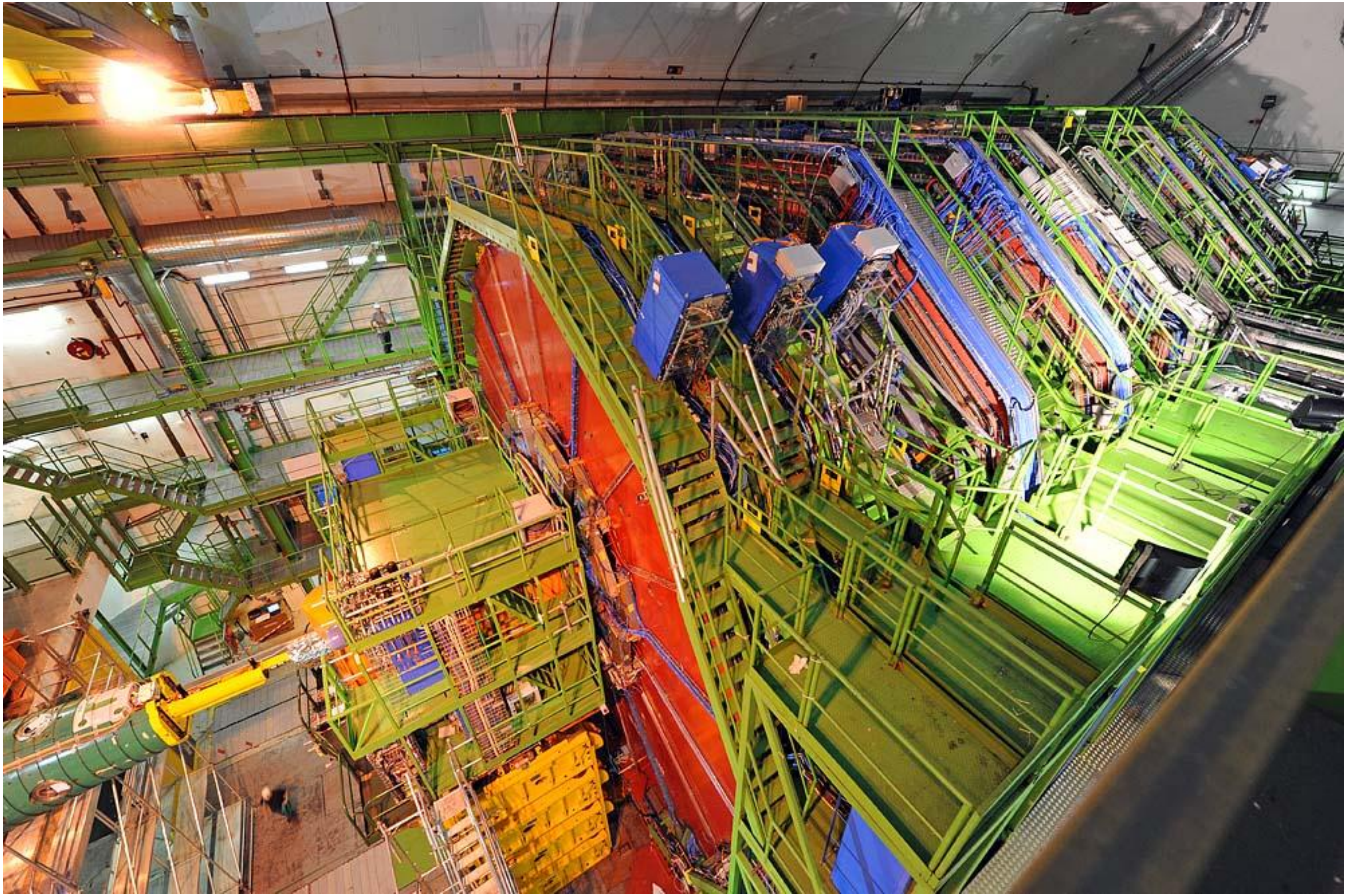
Total weight	: 14000 tonnes
Overall diameter	: 15.0 m
Overall length	: 28.7 m
Magnetic field	: 3.8 T

October 2009: 182 Institutions with about 3110 scientists and engineers
~ 2000 Signing Authors (including students)

CMS Detector

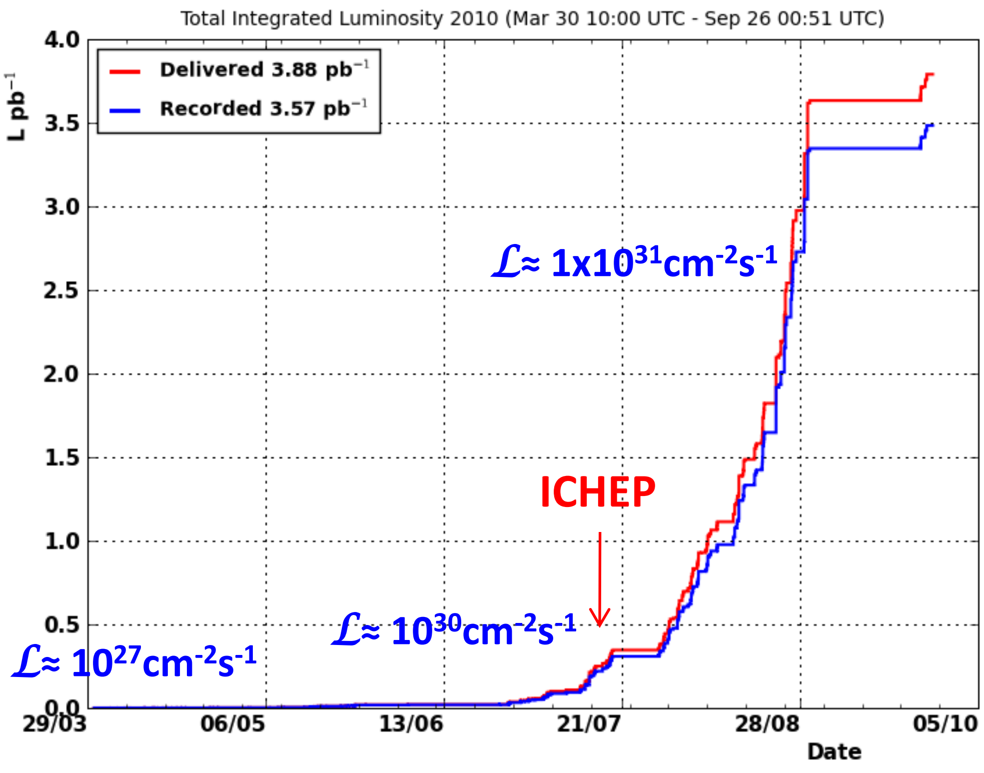


CMS Detector in the Underground Cavern



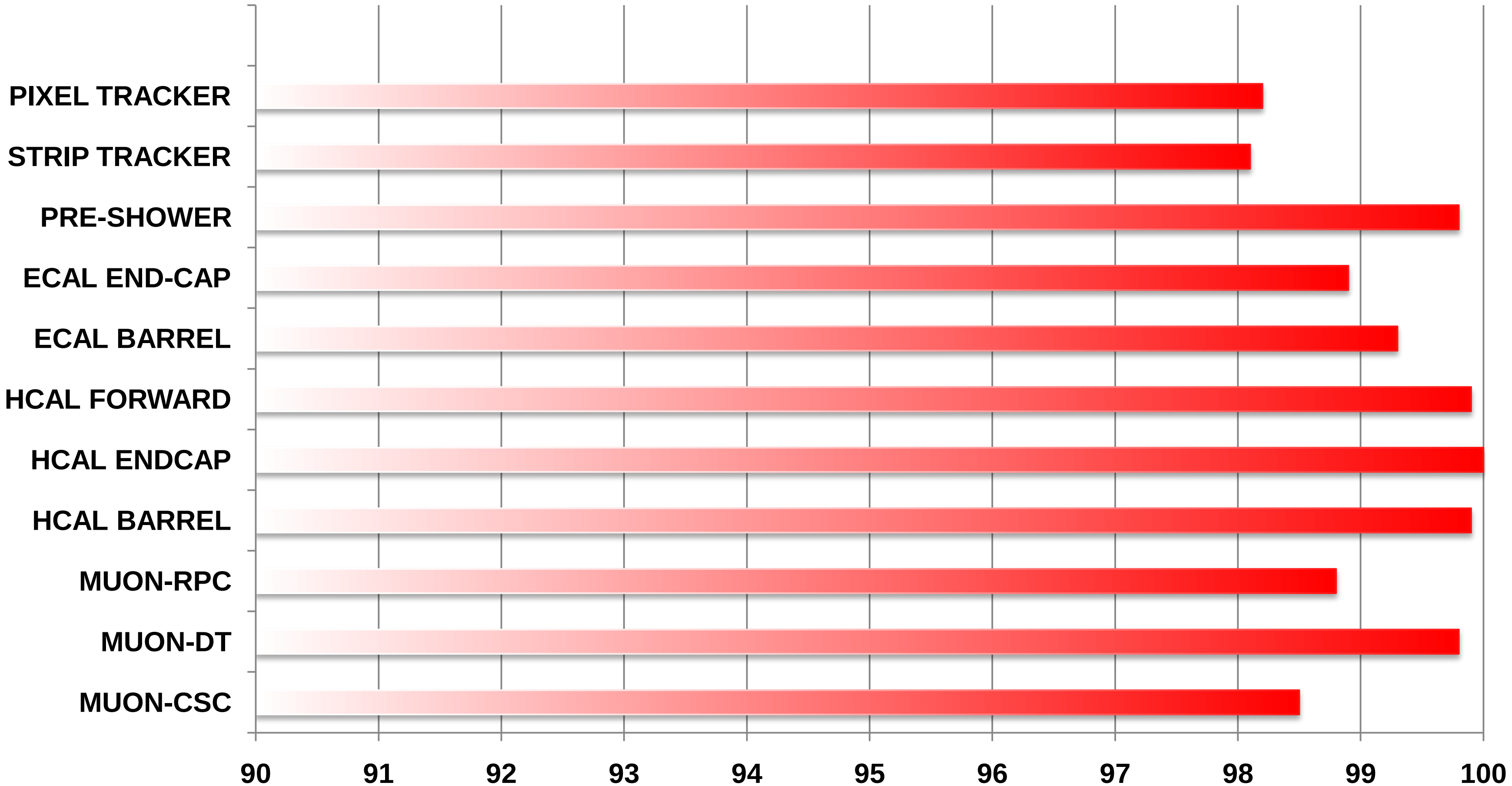
7 TeV operations since March 30

About **3.9pb^{-1}** delivered by LHC and **~3.6pb^{-1}** of data collected by CMS. Overall data taking efficiency **>90%.**



Good performance of CMS in coping with 4 orders of magnitude increase in instantaneous luminosity. Since ICHEP we have recorded another **3.0pb^{-1}** of data: **2.9pb^{-1} validated for physics in total (86% of the recorded data)**

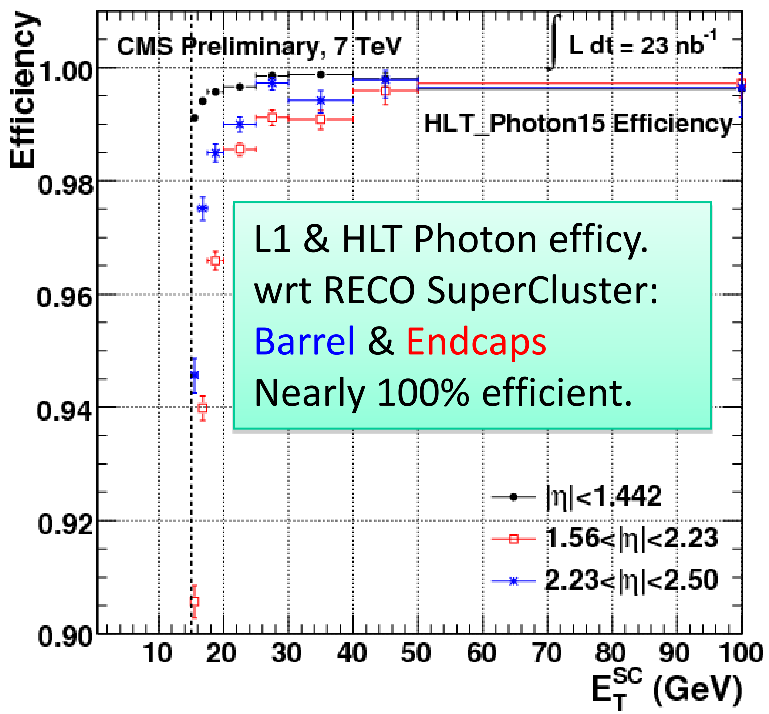
Sub-detectors operational status

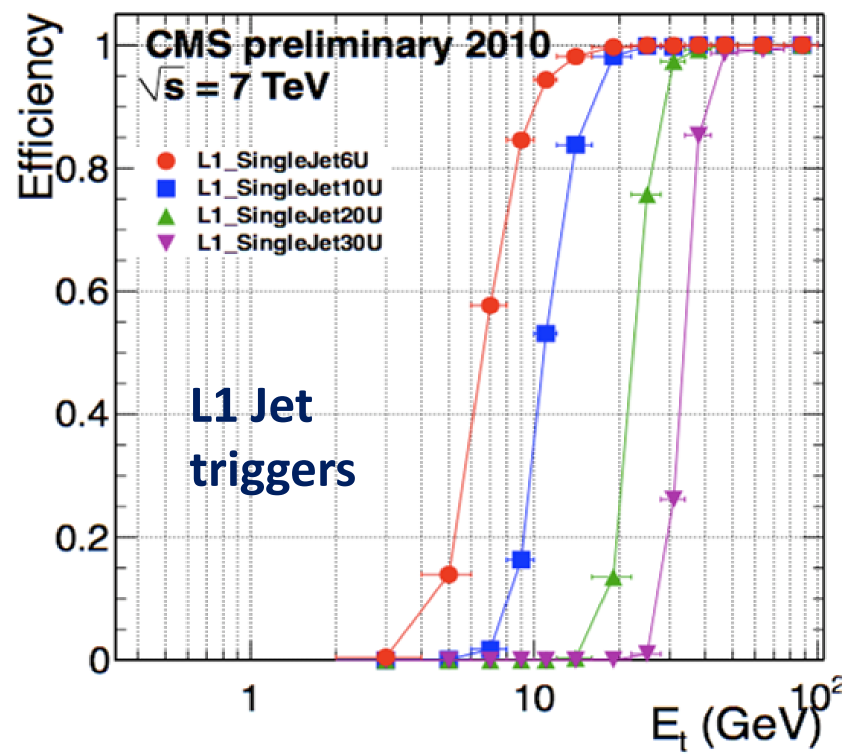


	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER	
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2	

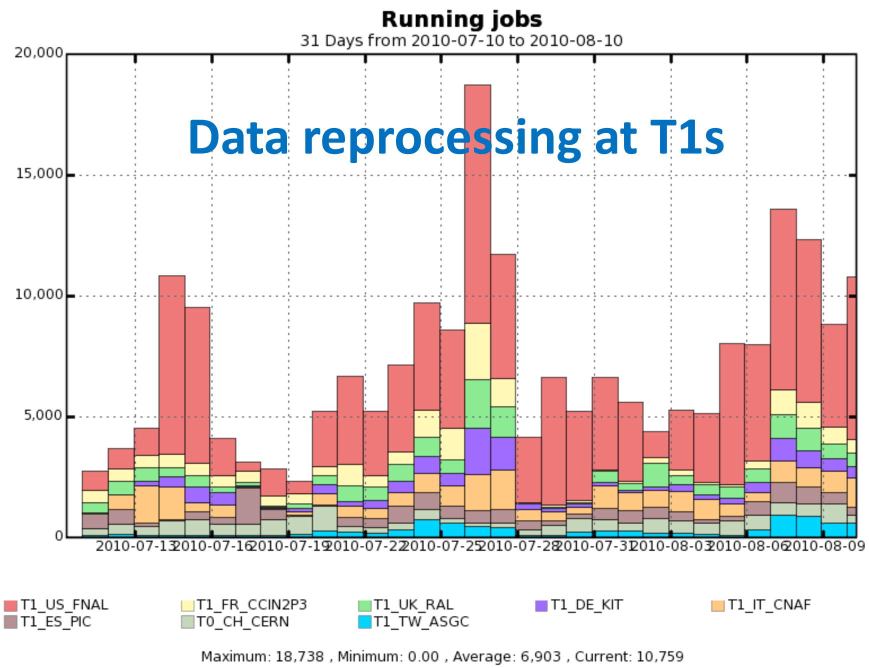
Trigger and DAQ

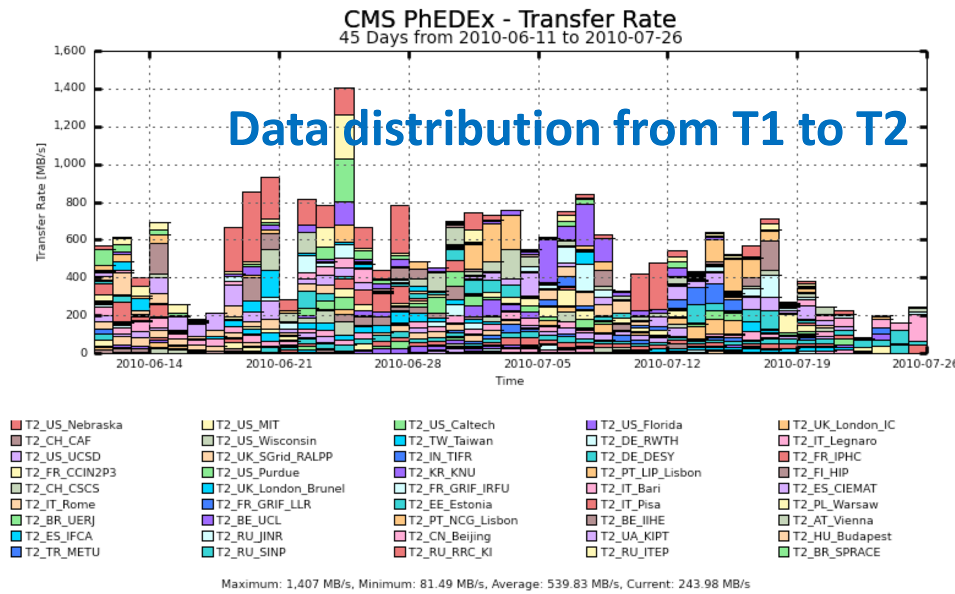
- L1 rate – 45 kHz
- HLT menu for $6x10^{31}$ is prepared , will run till the end of year accumulating in total ~ 30 pb^{-1}
- Transfer to T0: ~ 300 MB/s; Rate of Stream A: 200-400 Hz; event size after compression: ~ 250 kB.





Data Processing, Transfer and Analysis

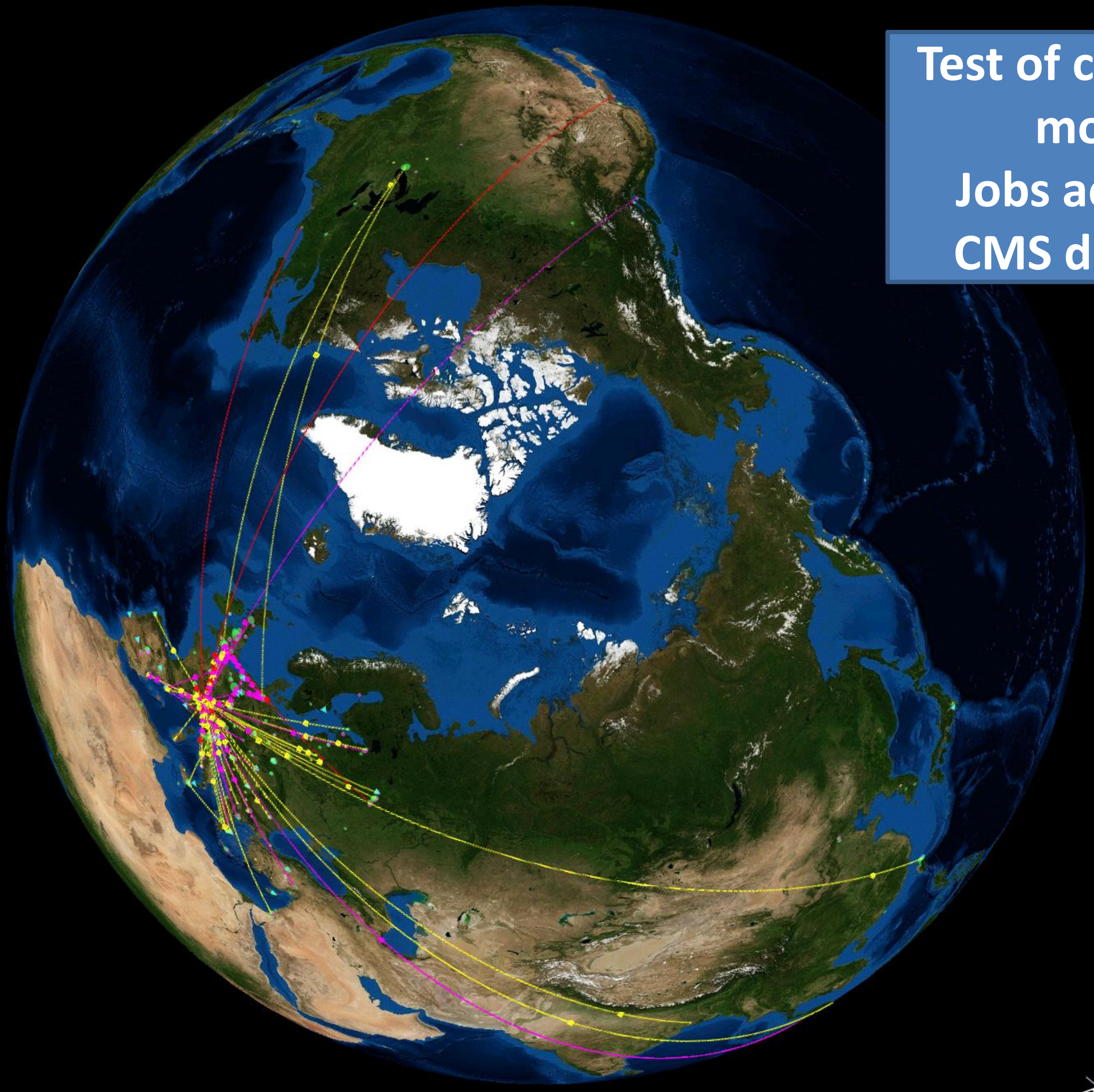




=> Distributed data analysis at T2 exploiting grid computing

The whole Offline and Computing organization + GRID infrastructure performing well.

Test of computing model: Jobs accessing CMS data now



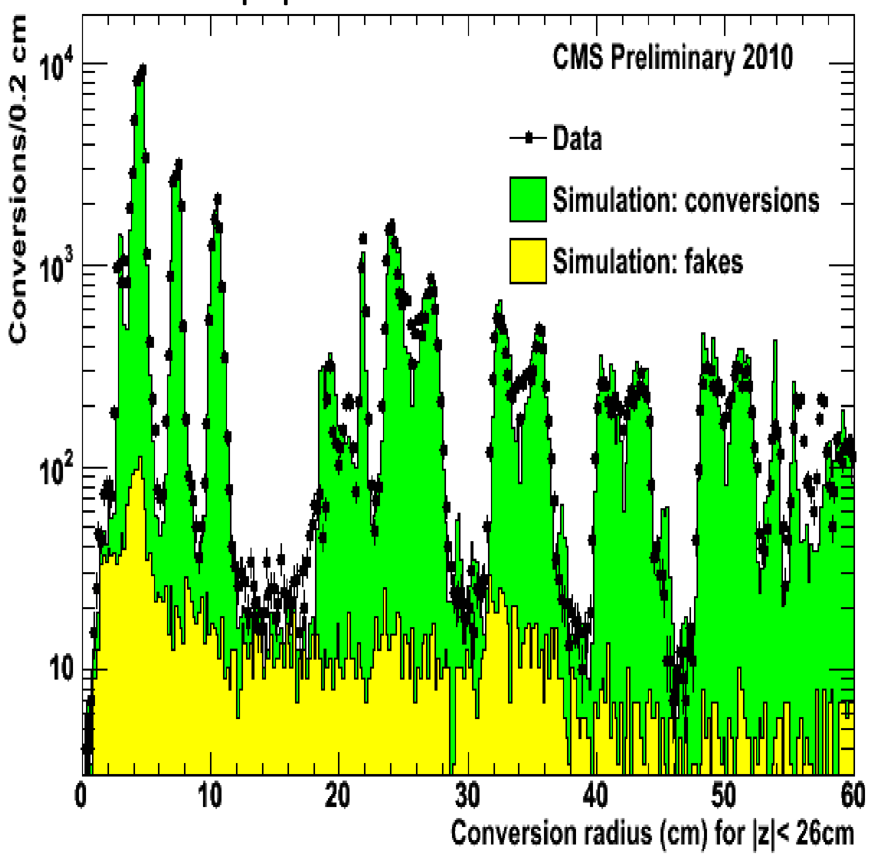
Scheduled = 9886
Running = 17986

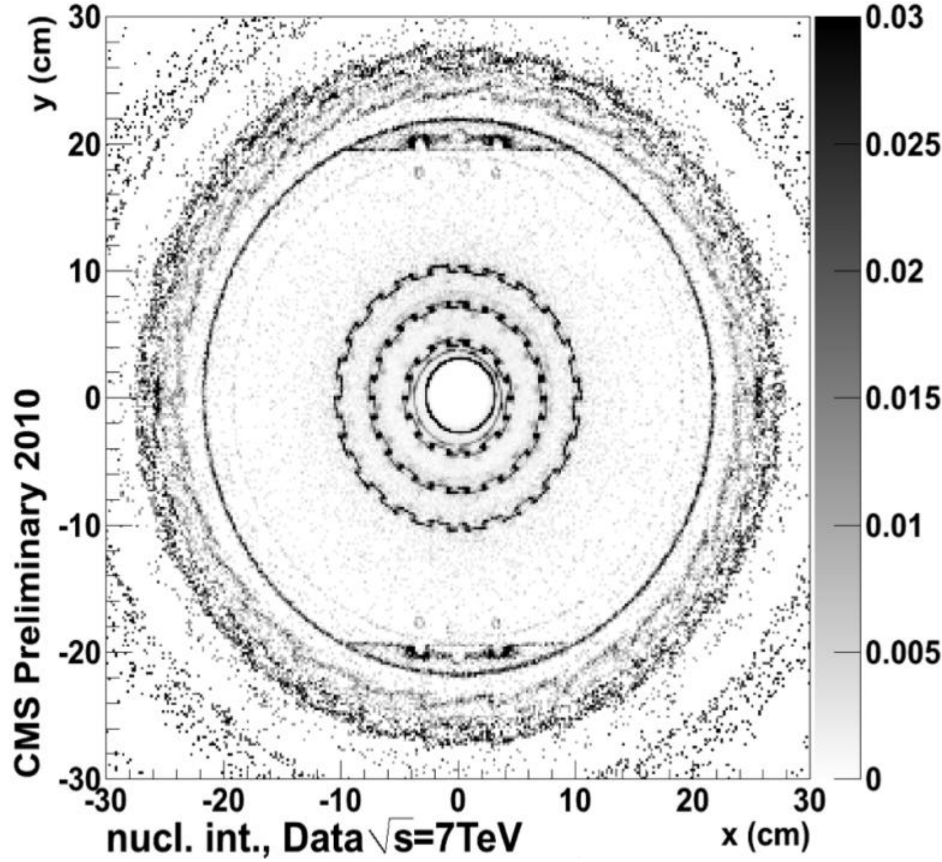
15:17:24 UTC

UK Computing for Particle Physics

CMS is well-described in simulation e.g. Tracker

|z|<26 cm



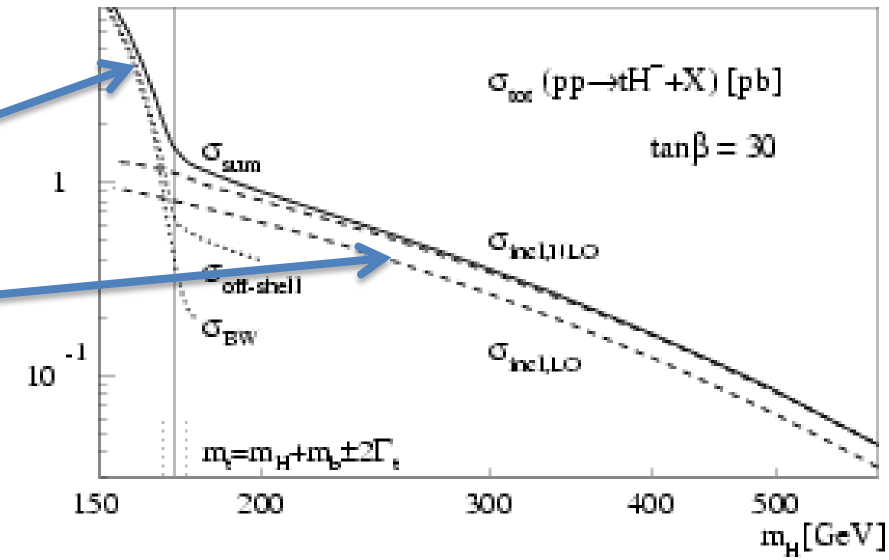


Using complementary methods: conversions, nuclear interactions, multiple scattering etc

Material uncertainty today better than 10%→Systematics uncertainties on physics quantities related to material budget <1% .

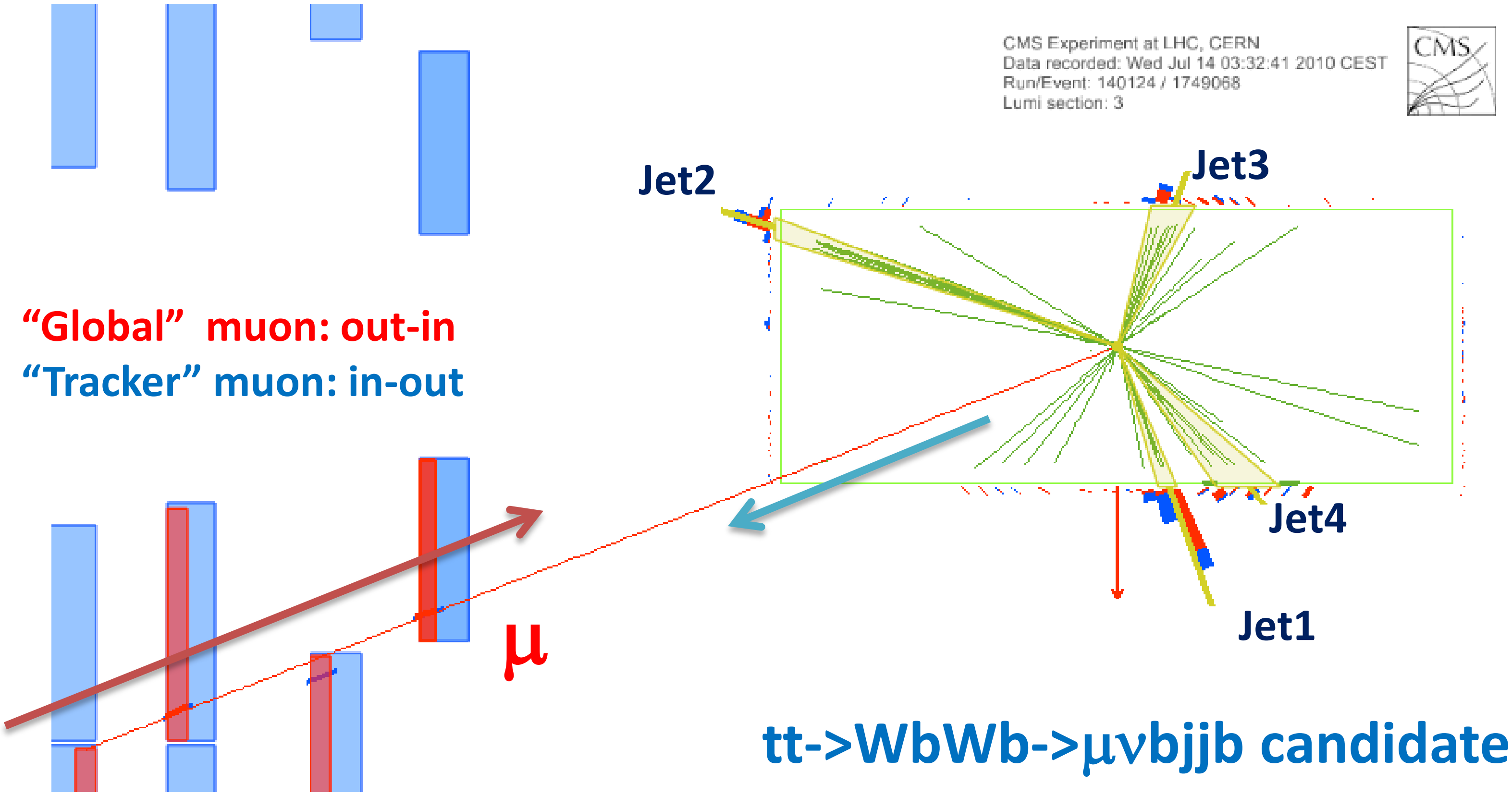
H^+ analyses

T. Plehn et al., hep-ph/0312286
used in CMS PTDR 2006



- CMS analyses so far:
  - $t\tilde{t} \to H^+bWb \to \tau_{had}\nu bl\nu b$ for $m_{H+} < m_t$
  - $pp \to H^+t(b) \to \tau_{had}\nu jjb(b)$ for $m_{H+} > m_t$
- All variety of reco objects used:
  - high p_T leptons, τ_{had} and b-tagging, jets and E_T^{miss}
- Backgrounds:
  - tt~, W+jets, QCD multi-jets

Muons

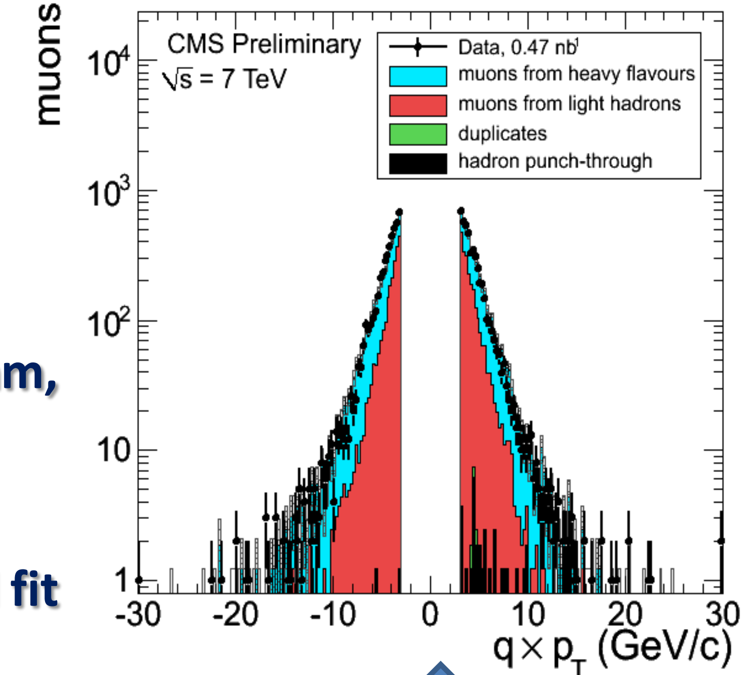


tt->WbH⁺b->μνbτνb analysis uses high p_T muon from W for trigger.

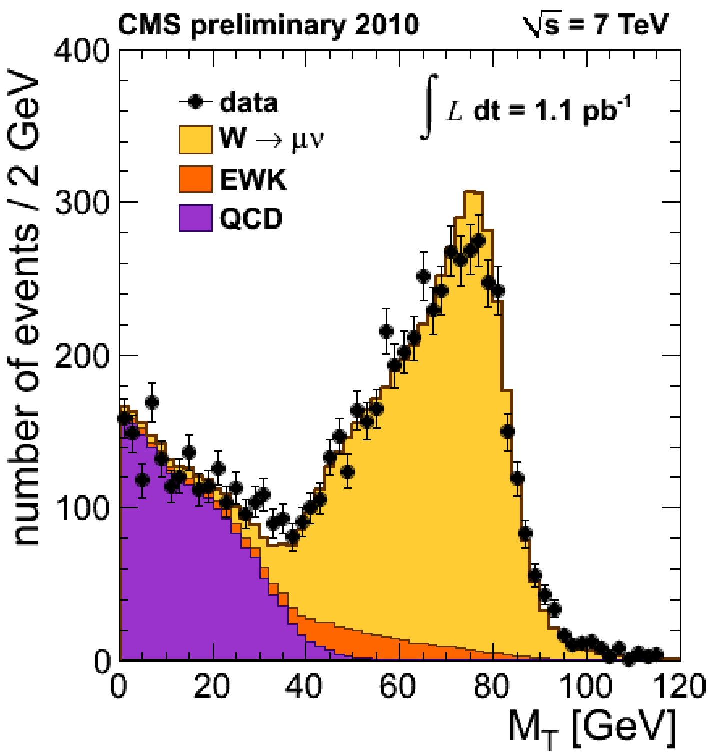
W, Z, tt~ analyses use "Tight muons": *good quality tracks from a combined fit of the hits in the tracker and muon system, requiring signal in at least two muon stations.*

"Tight muons"

- Tight muon: is "global" AND "tracker" muon, $\chi_{gl.trk}^2 < 10$, > 0 muon hits, > 1 matched muon segments, > 10 trk. Hits, >0 pixel hits, $ip_{xy} < 2$ mm, $p_T > 3$ GeV
  - "tracker muon" : inside-out approach
  - "global muon": outside-in approach+global fit

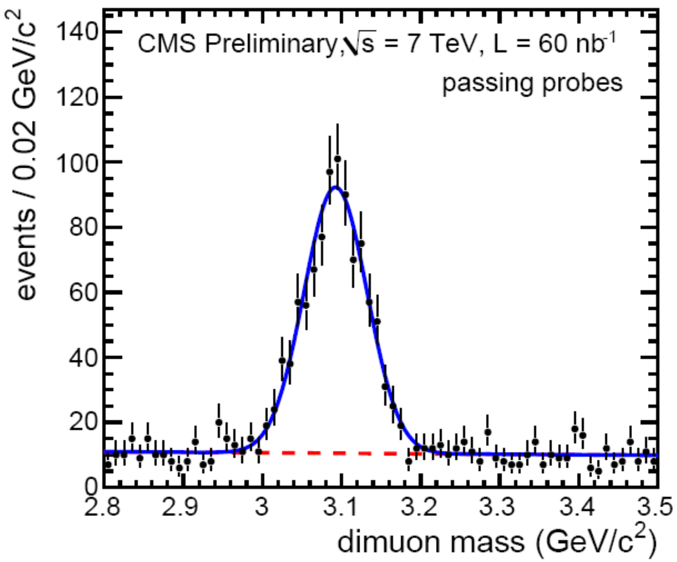


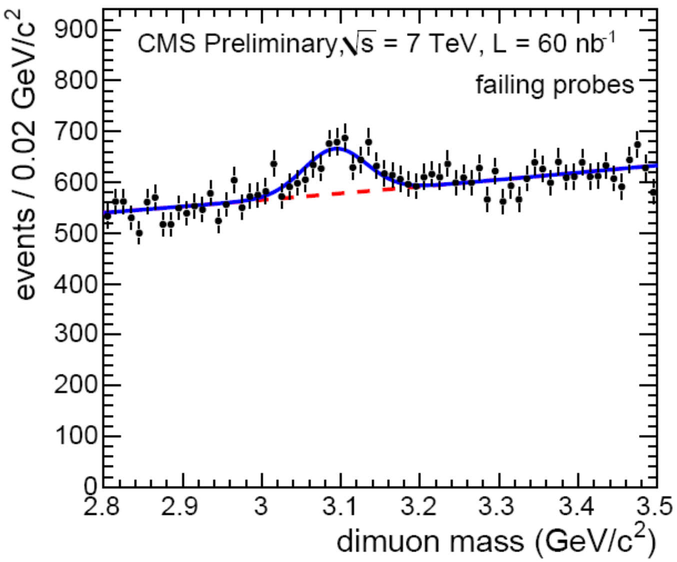
from min. bias trigger



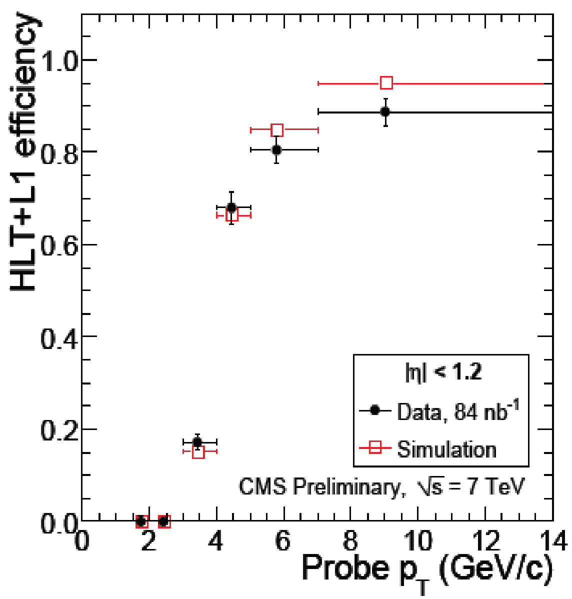
used in W->μν and tt~ analyses

trigger and ID efficiency from J/ψ–>μμ

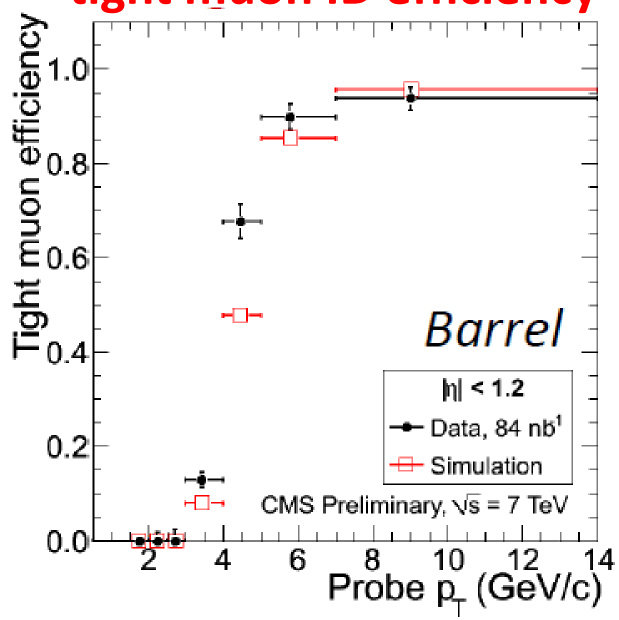




trigger efficiency

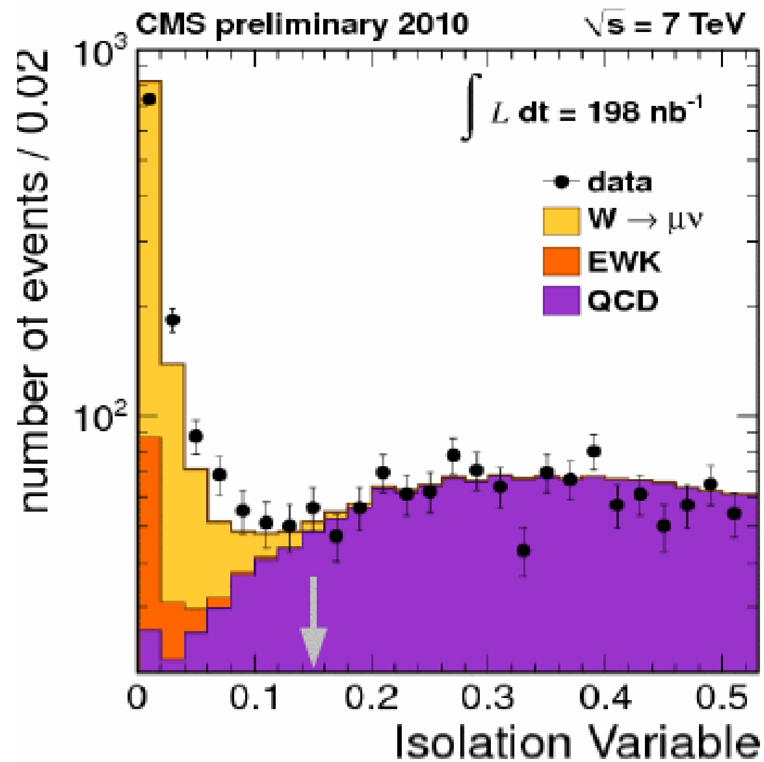


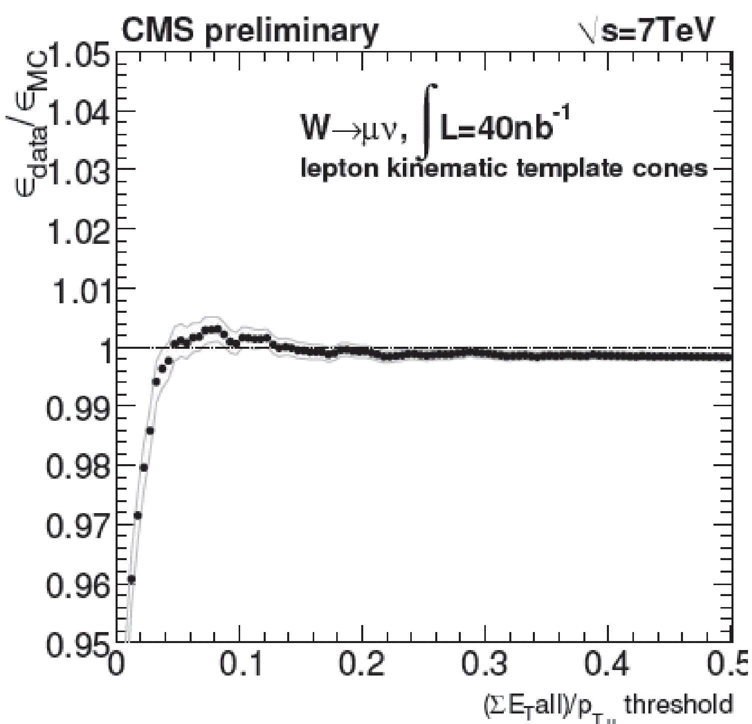
tight muon ID efficiency



Muon isolation in W->$\mu\nu$ analysis
Isolation Variable in cone 0.3:

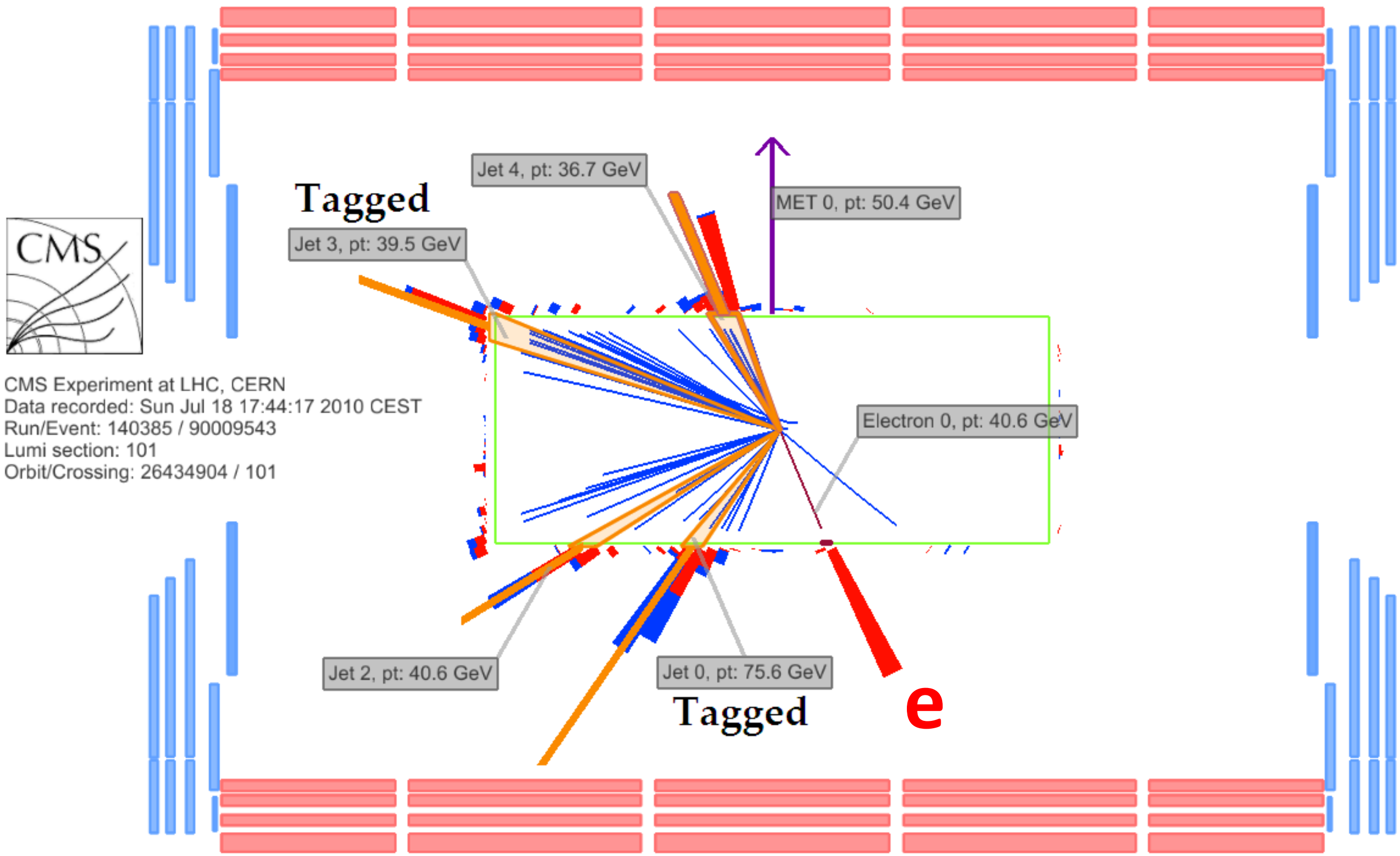
$$I = \Sigma\, p_T^{trk} / p_T^{\mu} + \Sigma\, E_T(em) / p_T^{\mu} + \Sigma\, E_T(had) / p_T^{\mu}$$





Data / MC efficiency of muon isolation obtained with Lepton Kinematic Template Cones using W-> $\mu\nu$ events

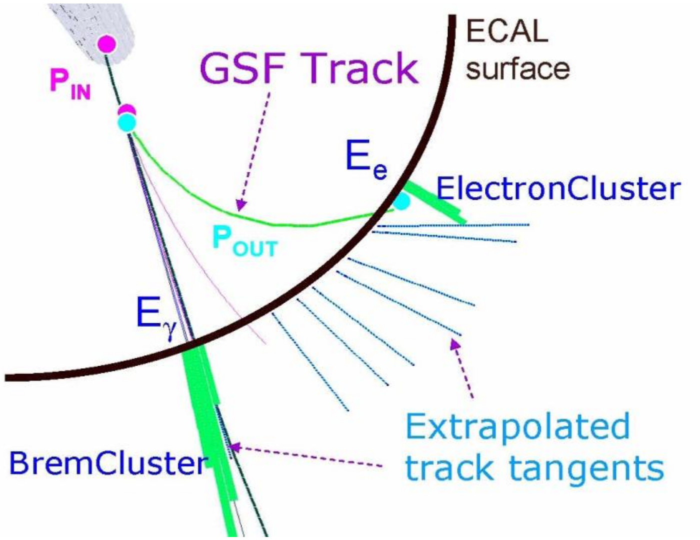
Electrons

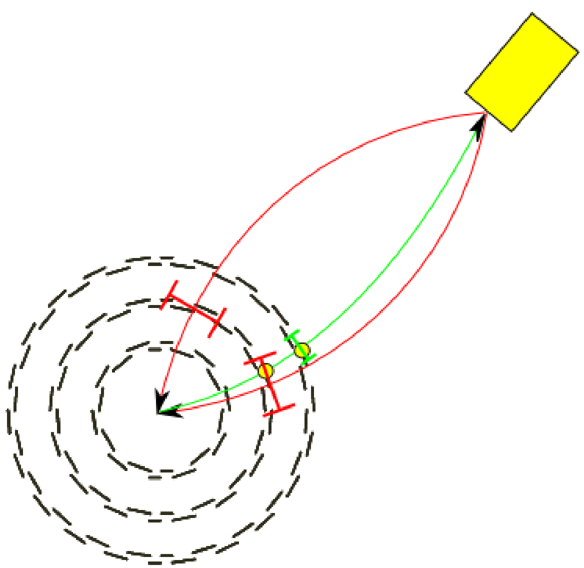


tt->WbWb->eνbjjb candidate

tt->WbH^{+}b->eνbτνb analysis uses hight p_T electrons from W for trigger

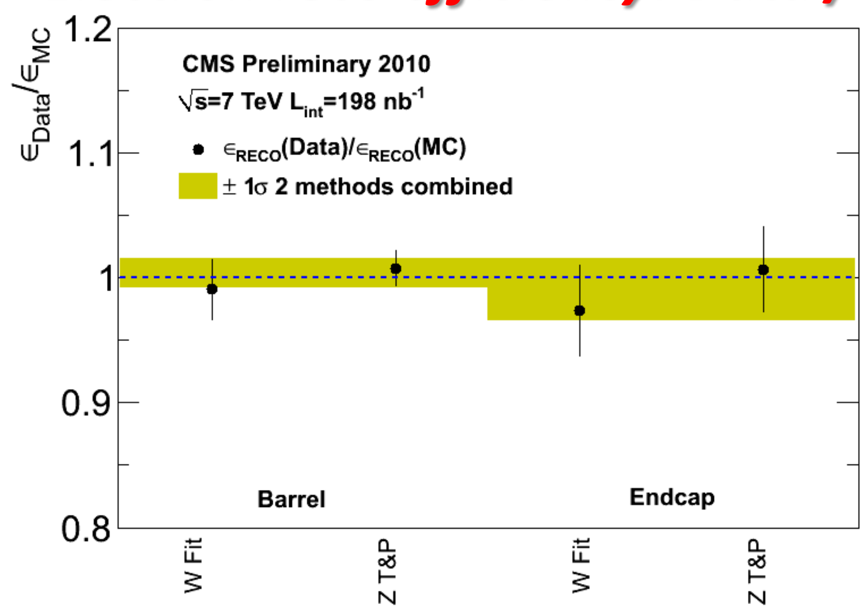
Electron reconstruction





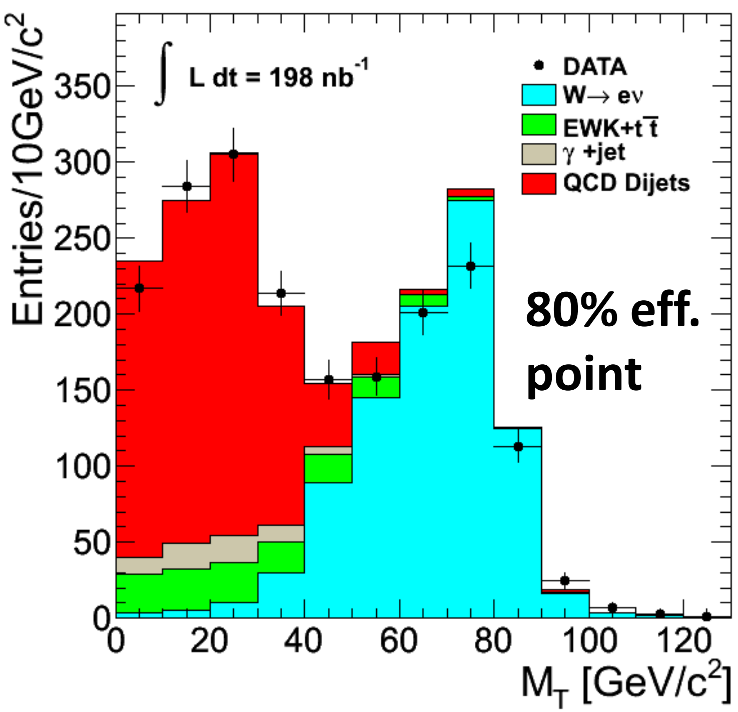
- High p_T electrons are "ECAL driven":
  - start by high ECAL super cluster and extrapolate toward innermost tracker layers
  - pair of hits are selected within a window around the expected position (r-phi and r-z planes)
  - pre-selections using $\Delta\eta$, $\Delta\phi$, H/E

Electron reco efficiency: Data / MC

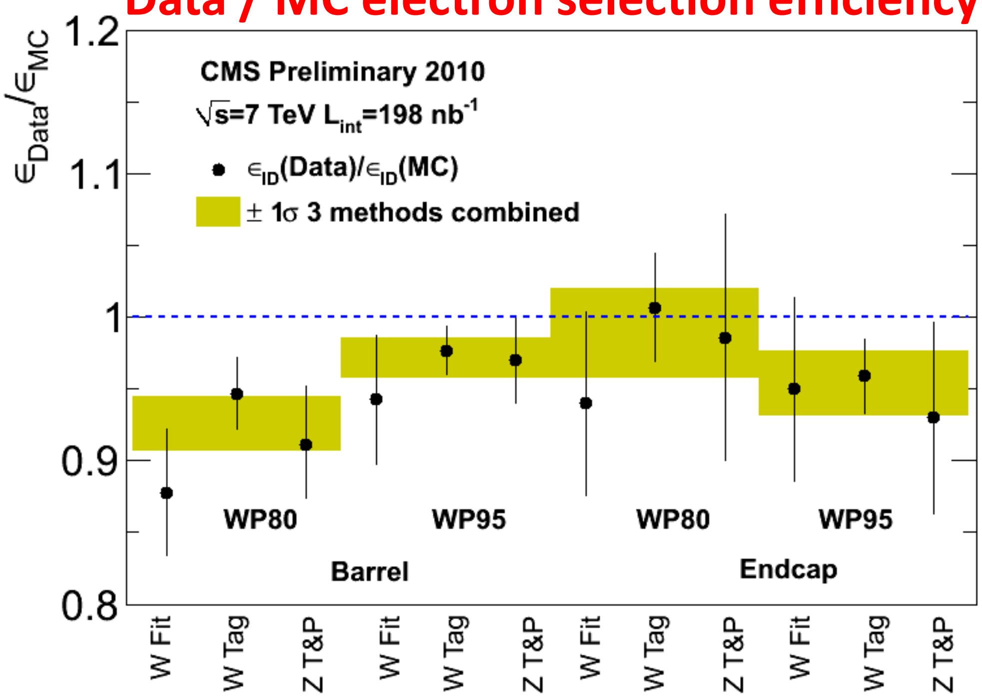


Electron selections (in W->eν analysis)

- identificaions: based on cluster shape, cluster-track matching simple cuts ($\Delta\eta_{in}$, $\Delta\phi_{in}$, $\sigma_{i\eta i\eta}$, H/E)
- Isolation in cone 0.3: cuts on $\Sigma\, p_T^{trk}/p_T^e$, $\Sigma\, E_T^{ECAL}/p_T^e$, $\Sigma\, E_T^{HCAL}/p_T^e$
  - tracks and ECAL energy associated with electron are excluded from sums.
- γ conversion rejection: no inner missing trk. hits; no close by tracks

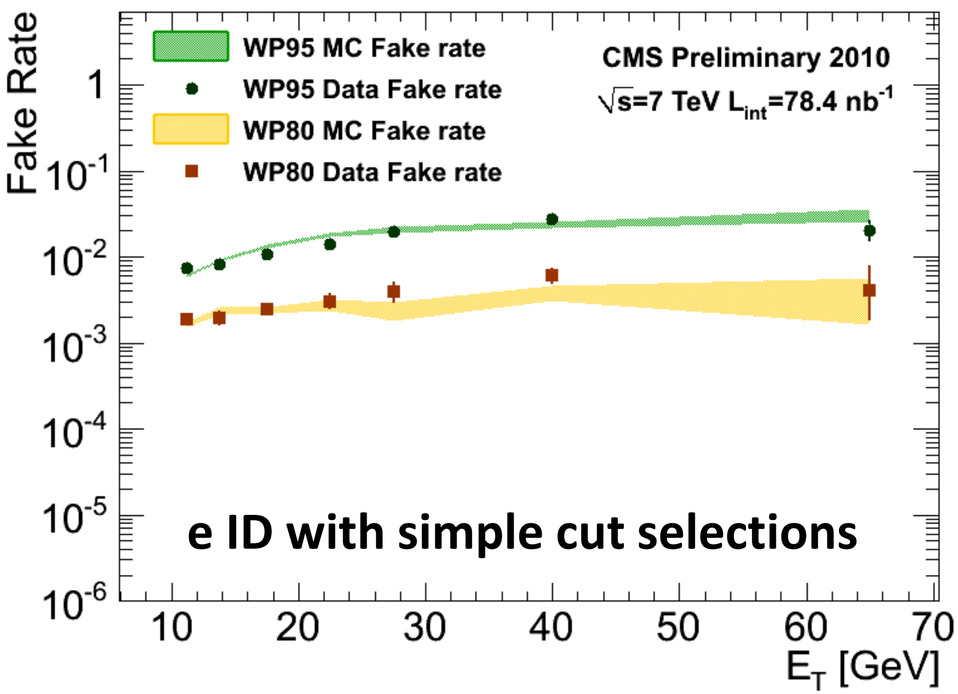


Data / MC electron selection efficiency

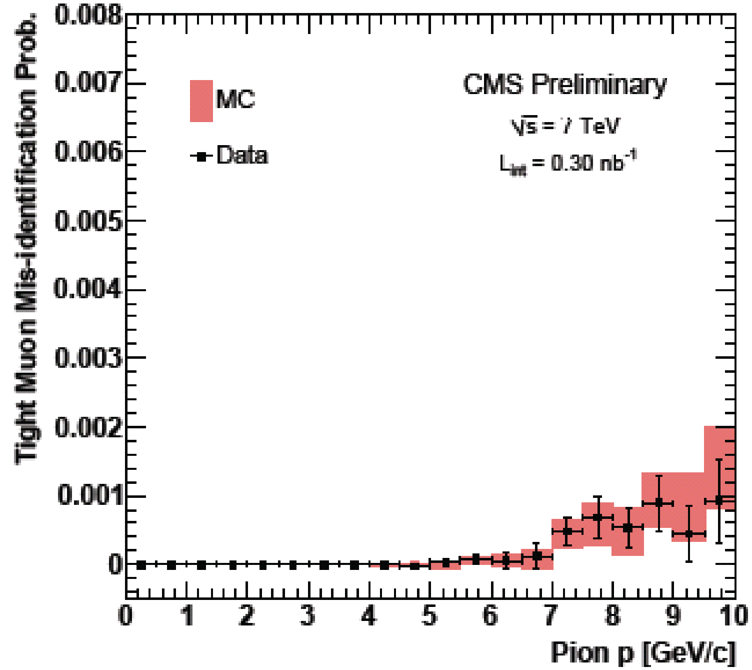


Fake rate for electrons and muons

Jet->"electron" mis. ID using jet events and electron candidates not matched with leading E_T jet



pions -> "tight" muon Mis. ID using $K^0 \to \pi^+\pi^-$



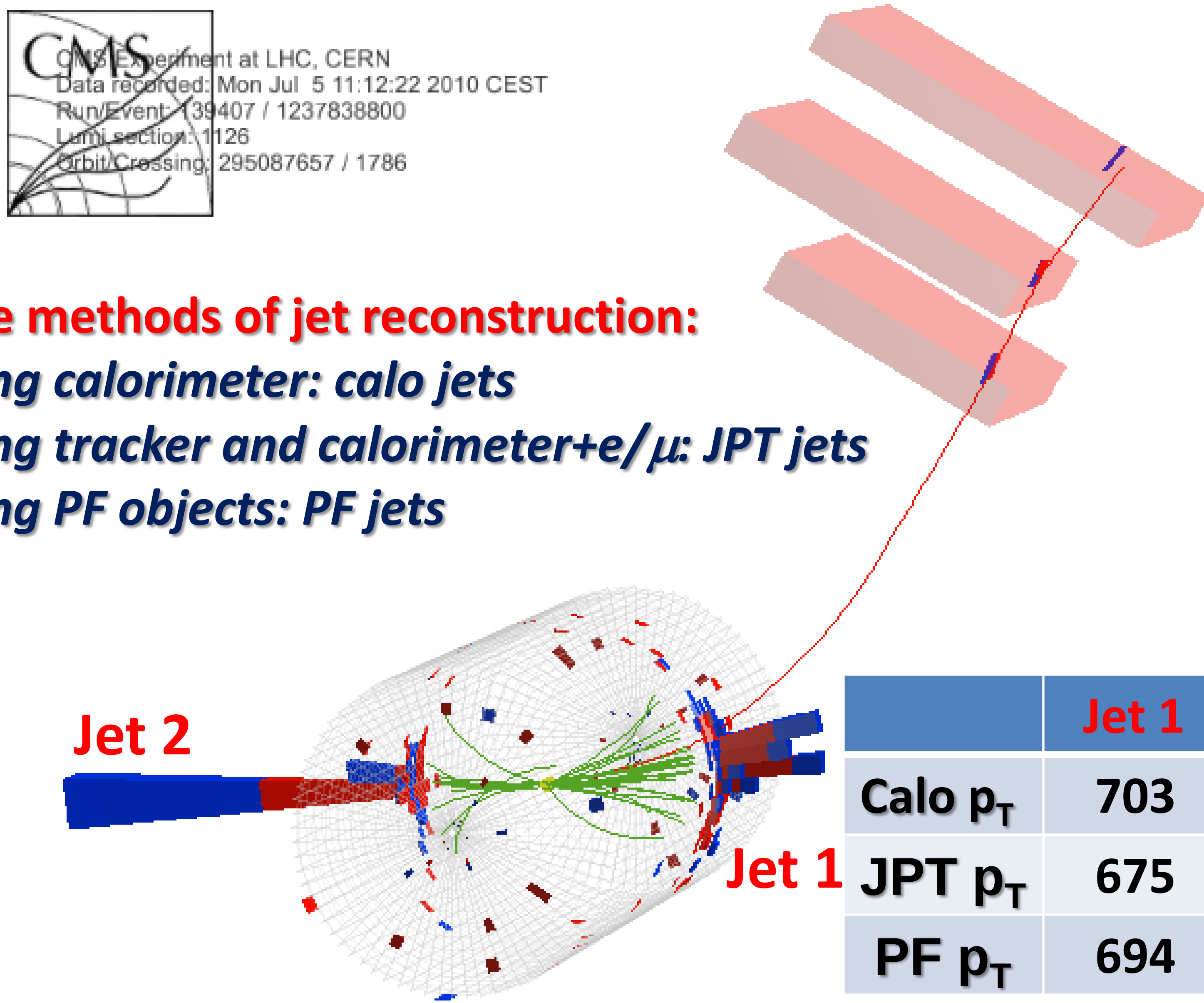
Jets (I)

Three methods of jet reconstruction:

using calorimeter: calo jets

using tracker and calorimeter+e/μ: JPT jets

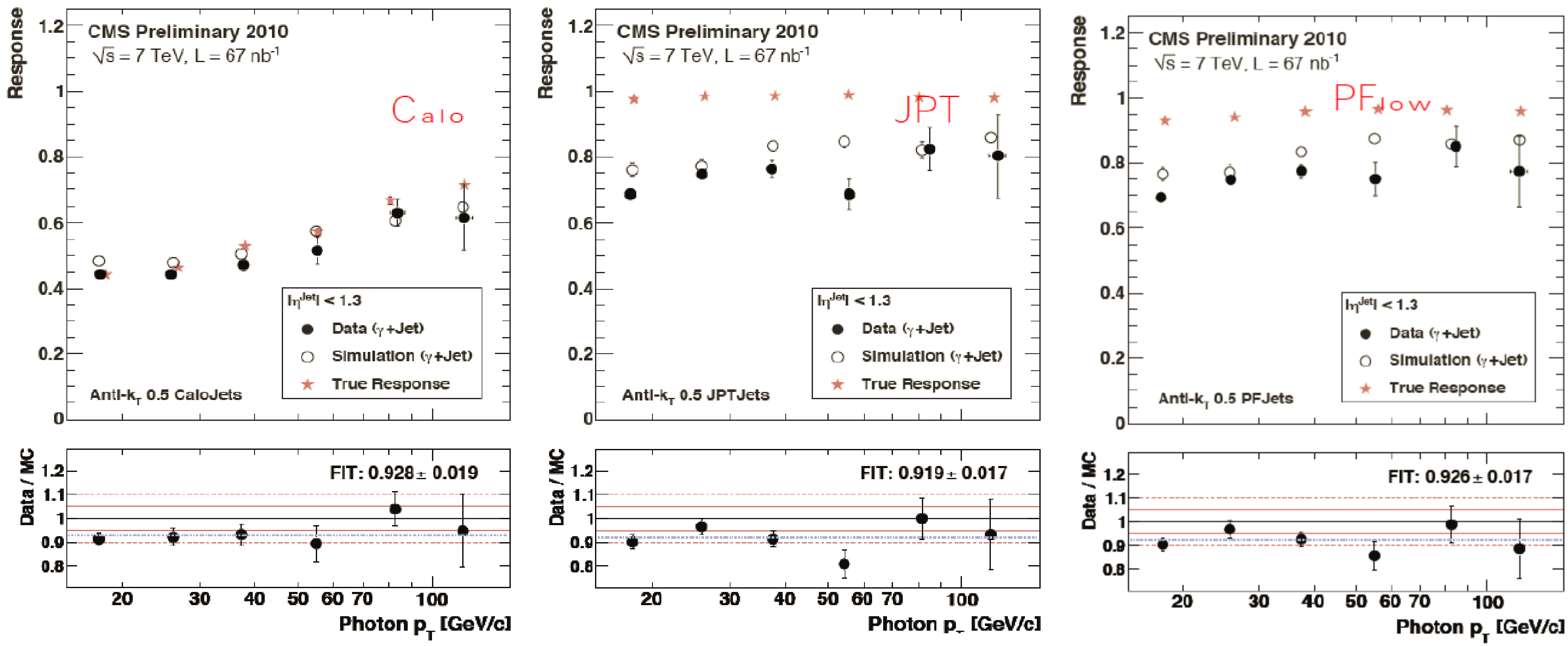
using PF objects: PF jets



	Jet 1	Jet 2
Calo p_T	703	550
JPT p_T	675	580
PF p_T	694	567

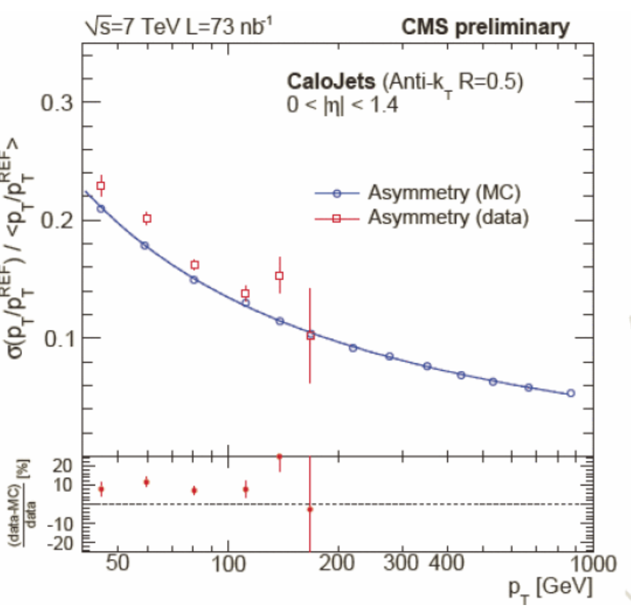
Jets (II)

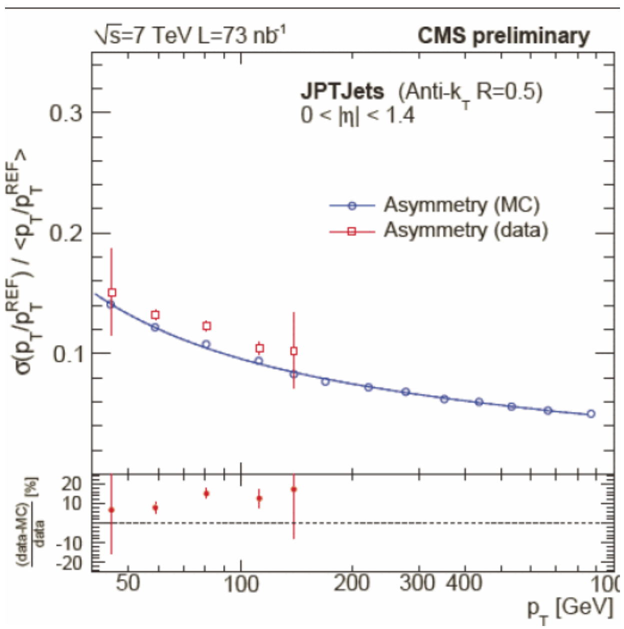
- Jet response vs p_T^{γ} from γ+jet data
  - JPT and PF gives higher response than calo jets
    - *smaller energy corrections needed*

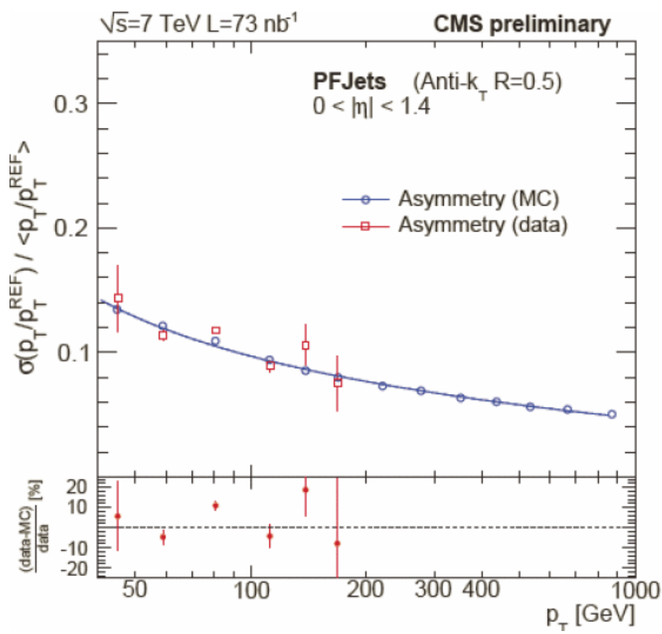


Jets (III)

- **Jet energy resolution from di-jet events**
  - **JPT and PF have better resolution than calo jets**



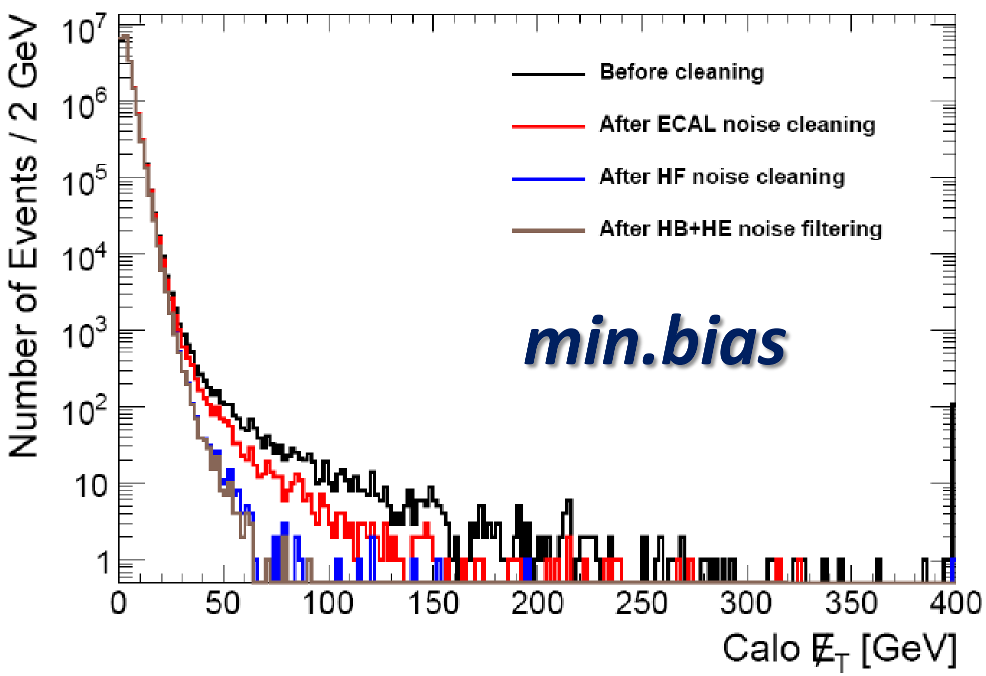




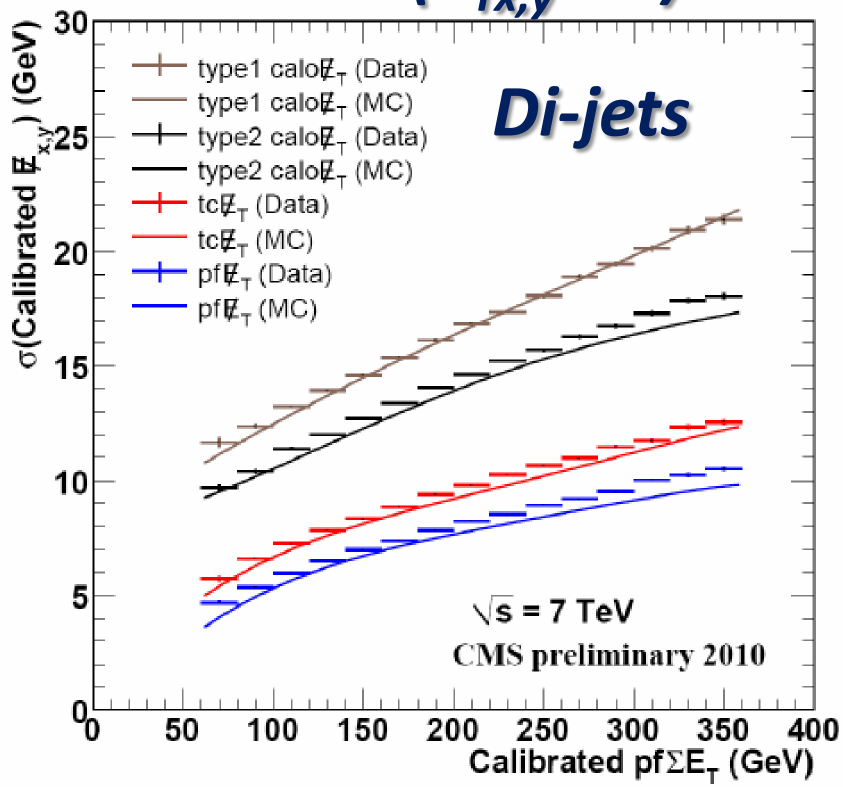
Missing E_T

- **Three methods of E_t^{miss} measurement in CMS**
  - *using calorimeter + μs: calo MET*
  - *using tracks and calorimeter + μs: tcMET*
  - *using particle flow objects: pfMET*

E_T^{miss} cleaning against noise

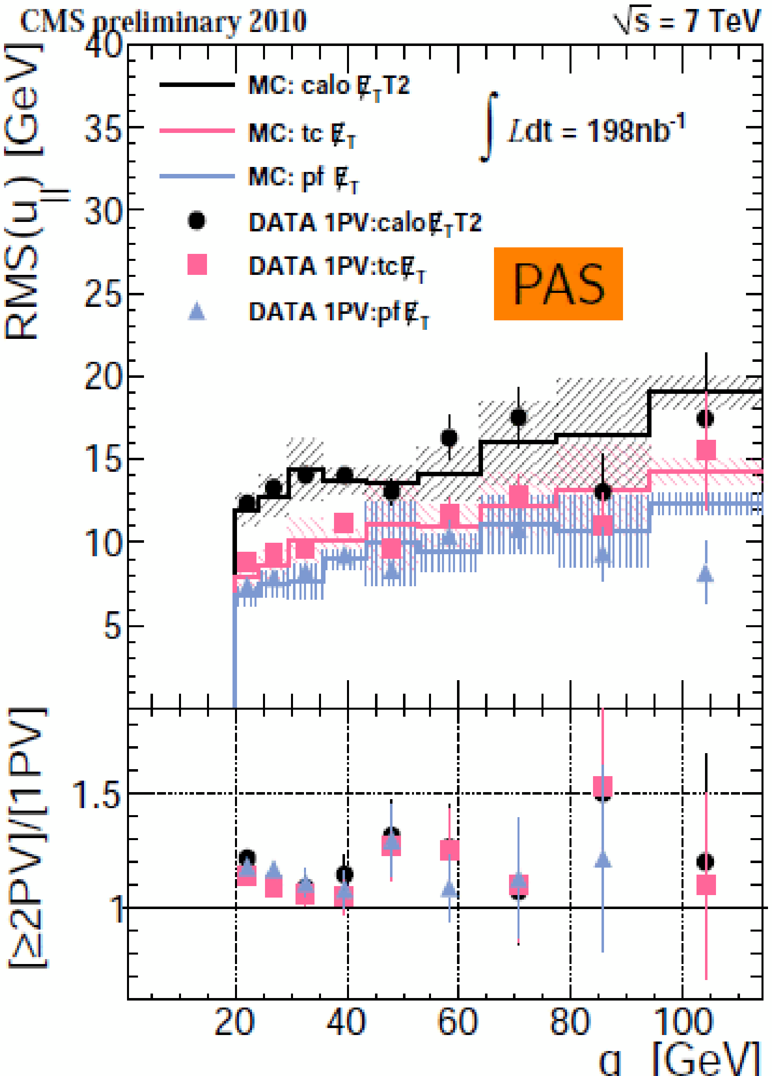


$\sigma(E_{Tx,y}^{miss})$



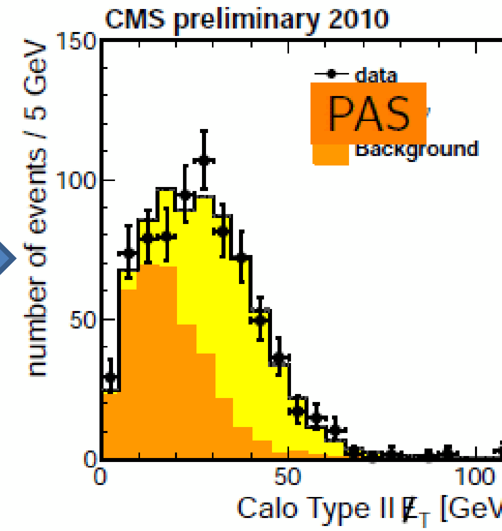
Missing E_T for evens with real E_T^{miss}

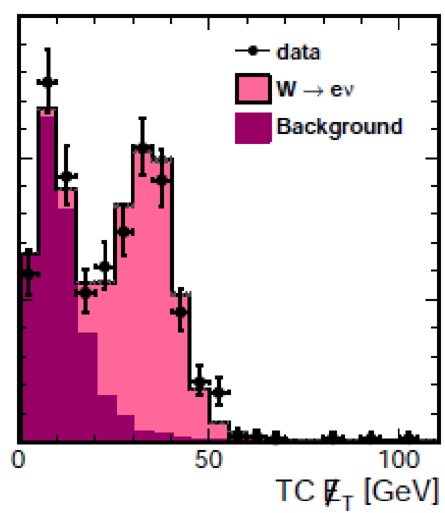
- **tcMET and pfMET gives better performance than calo MET**

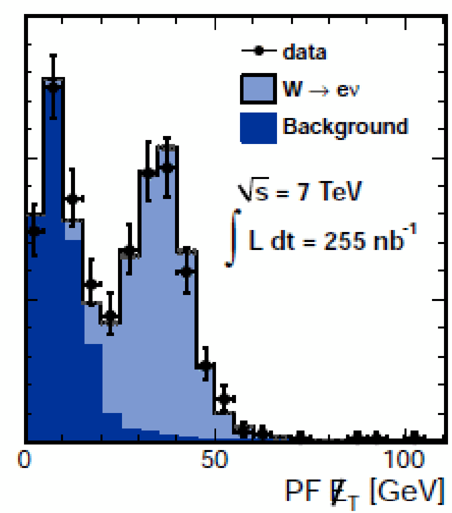


γ+jet

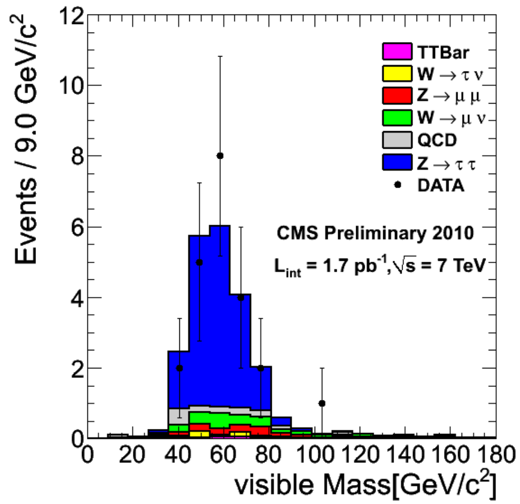
W->eν



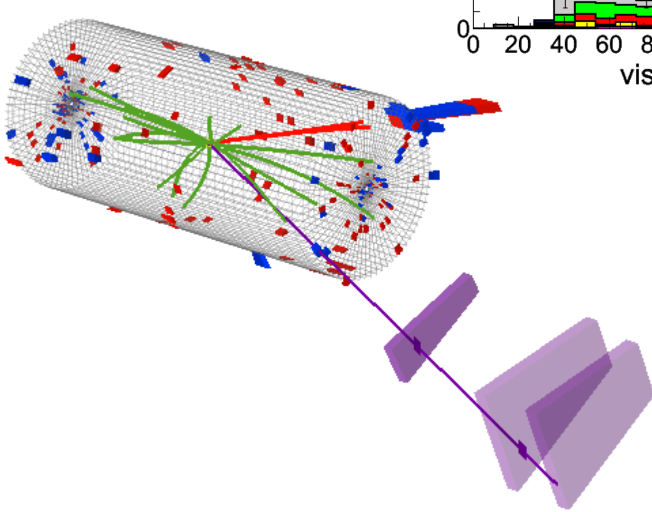


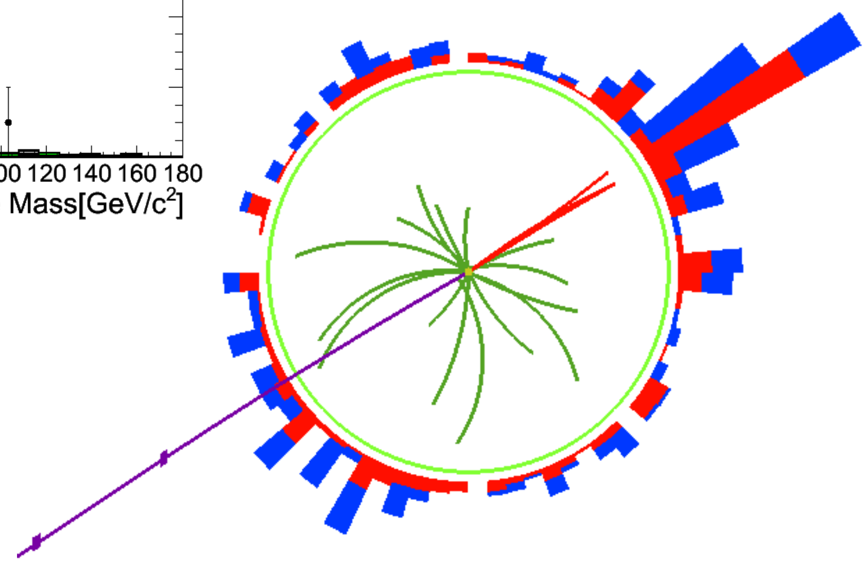


τ reconstruction and identification



CMS Experiment at LHC, CERN
Data recorded: Sun Aug 15 03:57:48 2010 CEST
Run/Event: 142971 / 323188785
Lumi section: 348
Orbit/Crossing: 91187947 / 2286

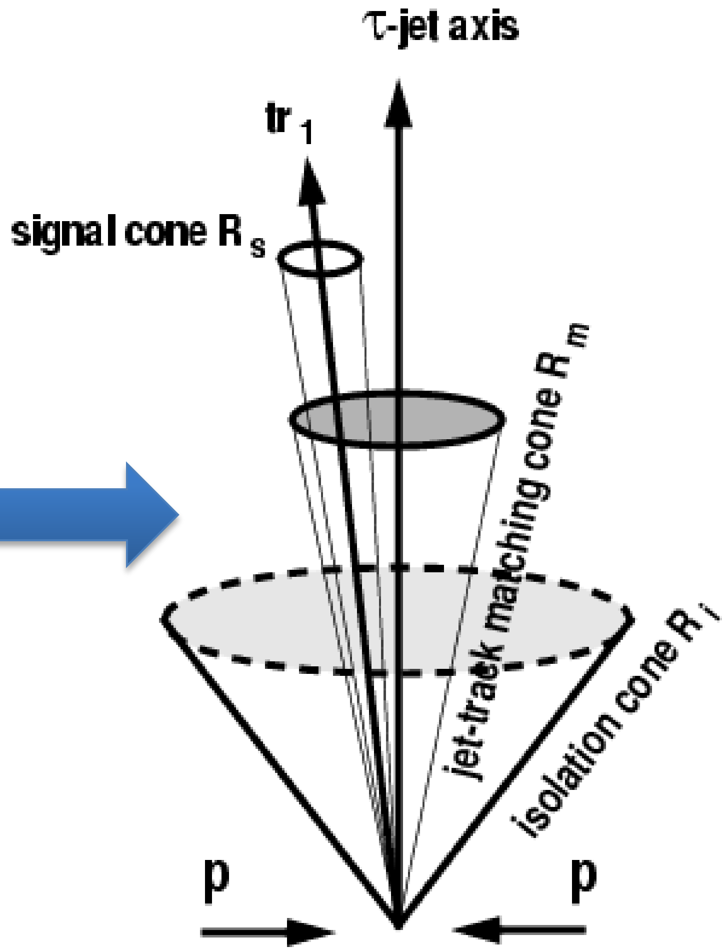




$Z \to \tau\tau \to \mu + \tau_{had}$ candidate

Off-line τ–jet reco and ID

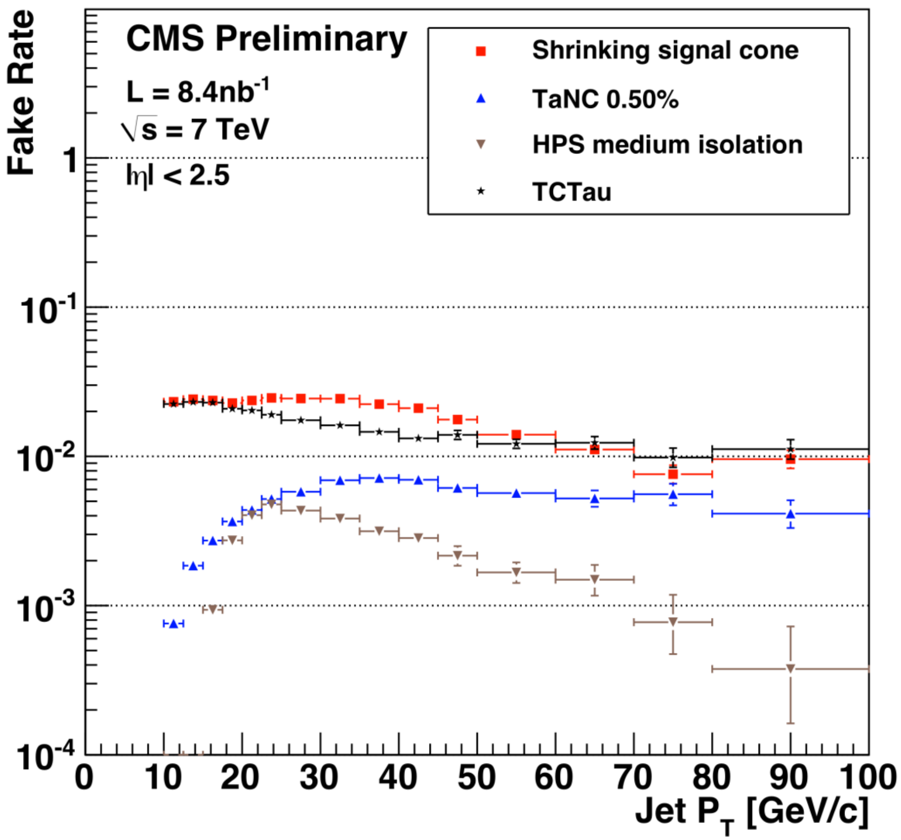
- **Reconstruction of τ-jet using**
  - Particle Flow objects; PF Tau
  - track corrected calo jet; TC Tau
- **Identification**
  - basic selections based on isolation criteria for PF and TC Taus
  - advanced ID based on reconstruction of τ decay modes using PF objects
    - Hadron Plus Strip (HPS)
    - Tau Neural Classifier (TaNC)



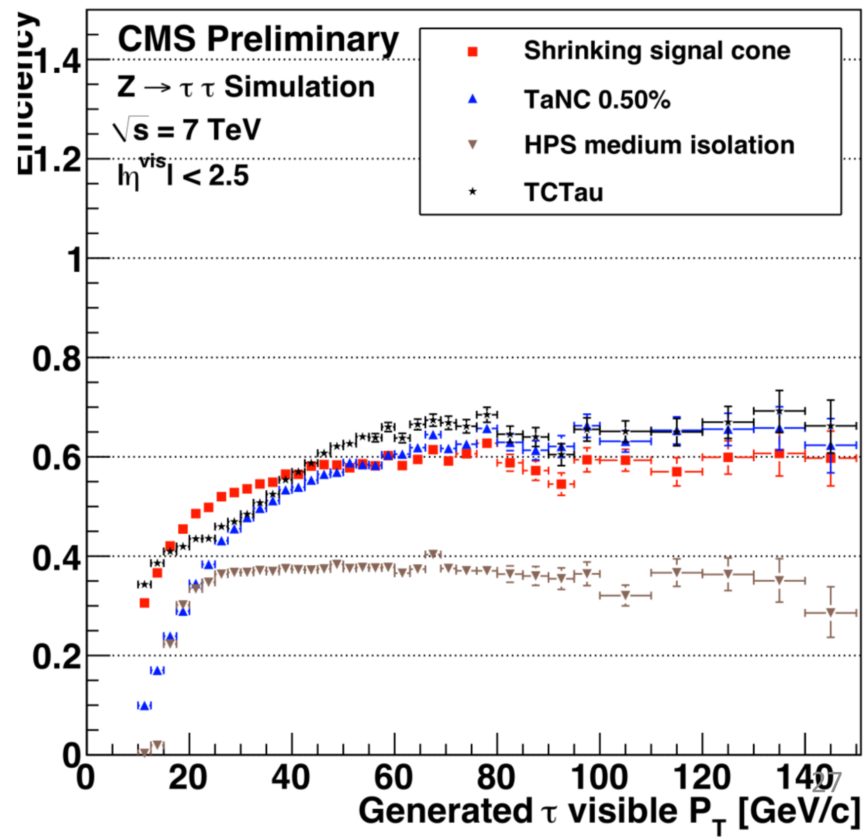
Fake rate and efficiency vs $p_T^{\tau\text{-jet}}$

- Shrinking signal cone recovers 3-prong τs at $p_T^{\tau\text{-jet}} < 30$ GeV by price of increased bkg. rate
- "advanced" τ ID provides better S/B ratio

Jet->τ_{had} fake rate: data

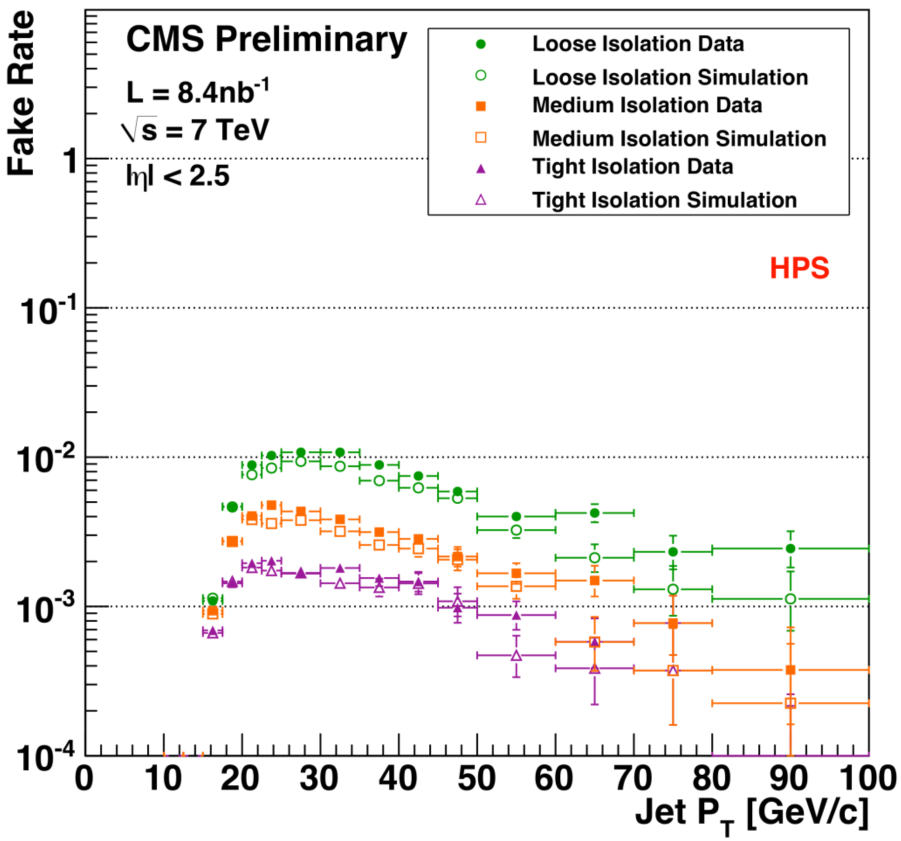


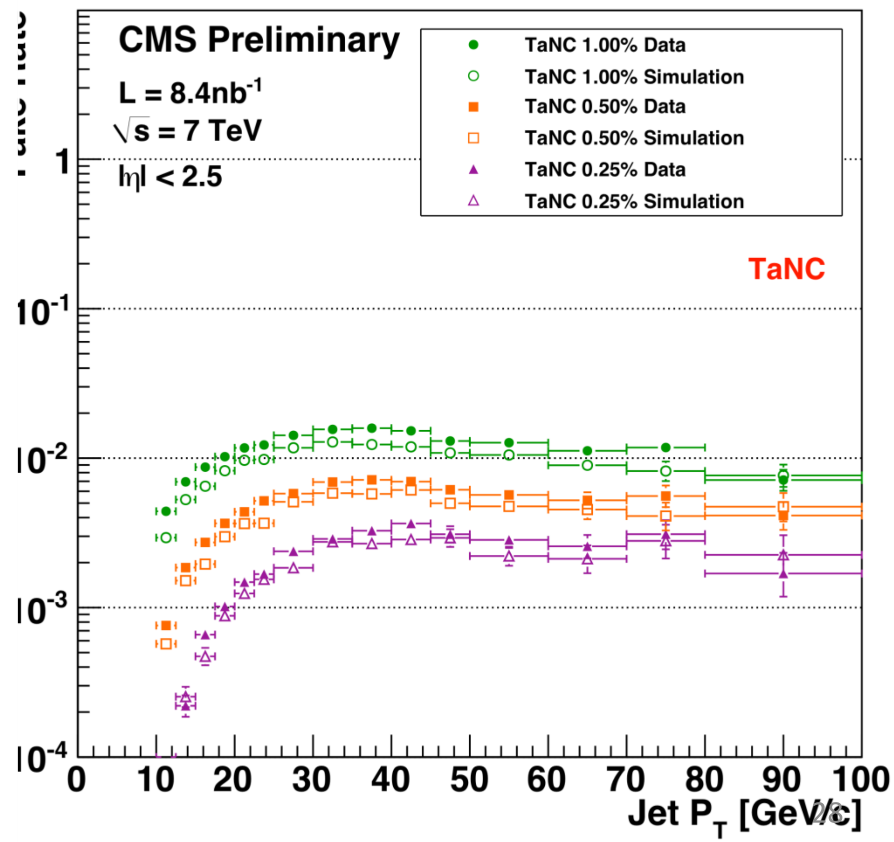
τ_{had} efficiency: Monte-Carlo



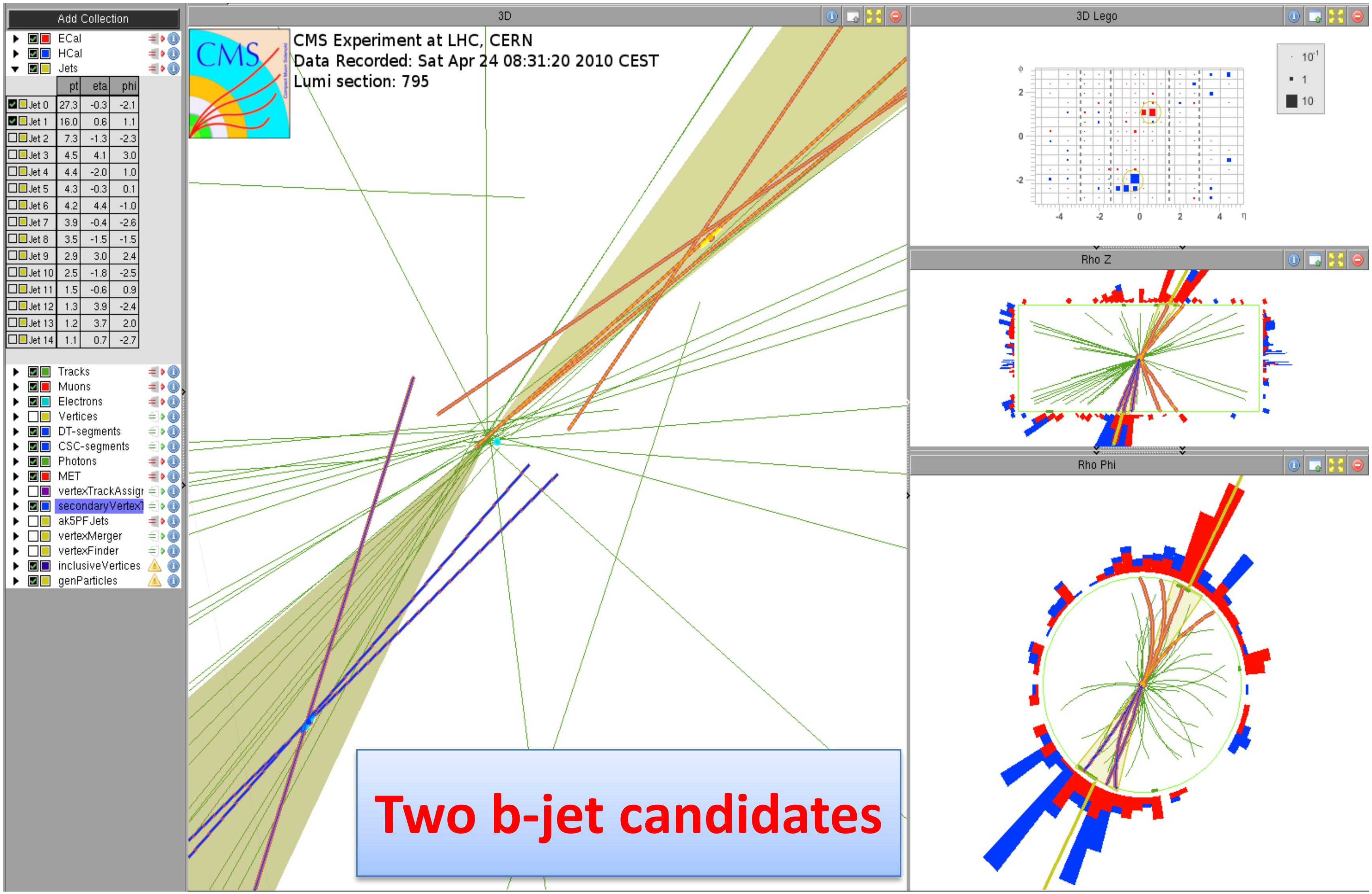
Data and MC for fake rate vs $p_T^{\tau\text{-jet}}$

- Fake rate is higher in data than in MC for all algorithms
  - need more understanding





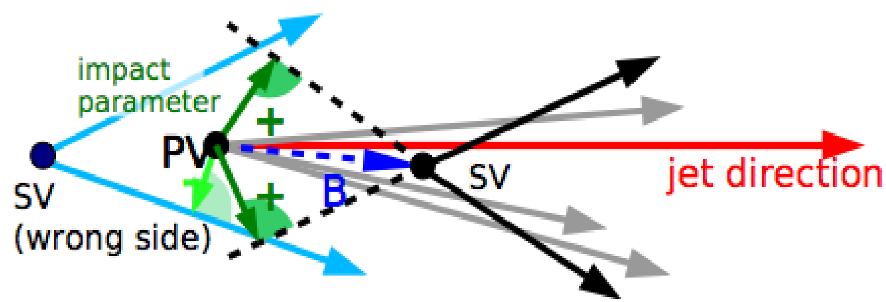
B-tagging


Add Collection
ECal
HCal
Jets
pt eta phi
Jet 0 27.3 -0.3 -2.1
Jet 1 16.0 0.6 1.1
Jet 2 7.3 -1.3 -2.3
Jet 3 4.5 4.1 3.0
Jet 4 4.4 -2.0 1.0
Jet 5 4.3 -0.3 0.1
Jet 6 4.2 4.4 -1.0
Jet 7 3.9 -0.4 -2.6
Jet 8 3.5 -1.5 -1.5
Jet 9 2.9 3.0 2.4
Jet 10 2.5 -1.8 -2.5
Jet 11 1.5 -0.6 0.9
Jet 12 1.3 3.9 -2.4
Jet 13 1.2 3.7 2.0
Jet 14 1.1 0.7 -2.7
Tracks
Muons
Electrons
Vertices
DT-segments
CSC-segments
Photons
MET
vertexTrackAssigr
secondaryVertexT
ak5PFJets
vertexMerger
vertexFinder
inclusiveVertices
genParticles
3D
CMS
CMS Experiment at LHC, CERN
Data Recorded: Sat Apr 24 08:31:20 2010 CEST
Lumi section: 795
3D Lego
Rho Z
Rho Phi
Two b-jet candidates

CMS b-tagging algorithms

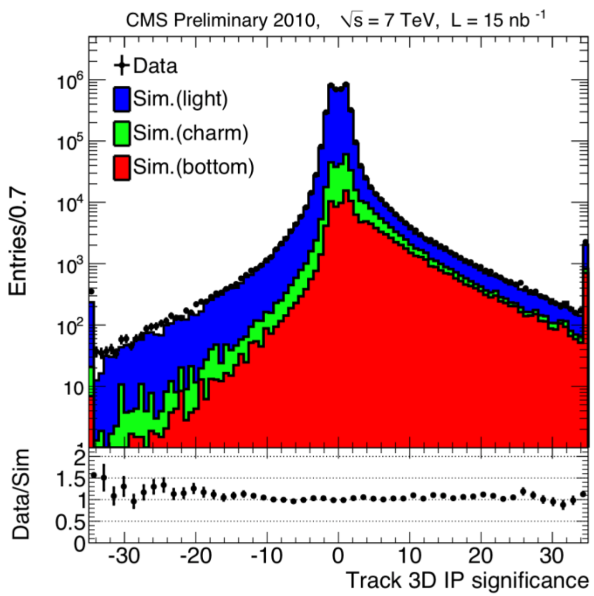
- **Track counting**
  - high efficiency; use 2nd track 3d ip significance
  - high purity; use 3rd track 3d ip significance
- **Jet probability**
  - use 3d ip significance of all tracks
  - use four most displaced tracks
- **Secondary vertex based on 3D flight path significance**
  - use >= 2 track vertex
  - use >= 3 track vertex
- **Lepton (e, μ) taggers**

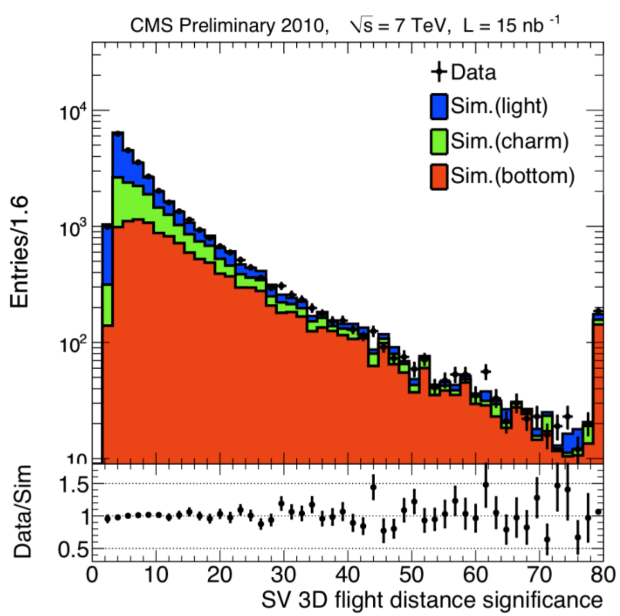
Signs of Impact parameter and of vertex decay length are defined according to jet direction

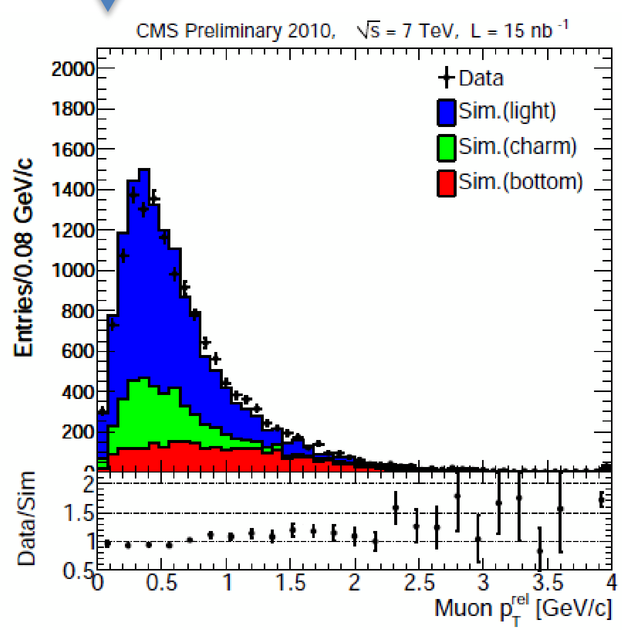


Data vs MC for b-tagging observables

- Track 3D ip significance
- SV 3D flight path signif.
- muon p_T^{rel}



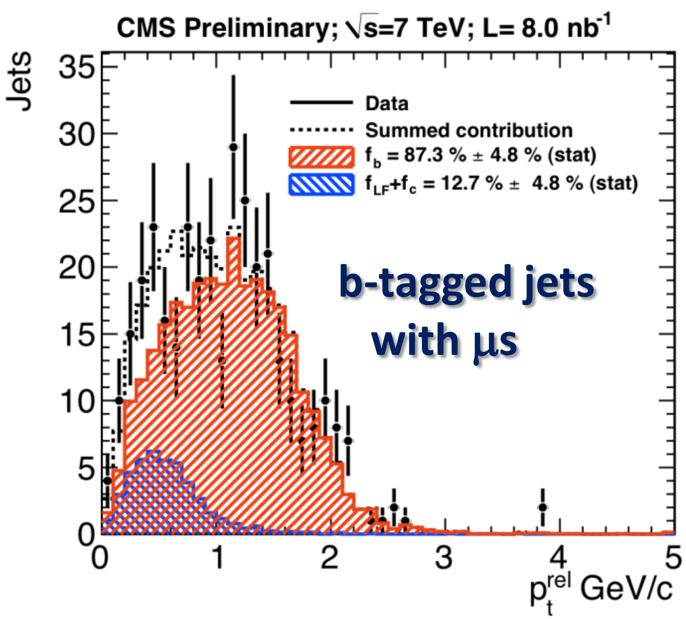




B-tagging efficiency

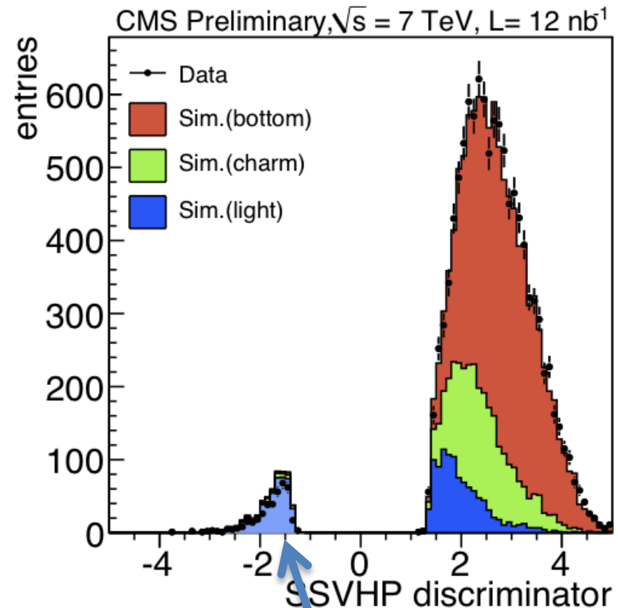
$$\epsilon_b^{data} = \frac{f_b^{tag} \cdot N_{data}^{tag}}{f_b^{tag} \cdot N_{data}^{tag} + f_b^{untag} \cdot N_{data}^{untag}}$$

Extract f_b^{tag}, f_b^{untag} from fit of $p_{t\mu}^{rel}$ for b-tagged (untag) jets with muons



- in general good agreement between ε_b^{data} and ε_b^{MC}

Fake rate

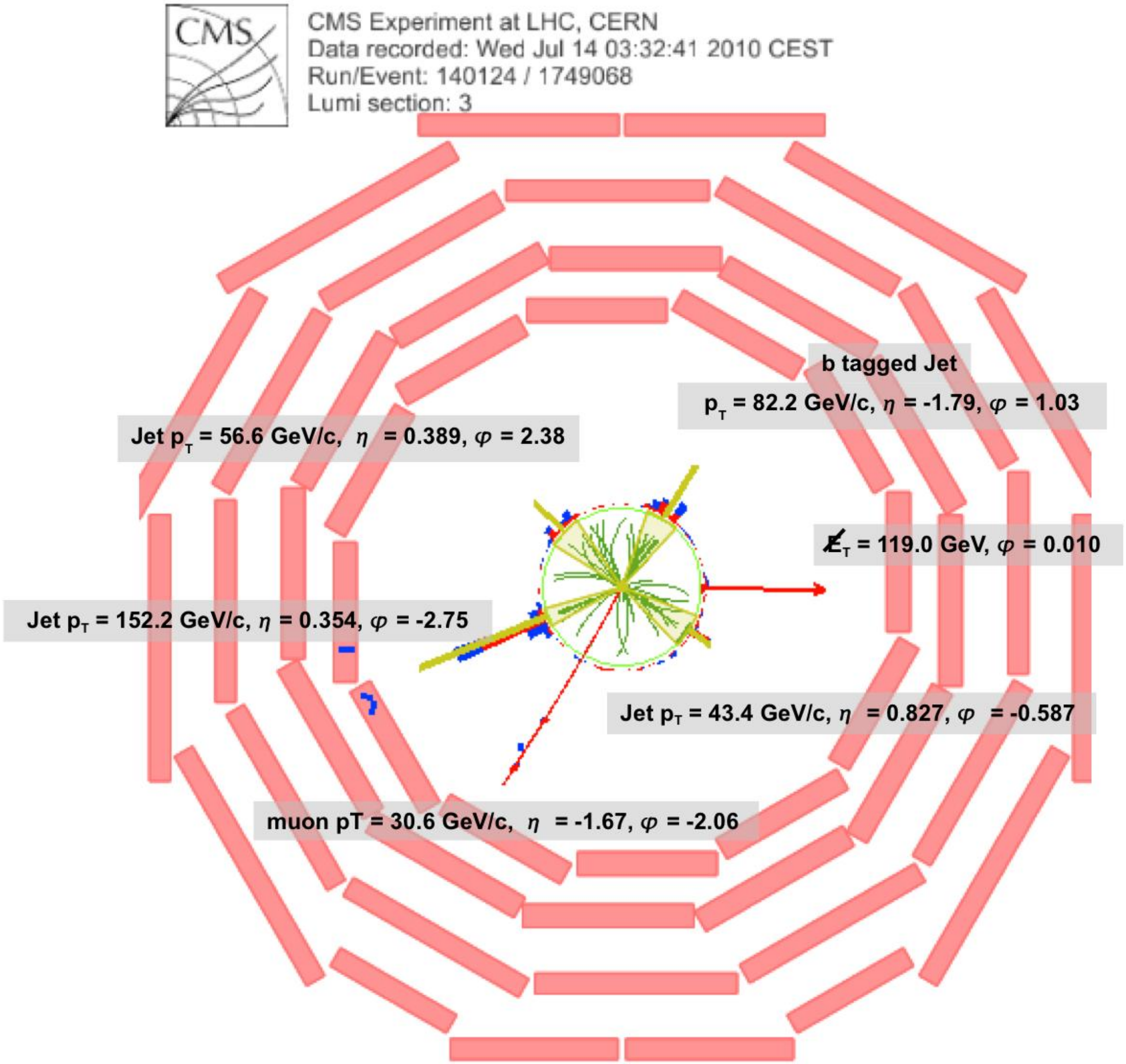


$$\varepsilon_{data}^{mistag} = \varepsilon_{data}^{-} \cdot R_{light}$$

$$R_{light} = \varepsilon_{MC}^{mistag} / \varepsilon_{MC}^{-}$$

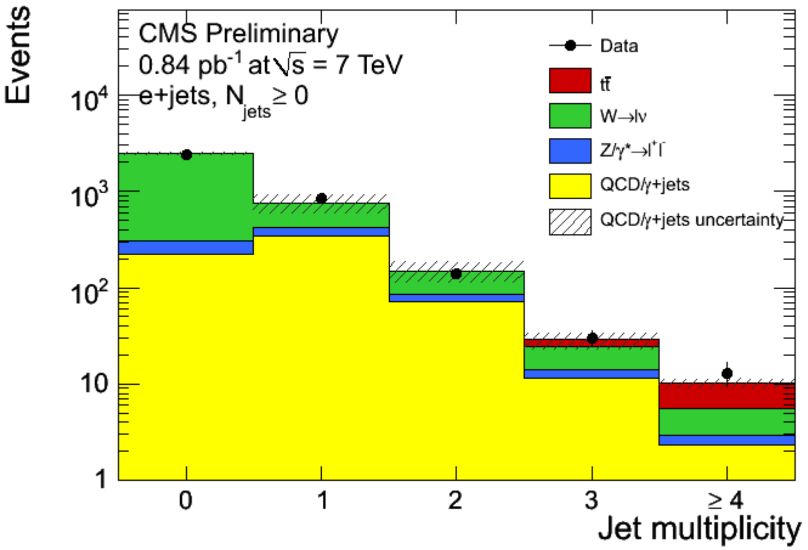
- $\varepsilon_{data}^{mistag} / \varepsilon_{MC}^{mistag} = f(p_T^{jet}, \eta^{jet})$ slightly less than 1.

tt~ with e/μ+jets

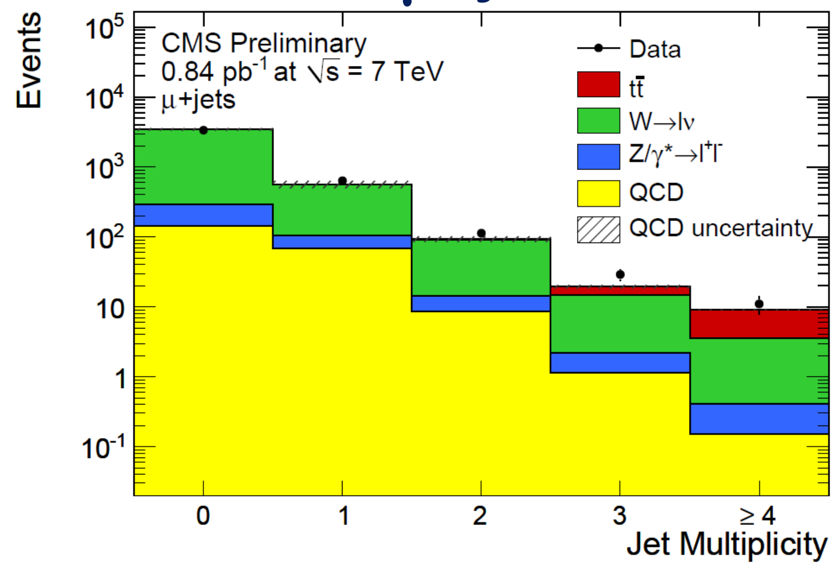


Jet multiplicity; No b-tagging, no MET cut applied

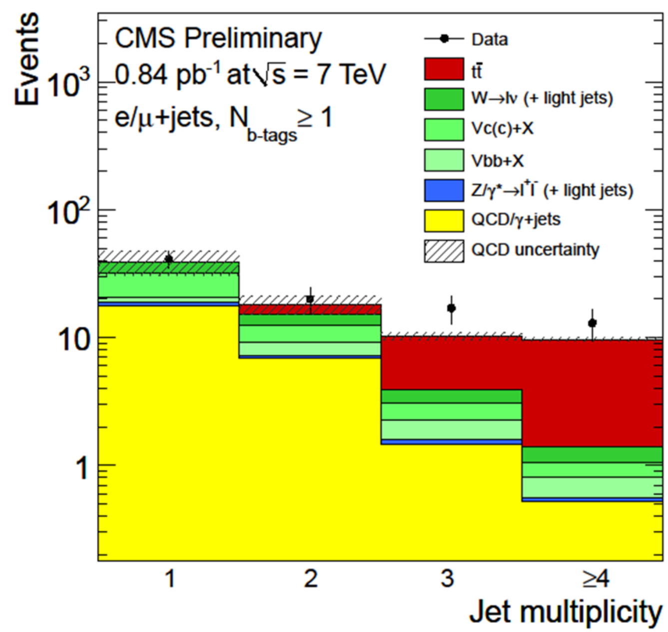
e+jets



μ+jets

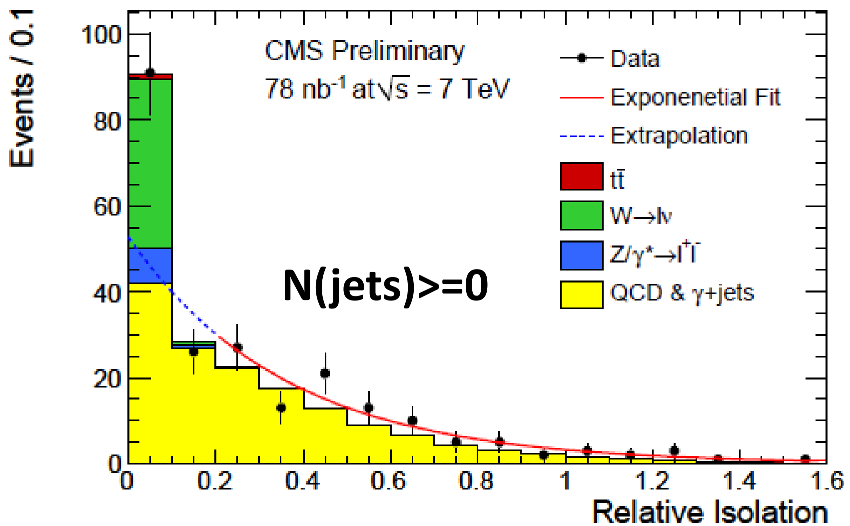


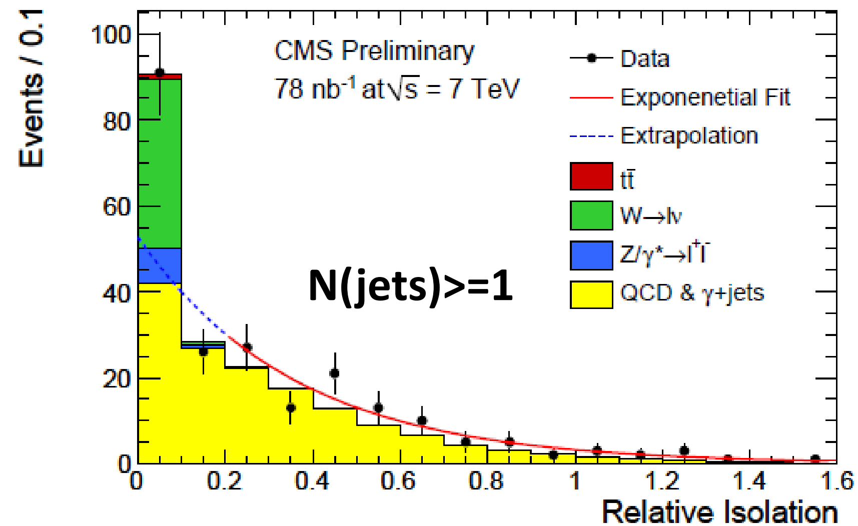
Combined e/μ + jets with at least 1 b-tagged jets using Secondary Vertex Tagger with 1% fake rate working point



How QCD "e"+jets is defined from data:

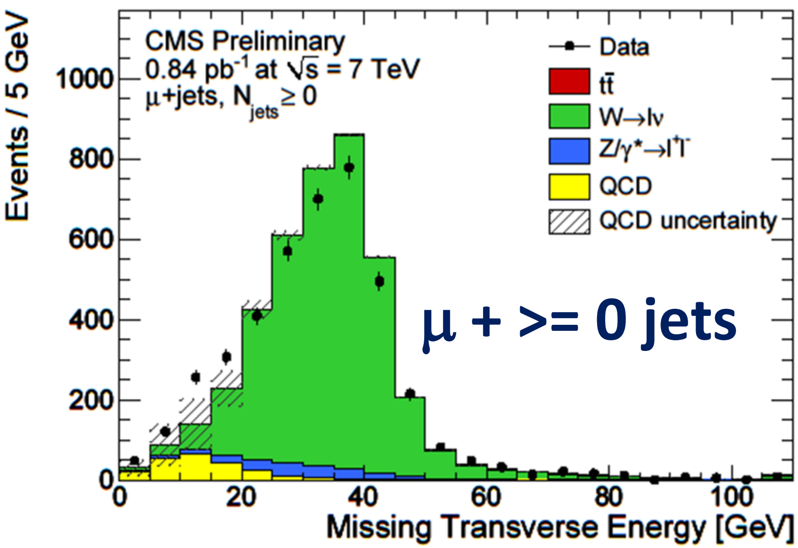
- **Fit function to isolation distribution in non-isolated (QCD dominated) region**
- **Extrapolate to isolated (W-like) region**

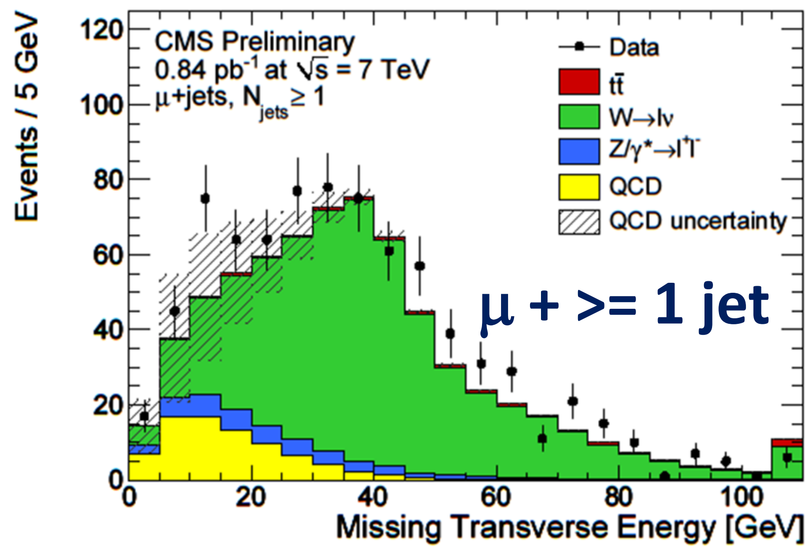




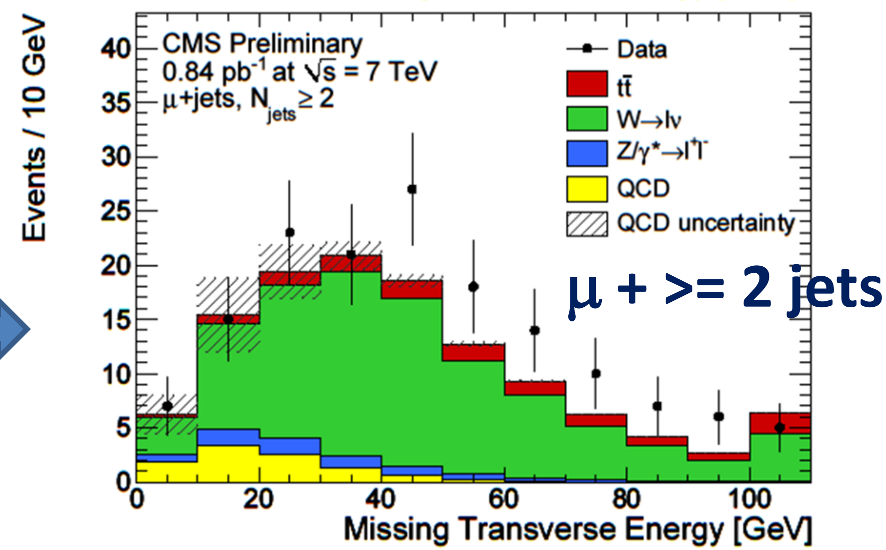
Isolation extrapolation method (e+jets)		
Fit Range	$N^{est.}_{QCD}$(≥0-jet)	$N^{est.}_{QCD}$(≥1-jet)
0.1–1.6	67 ± 9	40 ± 6
0.2–1.6	73 ± 13	46 ± 9
0.3–1.6	71 ± 17	45 ± 12
Average $N^{est.}_{QCD}$	70 ± 35	44 ± 22
Prediction N^{MC}_{QCD}	63 ± 7	42 ± 6

Missing E_T in tt~->lbjjb analysis





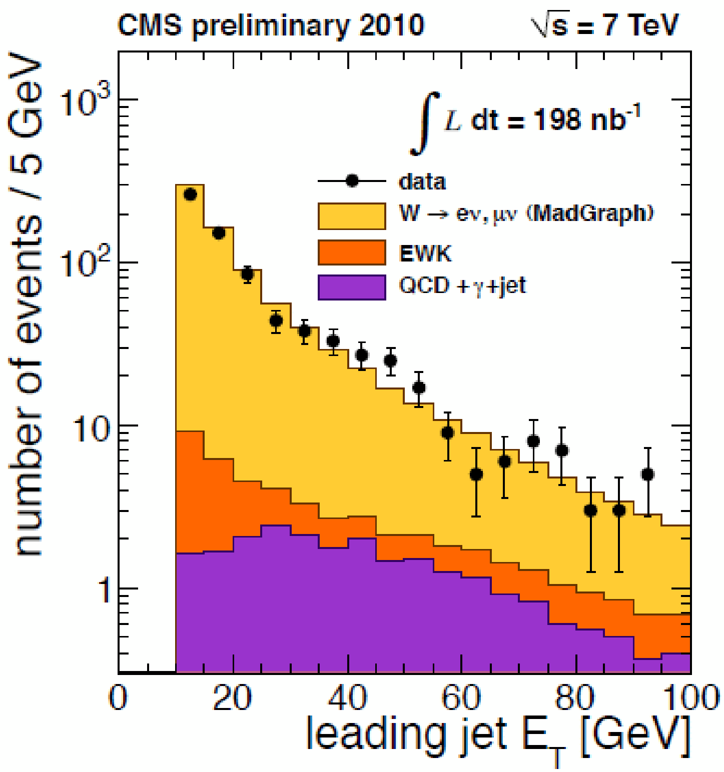
- *Initial selections of tt~->WbH$^+$b->l$\nu\tau_{had}$b analysis:*
  - p_T^{μ} > 20 GeV
  - N jets >= 2
  - Missing E_T > 40 GeV

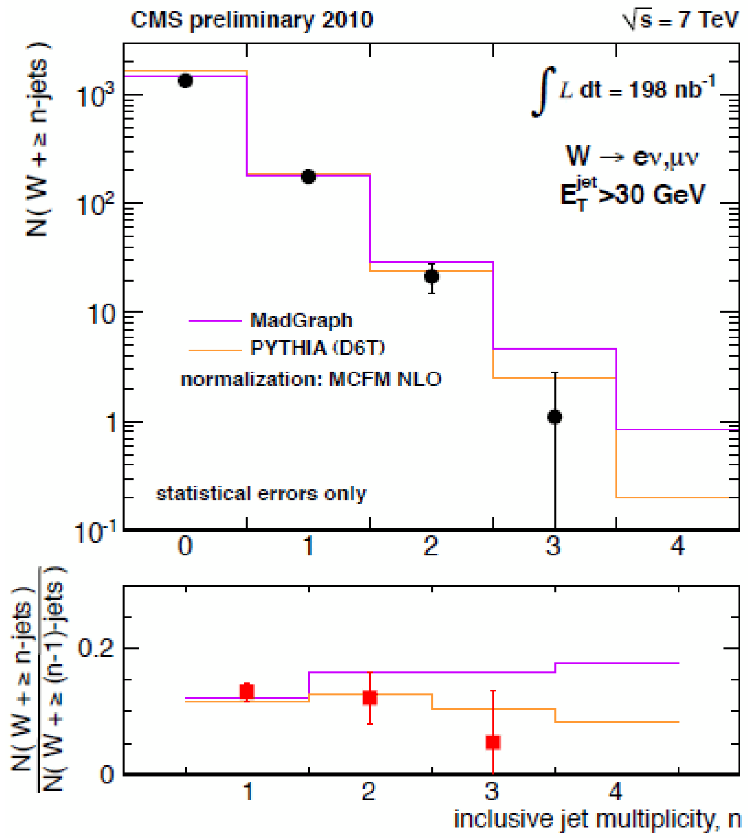


W+jets, W->eν, μν

- QCD backgroundis obtained from the fit
- tt~ is substracted using Monte-Carlo

Leading jet E_T distribution in W events



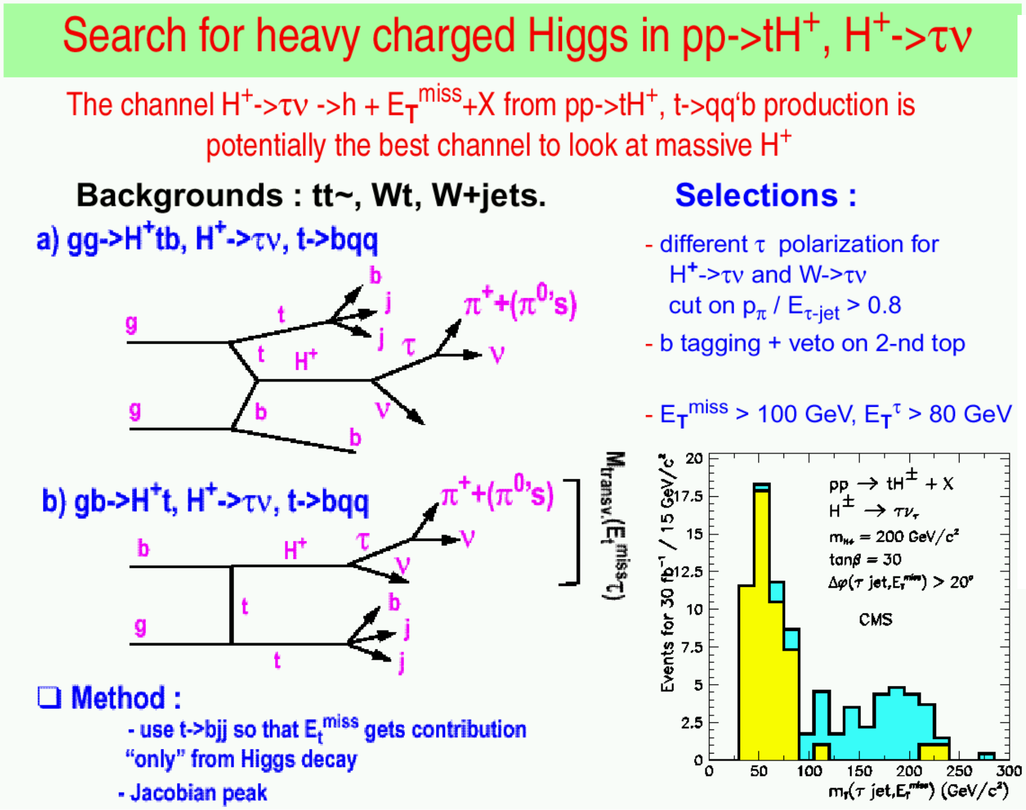


conclusions

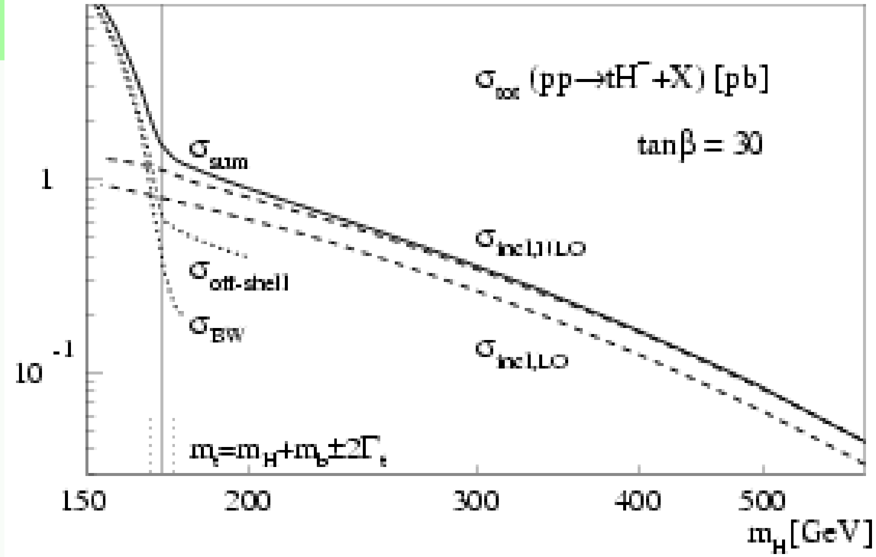
- After twenty years spent on the design, R&D, prototyping, construction, assembly and commissioning CMS is recording high energy collisions.
- Preparation of the experiment, the offline and computing systems, and physics analysis work flows has allowed very rapid extraction of quality physics results.
- Looking forward for the Charged Higgs boson analyses with data !

BACK UP

Pioneer analysis in CMS in ~ 199X



T. Plehn et al., hep-ph/0312286 used in CMS PTDR 2006

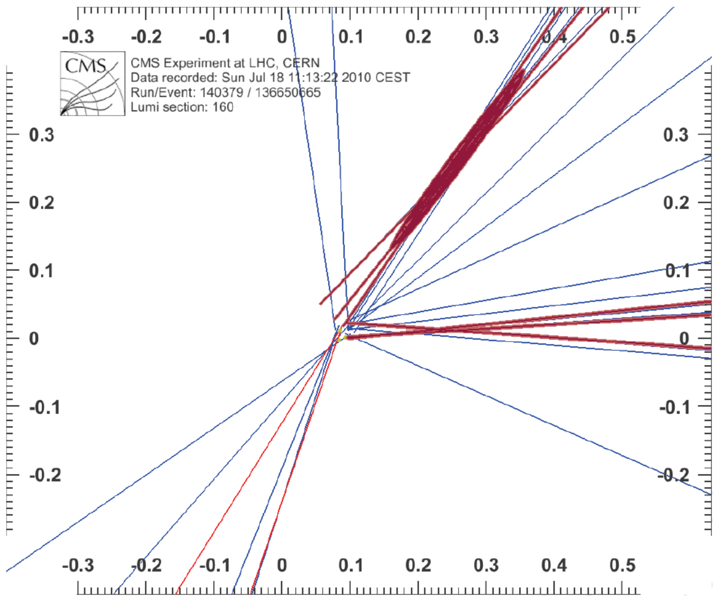


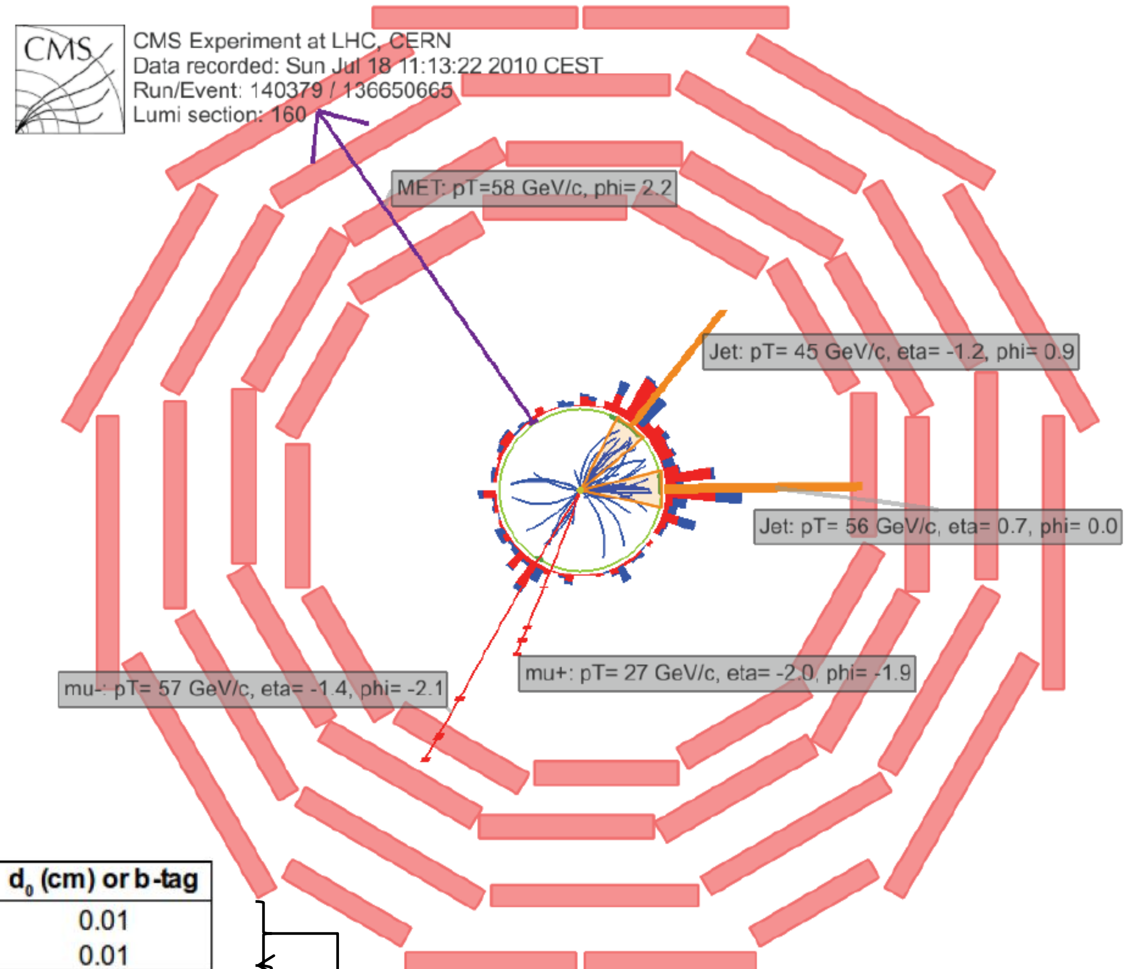
- **CMS analyses so far:**
  - $tt\sim \to H^+bWb \to \tau_{had}\nu bl\nu b$
  - $pp \to H^+t(b) \to \tau_{had}\nu jjb(b)$
- **Objects involved:**
  - High p_T e/μ s
  - Jets and E_T^{miss}
  - τ and b-tagging
- **Backgrounds:**
  - tt~, W+jets
  - QCD multi-jets

tt~ : Golden Dilepton Candidate

- **μμ + 4-jets + 2-tags+MET:**

UCSB/UCSD/FNAL, LIP





SSV's found for these 2 jets

Object	Algo	p_T (GeV/c)	η	ϕ (rad)	d_0 (cm) or b-tag
μ_1	global	56.80	-1.43	-2.13	0.01
μ_2	global	27.10	-2.04	-1.90	0.01
jet_1	calo	53.13	0.71	0.01	3.68
	jpt	55.69	0.71	0.02	3.68
	pf	53.71	0.72	0.03	3.68
jet_2	calo	46.30	-1.14	0.90	3.75
	jpt	44.52	-1.18	0.94	3.75
	pf	54.95	-1.21	0.97	3.75
MET	calo	54.84		2.37	
	tc	57.72		2.18	
	pf	55.12		2.32	

eu

$M_{\mu\mu}$ = 26 GeV/c^2

Values for Track Counting High Efficiency. Recall:
TCHEL: TCHE > 1.7
TCHEM: TCHE > 3.3