Challenges of hadron colliders

Regina Demina
University of Rochester
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Outline

- LPC at Fermilab and workshops
- Limiting factors
- Detector performance and physics objects
  - Lessons of commissioning
  - Calorimeter, jets and missing energy
  - Muons
  - Tracking and b-tagging
- Computing and Monte Carlo
- Sociology and politics
- Outlook

Fermilab LHC physics center

- Links from http://www.uscms.org/LPC/LPC.htm
- Aug 3,4 2004 Tracking Workshop
- April 14,15 2004 Muon Workshop
- Jan 28,29 2004 Jet/Met Workshop
- Photons/electron – to be announced

Workshops

- Very informative presentations
- Might be even more useful to promote communications between CDF and DØ than between Tev and LHC
- Almost therapeutic value of venting out the issues that long waited to be talked about
- In this talk slides/ideas taken from
- Song Ming Wang, I. Iashvili, B. Heinemann, D. Denisov, K.Bloom, F. Rizatdinova, M. Herndon, G. Watstts, T. Diehl…

LHC Physics Center

- Right now main activity is concentrated on understanding low level objects in CMS software
- 1st volume of physics TDR
- Some of the LHC ideas can be tried in Tevatron environment
- Working groups:
  - LPC Offline Coordinators: Liz Sexton-Kennedy and Hans Wenzel
  - Tracking: Kevin Burkett and Sasha Khanov
  - Electron/Photon: Yuri Gershtein and Heidi Schellman
  - Muon: Eric James and Martijn Mulders
  - Jet/Met: Rob Harris and Marek Zielinski
  - Trigger: Sridhara Dasu and Stephan Lammel
  - Simulation: Daniel Elvira and Boaz Klima

Limiting factors for Tevatron

- Run 2 T_0 = March 2001
- First publications from CDF and D0 – 2004
- Why did it take 3 years?
- Very non-scientific survey
- Asked CDF and DØ physics conveners
- What were the limiting factors for the first physics publication in Run 2 in your group?
- Thanks for the input:
- S. Lammel, B. Heinemann, D. Denisov, G. Borisov, V. Buescher, I. Iashvili, J-F. Grivaz, G. Watts, E. Thompson, J. Konigsberg

Limiting Factors

- What were the limiting factors for the first physics publication in Run 2 in your group?
- No clear leading limitation (is it good?)
- Detector (and accelerator) performance
  - Calorimeter calibration (CDF and D0),
  - Alignment (tracker and calorimeter)
  - Luminosity delivered by Tevatron (too low at start, too high now?)
  - Tracking – not so much,
  - Muons – no complains
- Maturity of reco algorithms
  - Performance and speed
- Complexity of the software, reliability of Monte Carlo (and availability of samples)
- CPU, speed and ease of data access, data format
- Social issues and politics

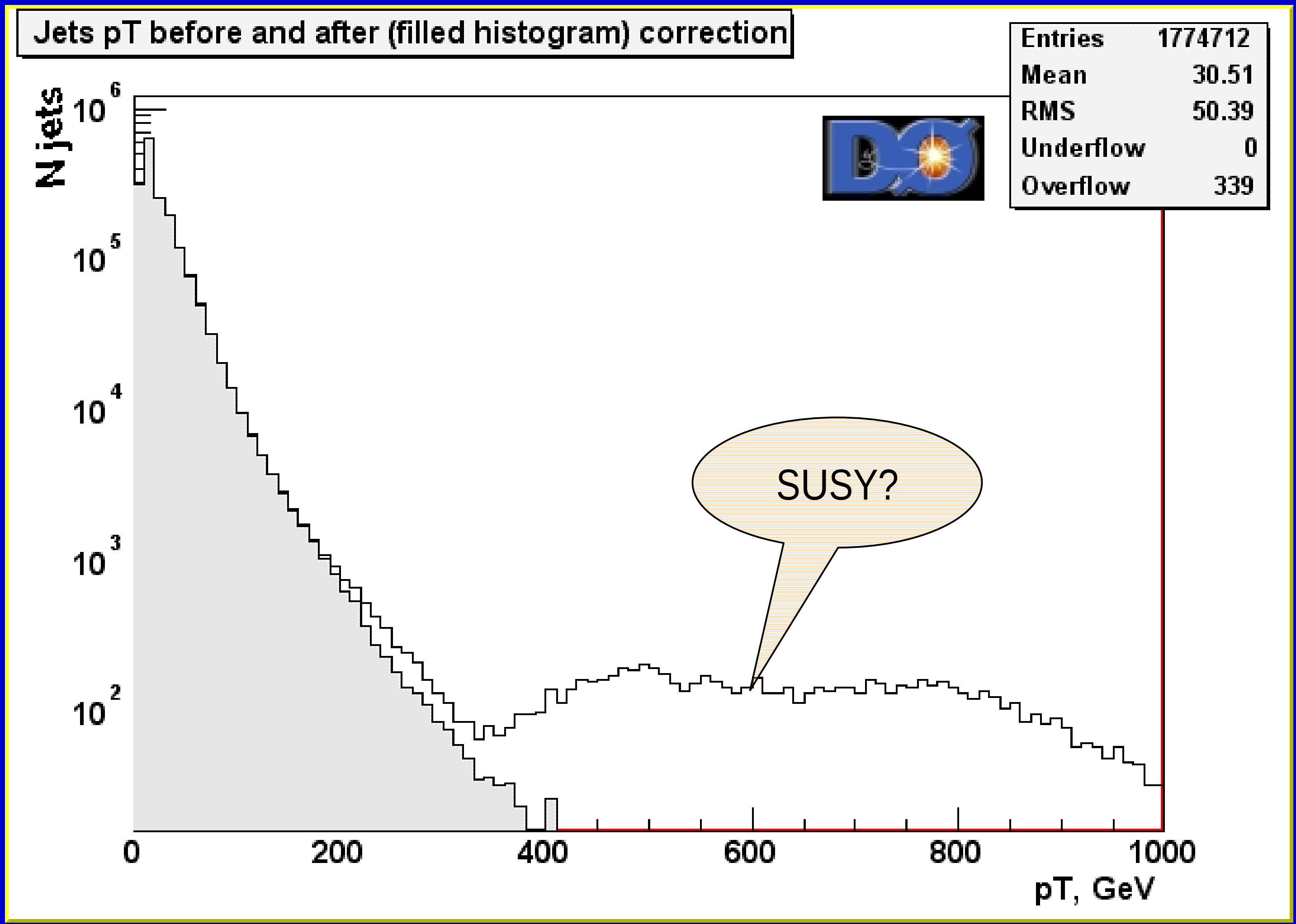
Lessons of commissioning

- Definition of T_0 is the main reason for 3 years
- Chris Hill (UCSB) – in charge of CDF silicon commissioning - presentation to CMS silicon group
- CDF Si installed 01/01 cabling completed 05/01
- It's hard to cable the detector while taking physics data, it's hard to commission the detector while taking data
- Premature emphasis on physics was counter productive
  - Limits resources
  - Hard to schedule access, special runs
  - Safety, reliability, coverage, trigger rates may not be compatible goals
- Politics ("soviet style reporting upstairs") is a major effect and I expect it would be even more so in LHC

Calorimeter, Jets, Met

- Both calorimeters essentially recycled from Run 1
- Still calorimeter calibration is the 1st issue to be mentioned in detector performance
- Monitoring of the data quality is the key
  - Important to have tools ready
  - Dedicated manpower (recognized and well promoted)

Jet P_T Distribution Before and After Steps 1,2,3.



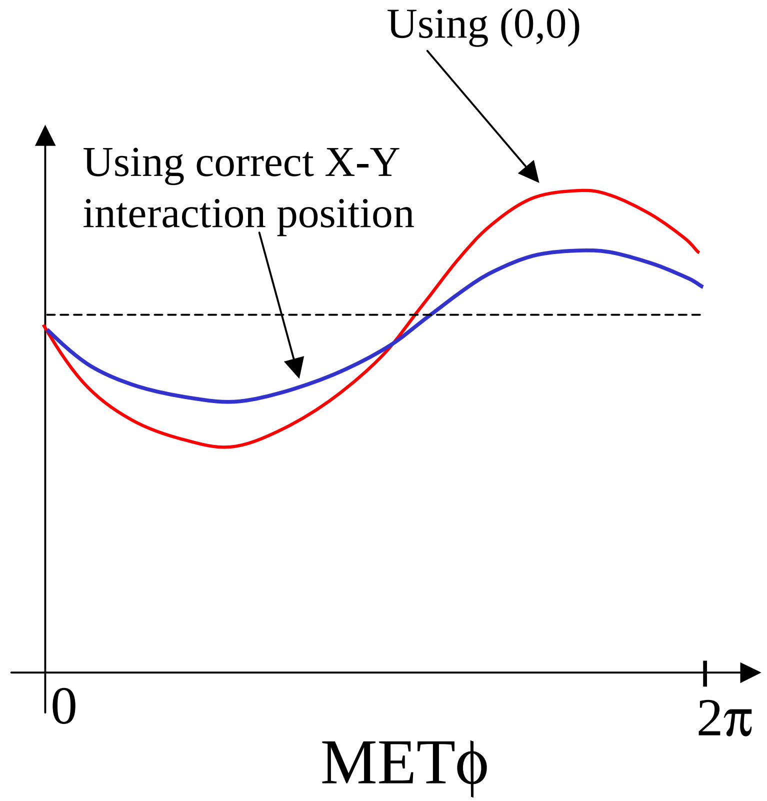
in average 2 – 6 bad cells killed per run and 0 – 2 of them are hot (with large occupancy).

Primary Vertex Position

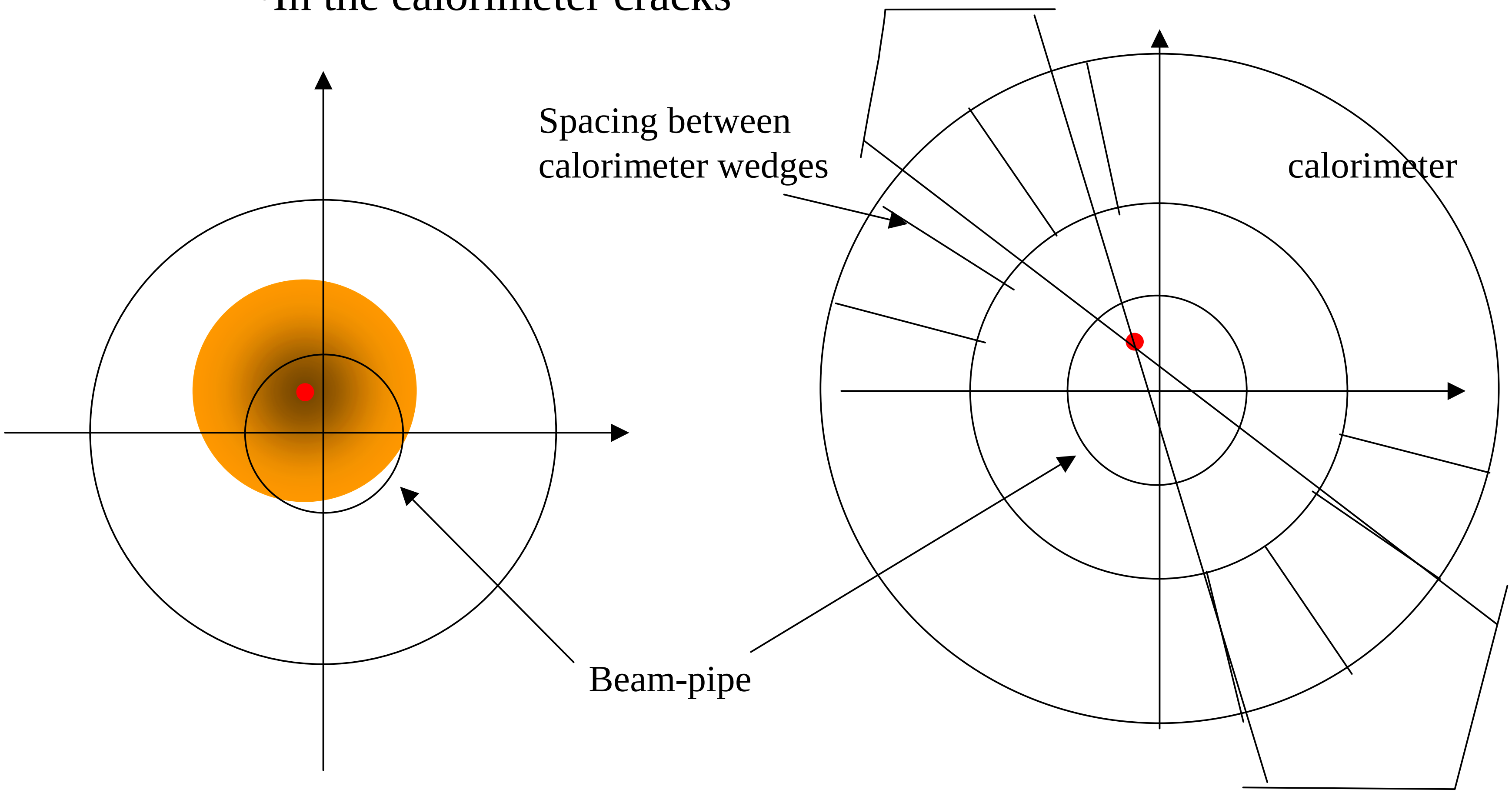
- Calculation of MET requires the knowledge of the positions of the calorimeter cells/towers w.r.t. the collision point
- At Tevatron, the σ_Z(luminous region) ~ 30 cm
- Usually at the trigger level the Z position of the collision point for an event is not readily accessible, => assume Z=0
  - <MET(Z=0)> > <MET(Z=VertexZ)>

<u>Beam offset in X-Y plane</u>

- At CDF, at VertexZ = 0
  - VertexX ~ -1mm, VertexY ~ +4mm (before Sept 2003 shutdown)
- Observe "sine" shape in the reconstructed METϕ distribution, when using (0,0) as the interaction point, instead the actual position
- The METϕ "sine" shape still remain (smaller) after using the right interaction point in the X-Y plane



- After Sept '03 shutdown, the beam is now much closer to (0,0) , and METϕ is also more flat
- Still don't know why the corrected METϕ distribution is not flat
- Maybe due to :
    - Non-uniform (in azimuth) energy lost
        - down the beam-pipe
        - In the calorimeter cracks



Muons

- I will not say much, no complains in this run
- Almost a Cinderella story
- A lot of good physics, e.g. D0 first publication based on events with 4 muons (Doubly charged H)
- B-physics relies on muon trigger

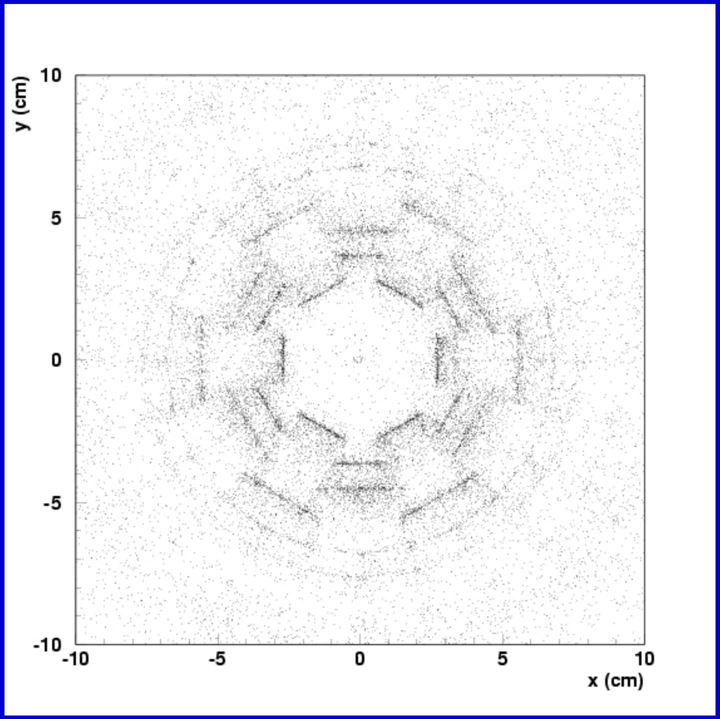
Tracking

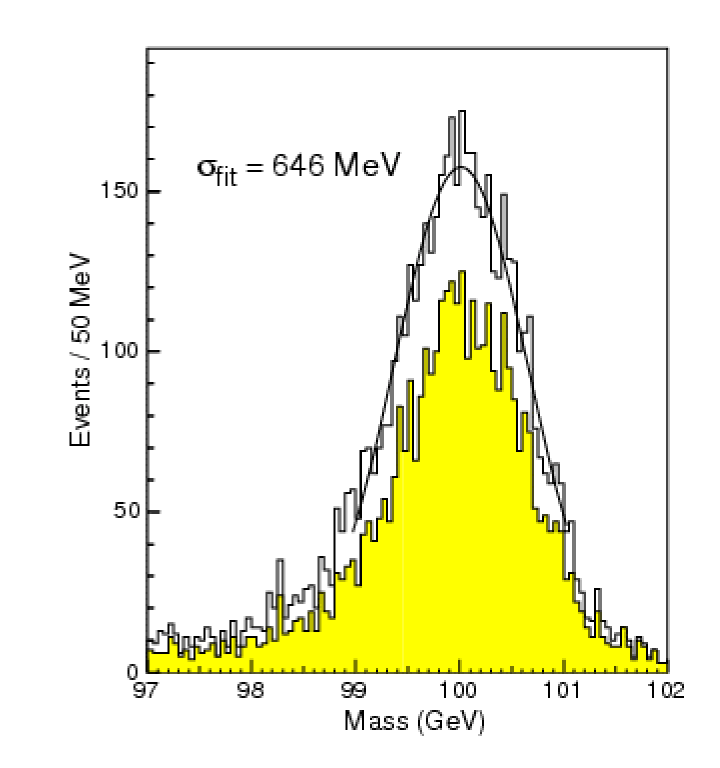
- It works really well now
- Both experiments developed ~3 alternative algorithms (it was actually a good idea)
- Slow algorithms
  - A lot of built in flexibility was not used
  - D0 ended up trading a lot of OO programming for a speed
- Alignment is still an issue
- Important to have stand alone tracking for different parts of the system
- Algorithms must not assume perfect defectors
  - Misalingment
  - Debugging

H → γγ

- Due to new CMS tracker design 42.0 (59.5)% of photons convert before reaching barrel (endcap) ECAL

- D0 conversions





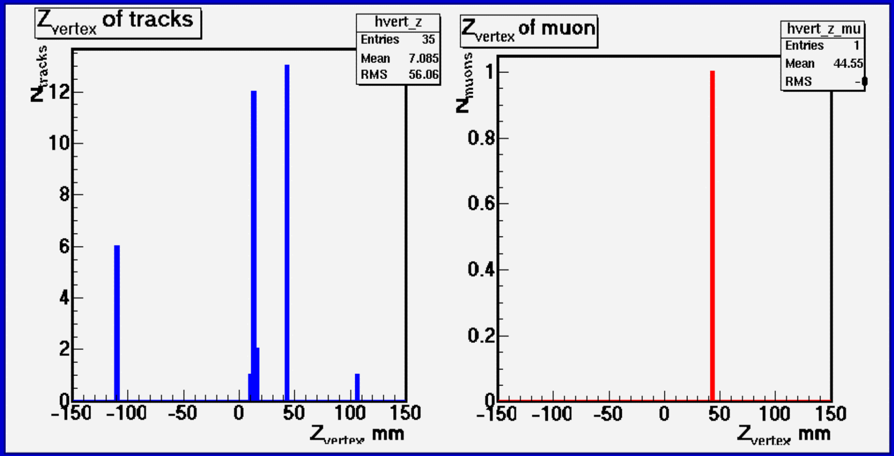
Converted – reco algorithms
Nonconverted γ

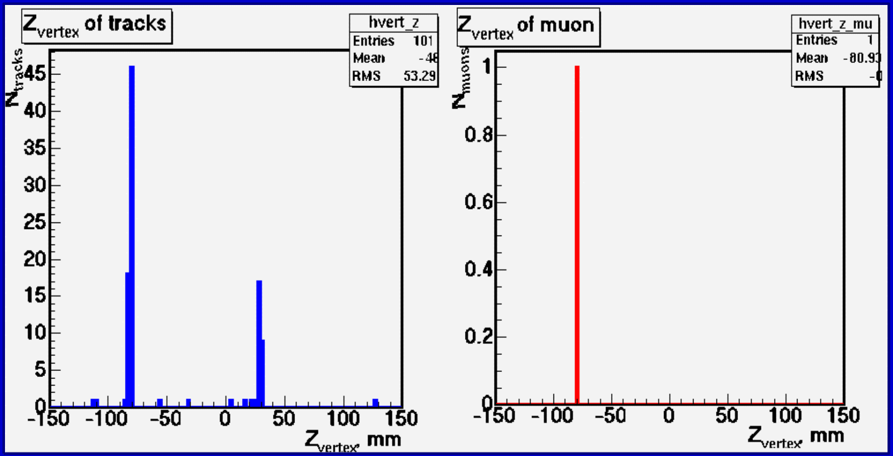
Vertex ID: VBF H→WW→μνjj

Tagging forward jets, vetoing hadronic activity in the central region

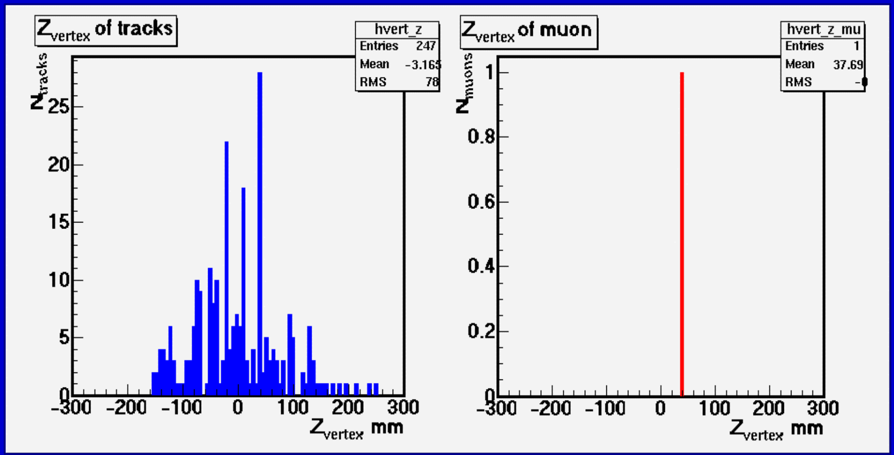
Muon's vertex – the good parameter for signal tracks determination

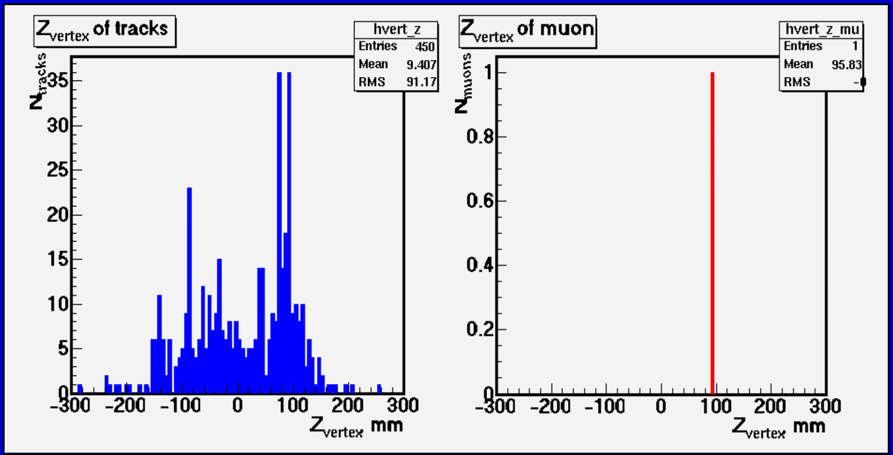
Low luminosity





High luminosity





Higgs Search: $t\bar{t}H \to t\bar{t}b\bar{b}$

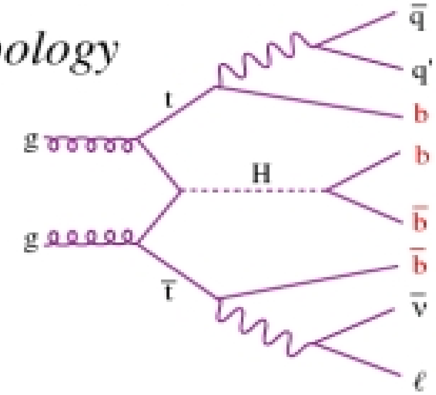
Challenging and complex topology

4 b-jets, 2 jets, 1 lepton

$H \to b\bar{b}$

$t \to \bar{b}qq'$

$\bar{t} \to \bar{b}\ell\nu$



σ x BR ≈ 300 fb

- Complementary to $H \to \gamma\gamma$
- Fully reconstructed final state (except ν)
- Requires good b-tagging

  $\varepsilon_b \approx 60\%$, $R_{uds} \approx 100\%$
- Backgrounds:
  - Combinatorial from signal
  - Irreducible $t\bar{t}b\bar{b}$ ($t\bar{t}jb$, $t\bar{t}jj$)
- Signal significance (5σ) :
  - $m_H < 120$ GeV needs 100 fb^{-1}
  - $m_H < 130$ GeV needs 300 fb^{-1}

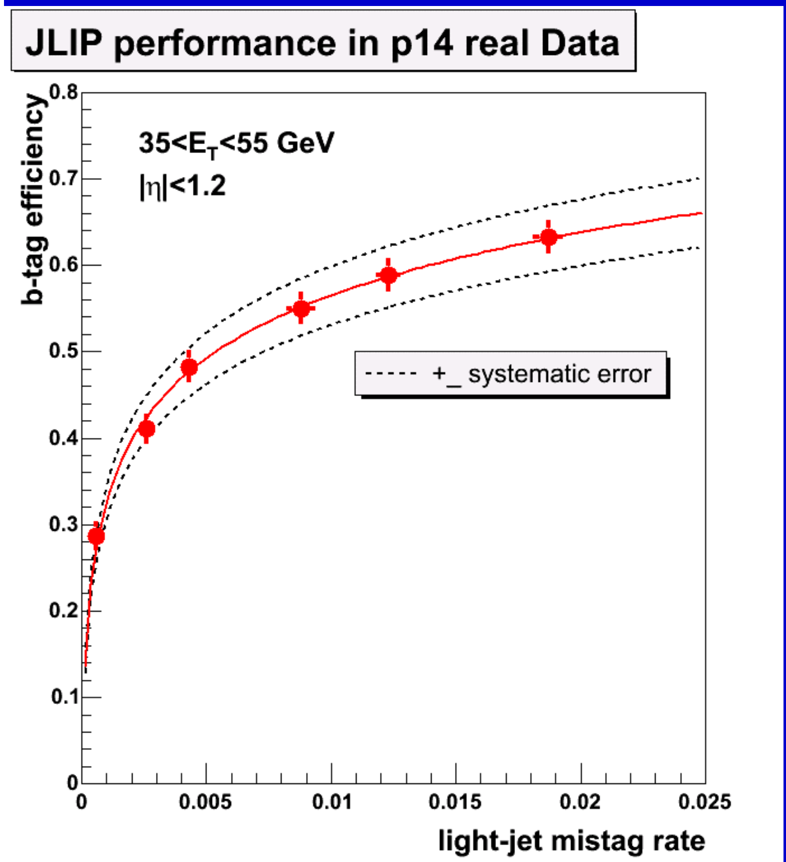
D0 performance plot

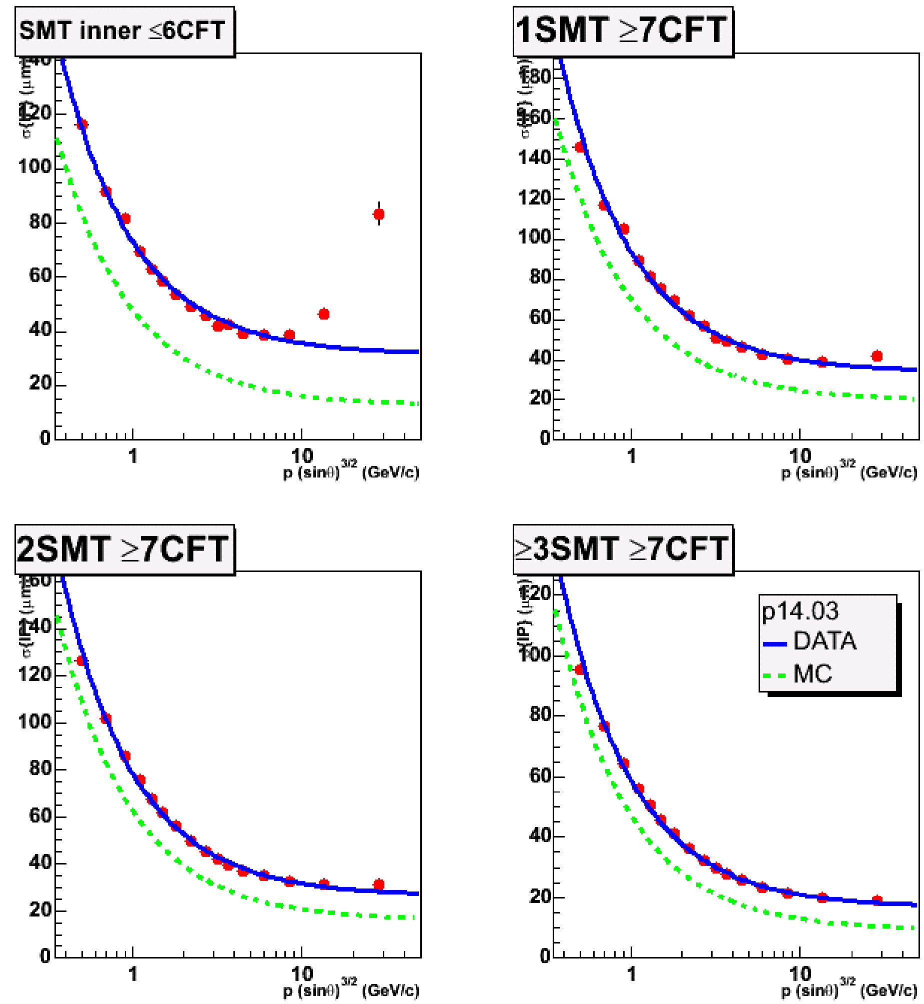
B-tagging

- Impact parameter plot

Green – Monte Carlo

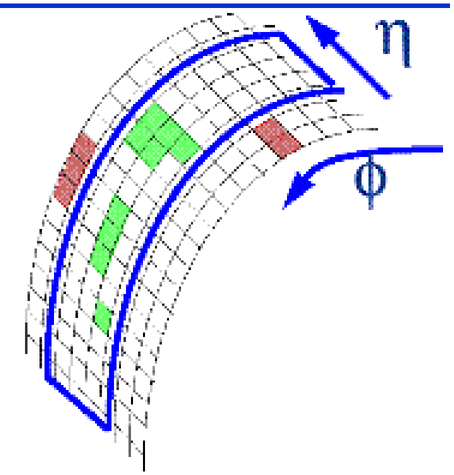
Blue – fit to data



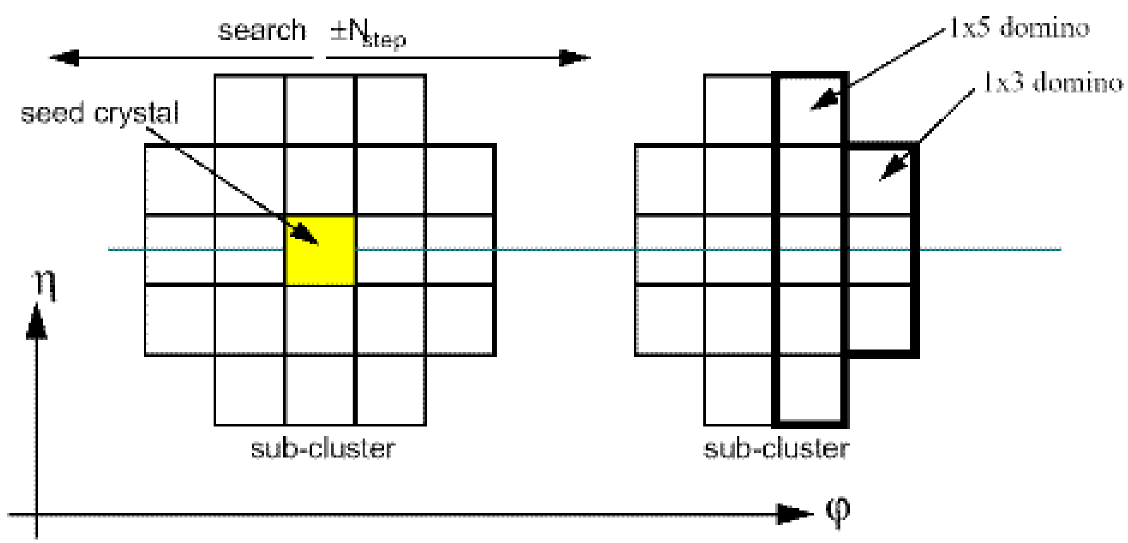


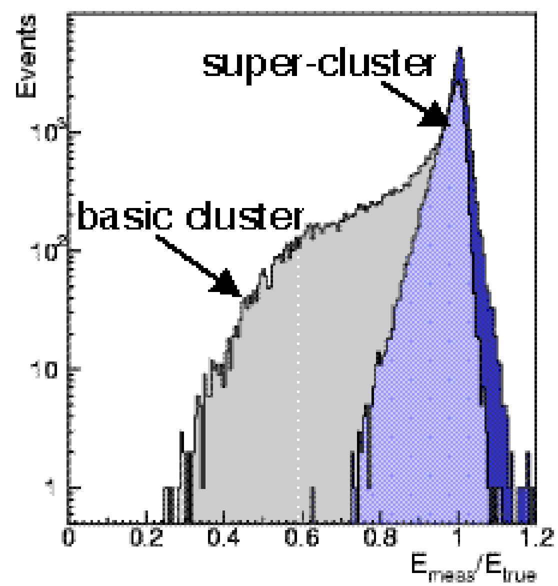
H→ZZ$^{(*)}$, WW$^{(*)}$: e reco

- Electron reco in high B=4T
- Shower shape reconstruction
- D0 – B=2T, interesting to try



- ***Brem recovery:***
  - Road along ϕ — in narrow η-window around seed
  - Collect all sub-clusters in road → "super-cluster"





Monte Carlo Issues: ttH, H→bb

- Main uncertainty –normalization for ttH, ttbb, ttjj
- Tevatron can play a big role in MC verfication

	CMS	ATLAS
Structure function	CTEQ4L	CTEQ5L
Q^2_{QCD}	m^2_{H} for $t\bar{t}H$, $t\bar{t}Z$ $m_t^2 + \left(p^2_{T\,t_1} + p^2_{T\,t_2} + p^2_{T\,q_1} + p^2_{T\,q_1}\right)/4$ for $t\bar{t}q\bar{q}$	$(m_t + m_H/2)^2$ for all but $t\bar{t}jj$
LO cross sections in pb		
$ttH(100)\times BR_{H\to bb}$	1.09	0.69
$ttH(115)\times BR_{H\to bb}$	0.65	0.43
$ttH(130)\times BR_{H\to bb}$	0.32	0.24
$t\bar{t}b\bar{b}$	3.3 (see text)	8.6
$t\bar{t}jj$	507	474
CMS: $t\bar{t}Z$	0.65	
ATLAS: $gg\to Z/\gamma/W\to t\bar{t}b\bar{b}$		0.9

Generation level cuts

Sociological issues

- A very big complain:
- Lack of involvement of senior people
  - Interference with LHC (LC)
  - Complexity of software, switching to C++
  - People do not feel comfortable if they cannot say “Show me your code!”
  - But actually feed back on physics would make a difference
- Too high standards, perfectionism
  - Run 1, LEP

Outlook

- Streamlining the road to publications in LHC is important for the well being of the field
- Commissioning must be decoupled from physics runs
- A good line of communication and experience transfer is established between LHC (CMS) and Tevatron experiments - LPC
  - Several new algorithm approaches can also be tested in TeV environment
- Monte Carlo verification in Tevatron

Backup slides