FRONTIER DETECTORS FOR FRONTIER PHYSICS

24-30 May 2009 La Biodola, Isola d'Elba, Italy

CDF trigger final balance: **offline resolution** at **low level selections** to cope with Tevatron **increasing luminosity**

Silvia Amerio

University of Padova & INFN

Outline

Tevatron performances

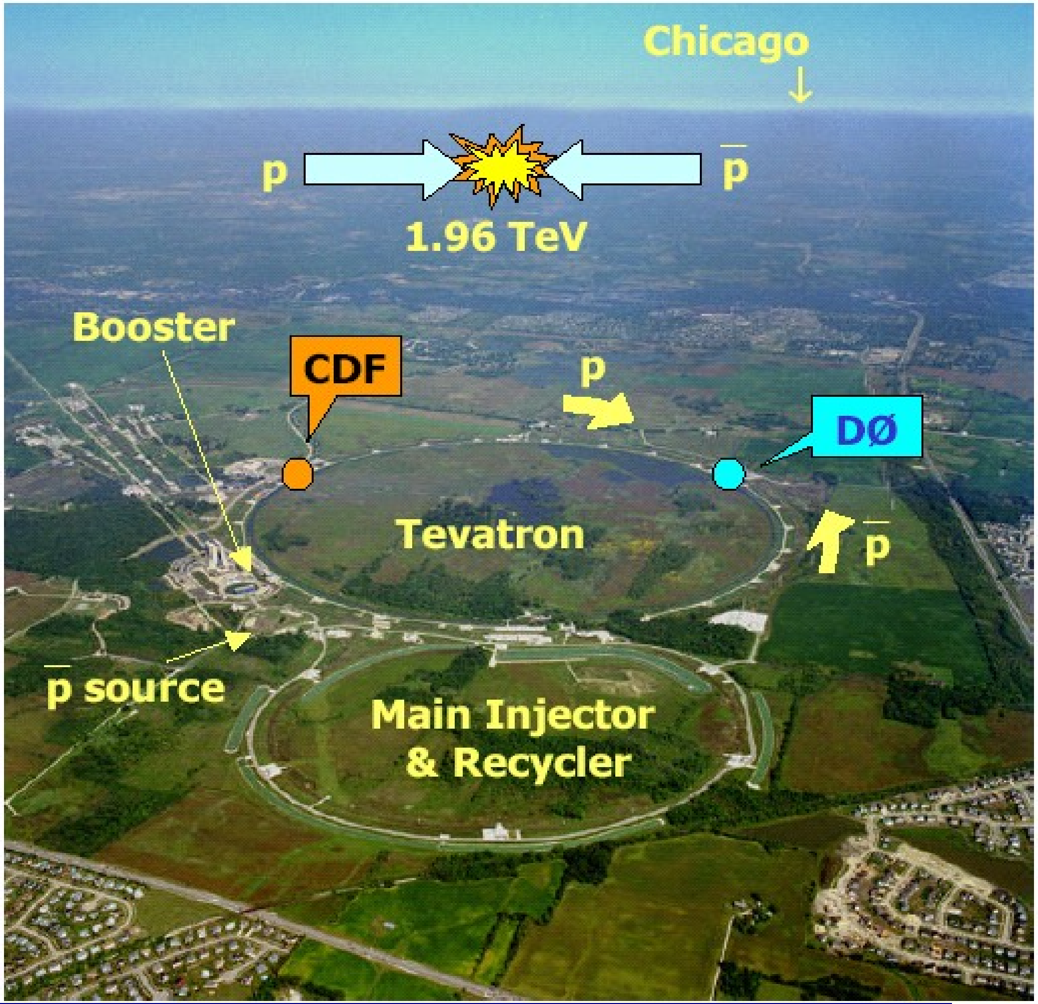
CDF trigger system

Recent upgrades:

- online tracking
- calorimetric trigger

Why?
How?
Impact on Physics?

Tevatron & CDF



CDF is a multipurpose detector

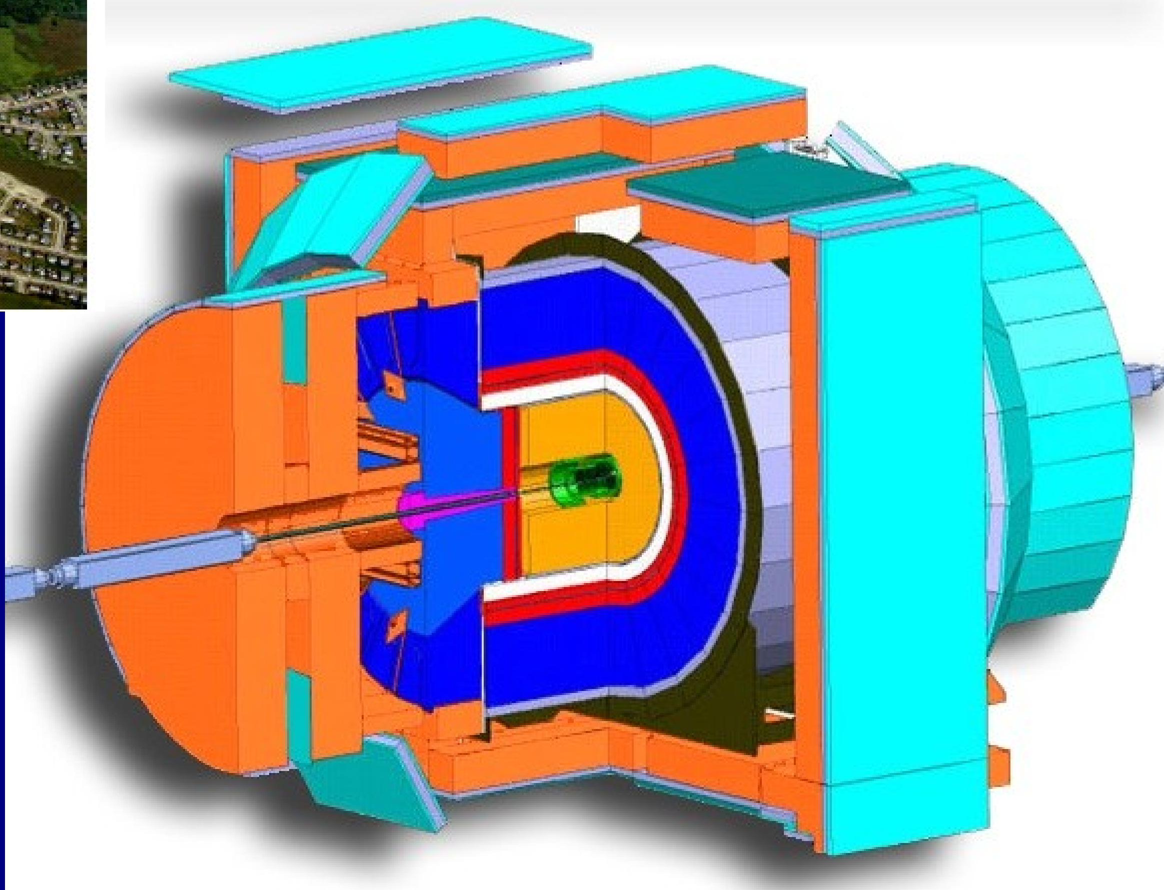
Silicon Vertex Tracker

Drift chamber

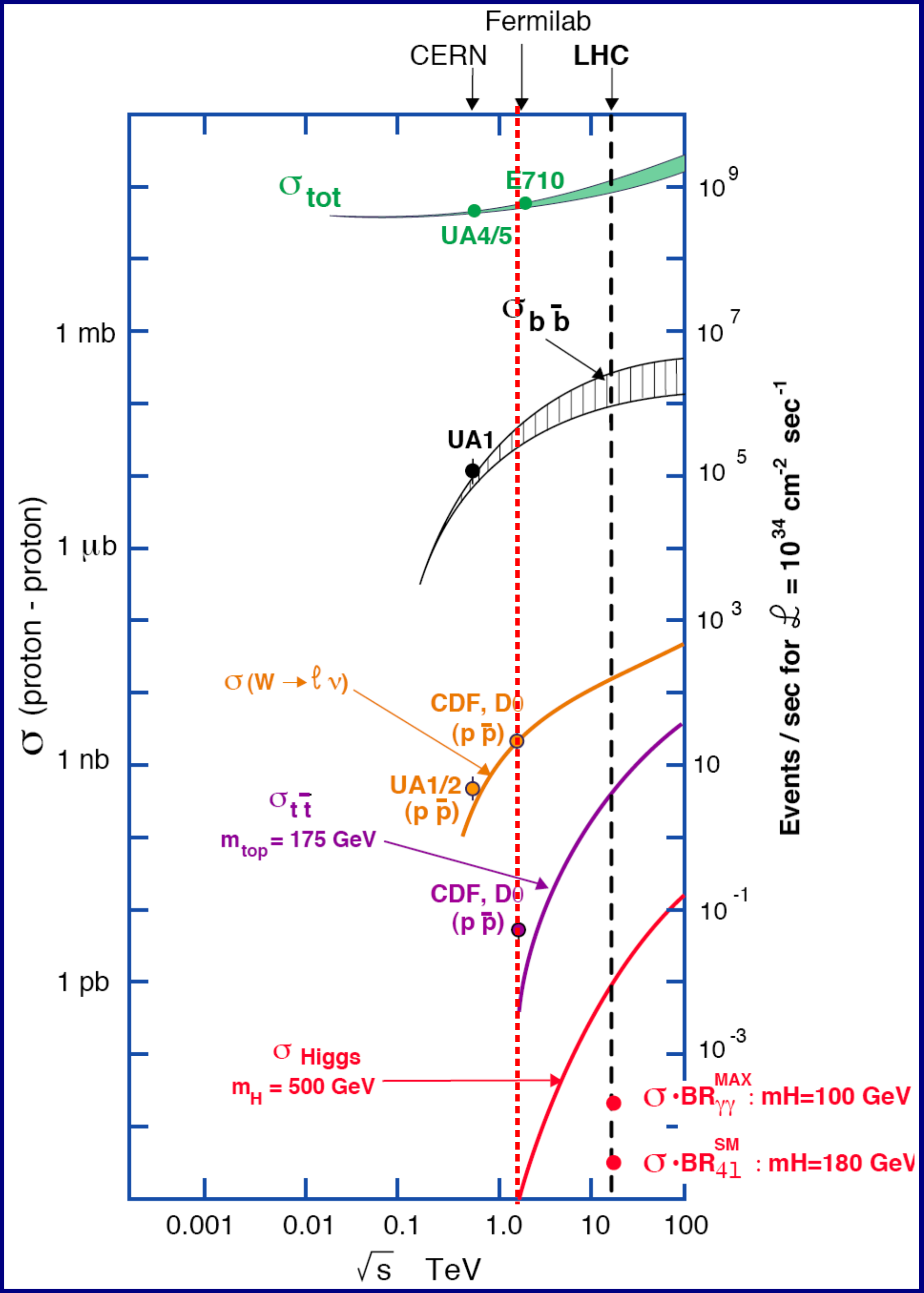
Electromagnetic and

hadronic calorimeters

Muon detectors



Physics at hadron colliders



Cross sections for particle production vary by a factor $> 10^{10}$

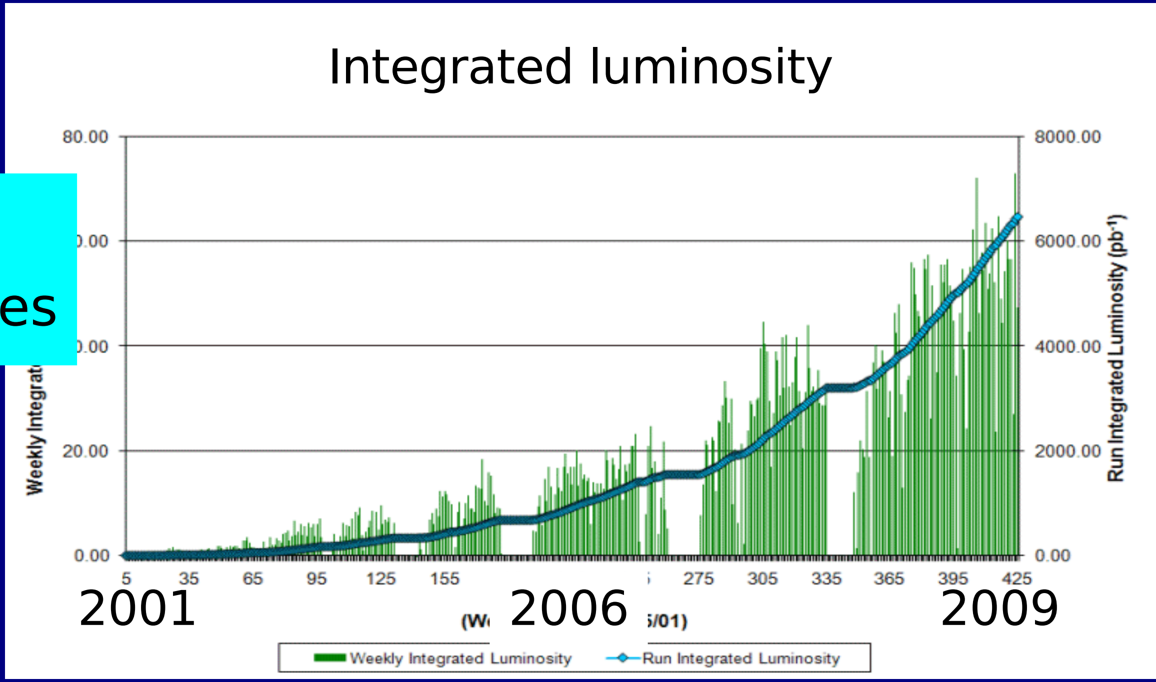
At Tevatron, 1 Higgs over 10^{10} collisions

Crucial the increase in **luminosity**

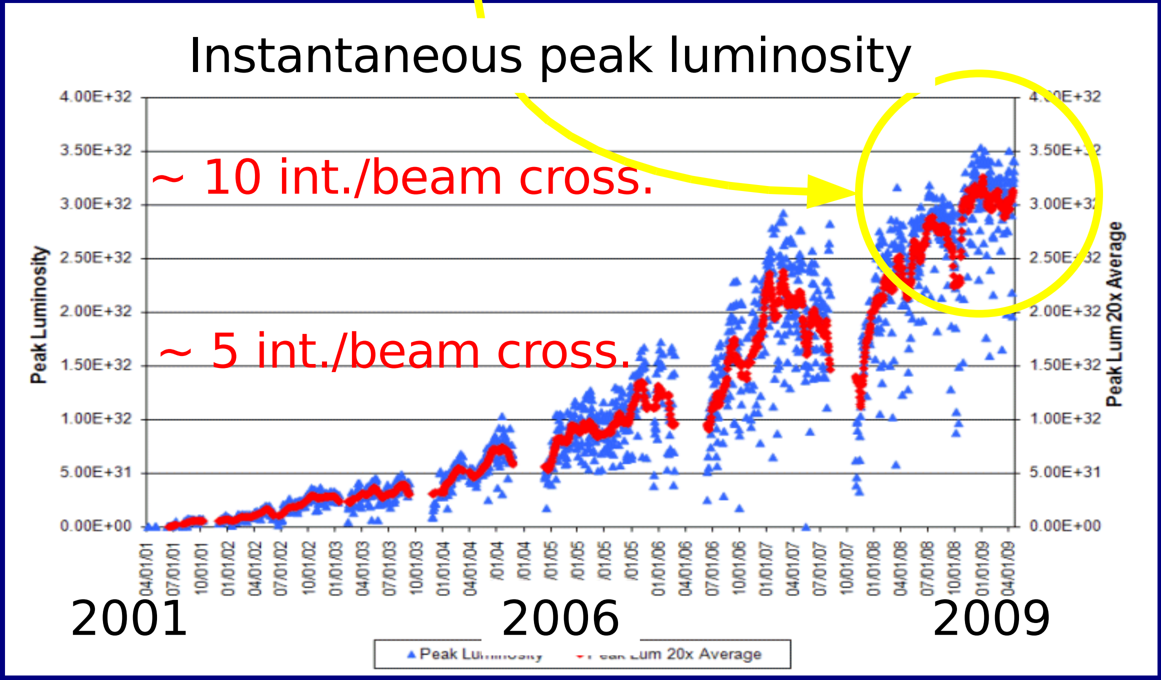
Tevatron luminosity

6 fb^{-1} on tape

5 fb^{-1} for next summer conferences



Average initial instantaneous lumi
> 3.0 10^{32} $cm^{-2}s^{-1}$



Peak luminosity increasing!

more data but...

pile-up → high detector occupancy

exponential **increase in trigger rates**

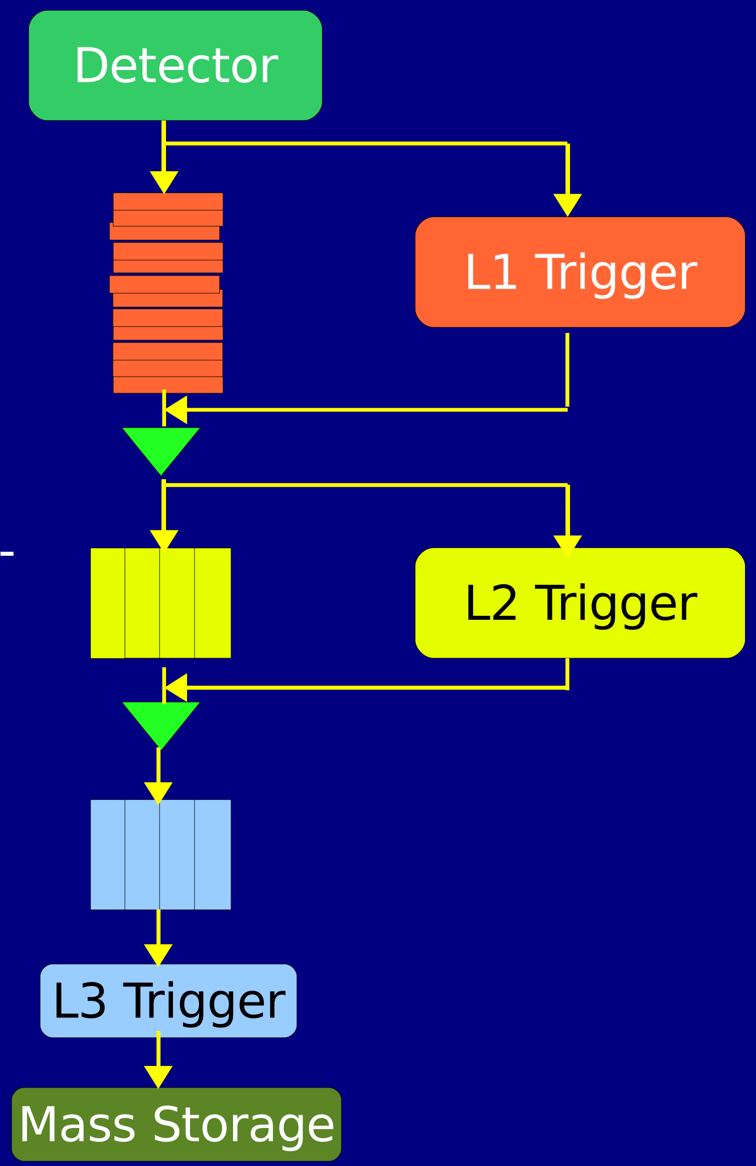
Need for **trigger upgrades!**

CDF Trigger system

2.53 MHz
synchronous
pipeline
Accept rate < 20 kHz

asynchronous 2-stages pipeline
Latency 20 μs
Accept rate < 1 kHz

PC farm
Accept rate < 100 Hz



At **each level** it can trigger on

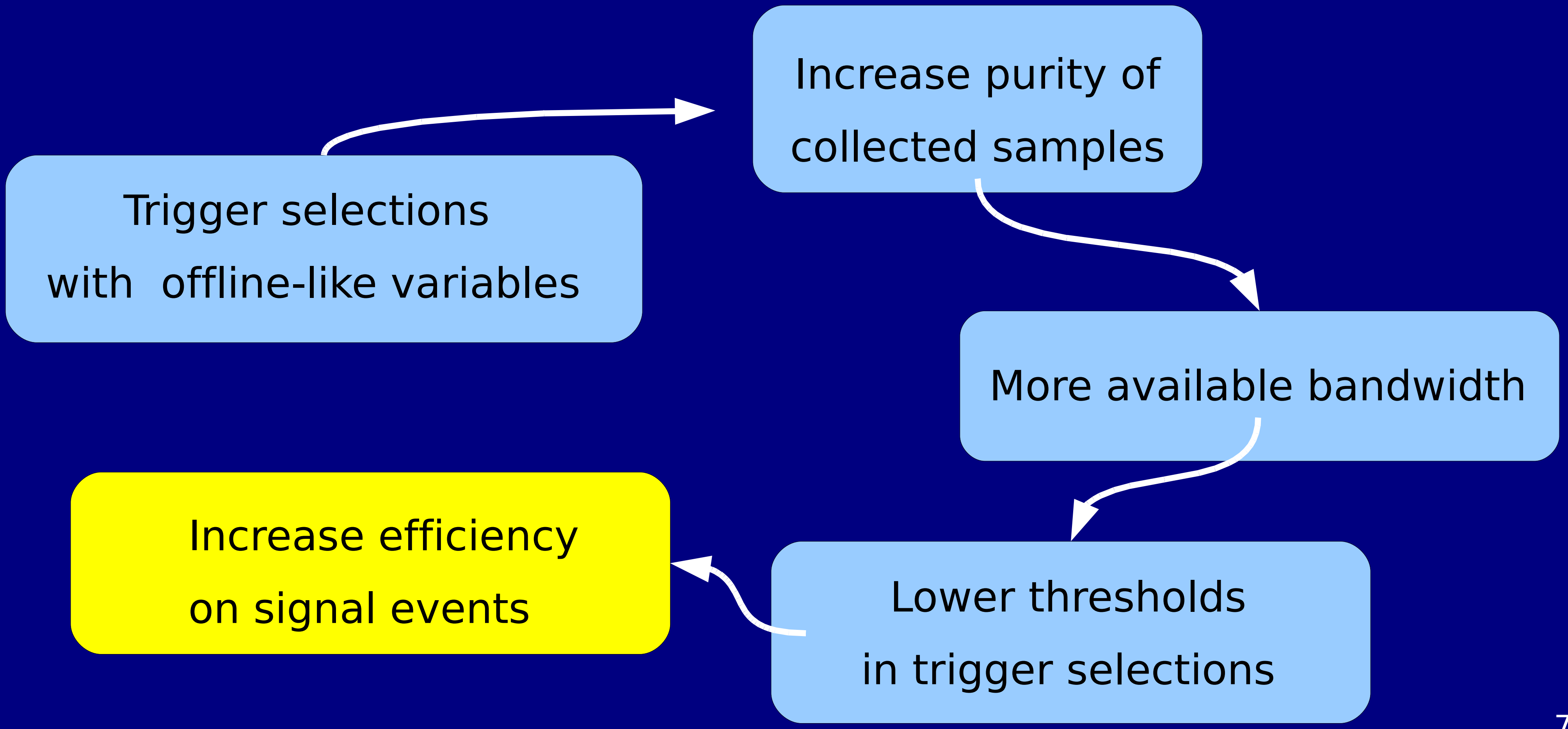
- calorimetric objects
- muons
- tracks

reconstructed with

increasing resolution

Why upgrade?

Not only for rate reduction....

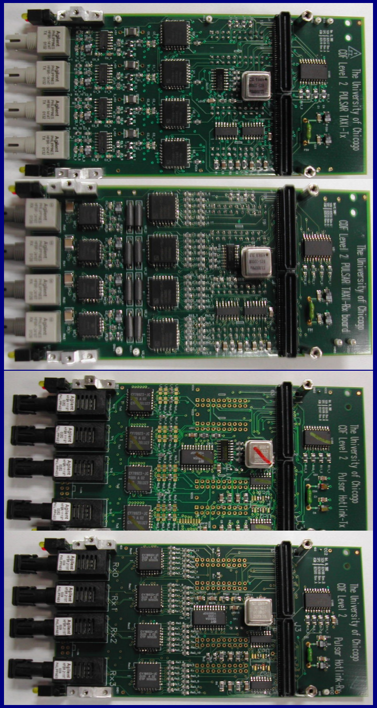


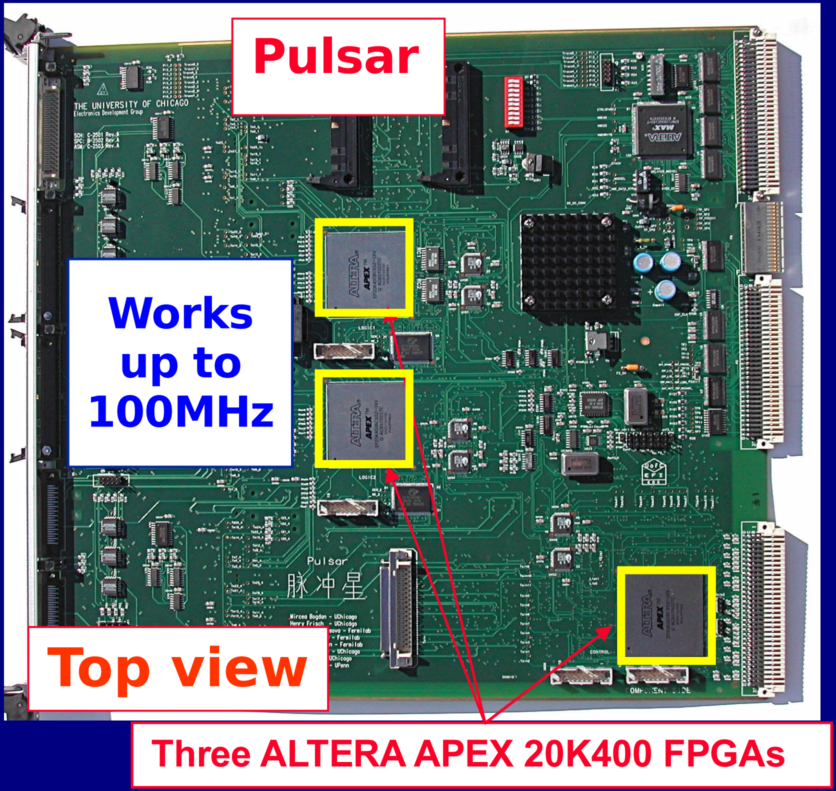
Main upgrade tool: the **Pulsar** Board

Design phylosophy:

- interface any user data with any any link format via mezzanine cards
- modular, self-testable

Custom Mezzanine

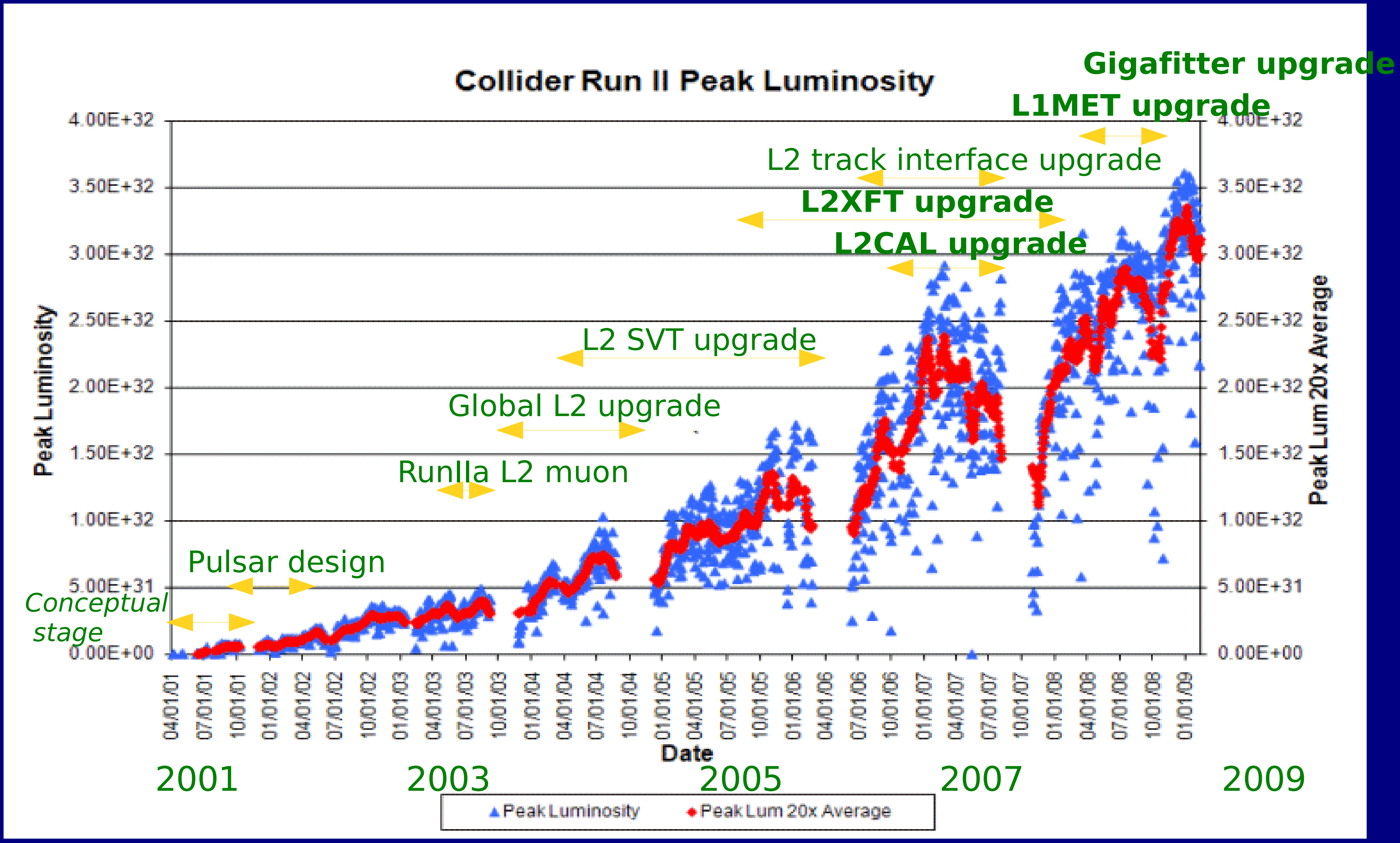




AUX card

Pulsar website: http://hep.uchicago.edu/~thliu/projects/Pulsar/

CDF trigger upgrades summary



Online
tracking upgrades

Online tracking at CDF

Level 1 — eXtremely Fast Tracker (**XFT**)

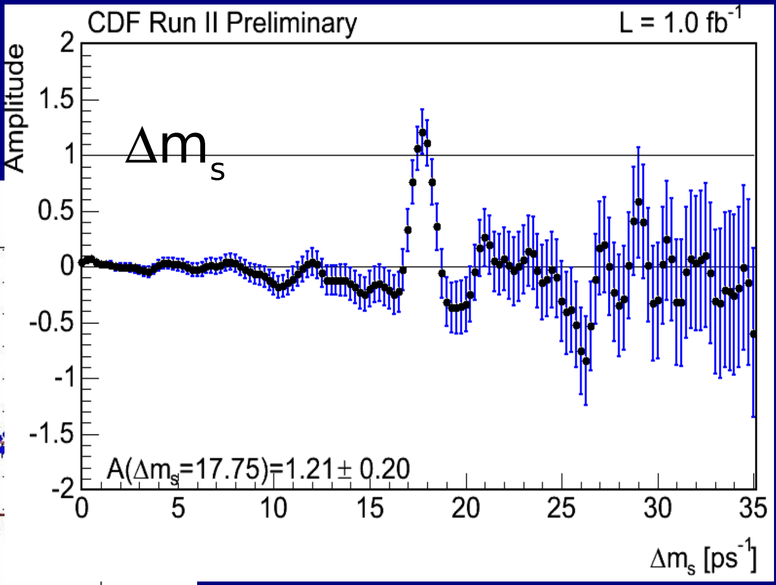
Level 2 — Silicon Vertex Trigger (**SVT**)

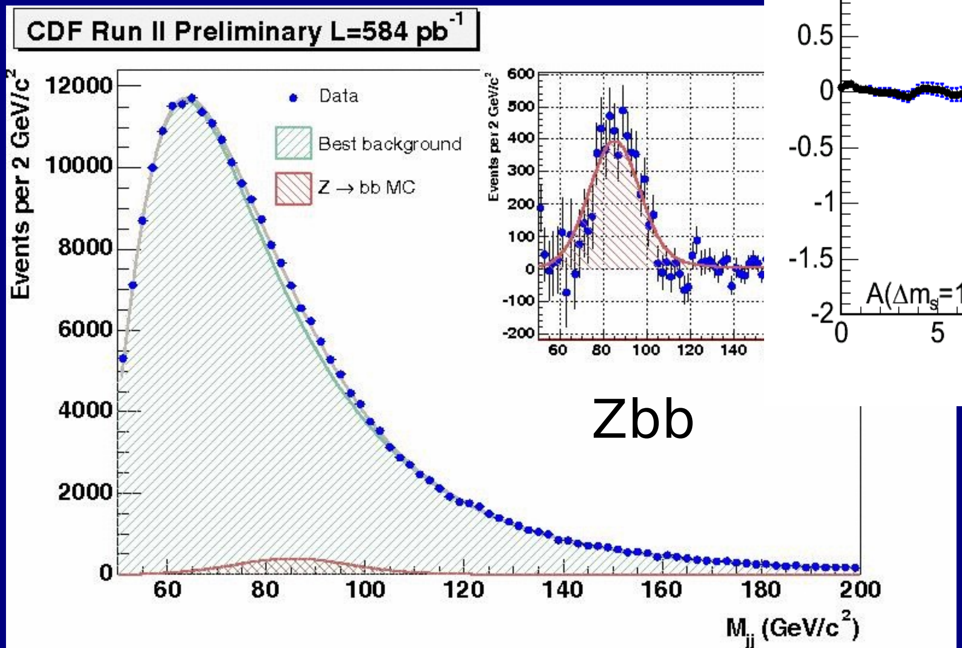
Online tracking at CDF

Level 1 — eXtremely Fast Tracker (**XFT**)

Level 2 — Silicon Vertex Trigger (**SVT**)

Displaced tracks:
- B-physics,
- Zbb





Online tracking at CDF

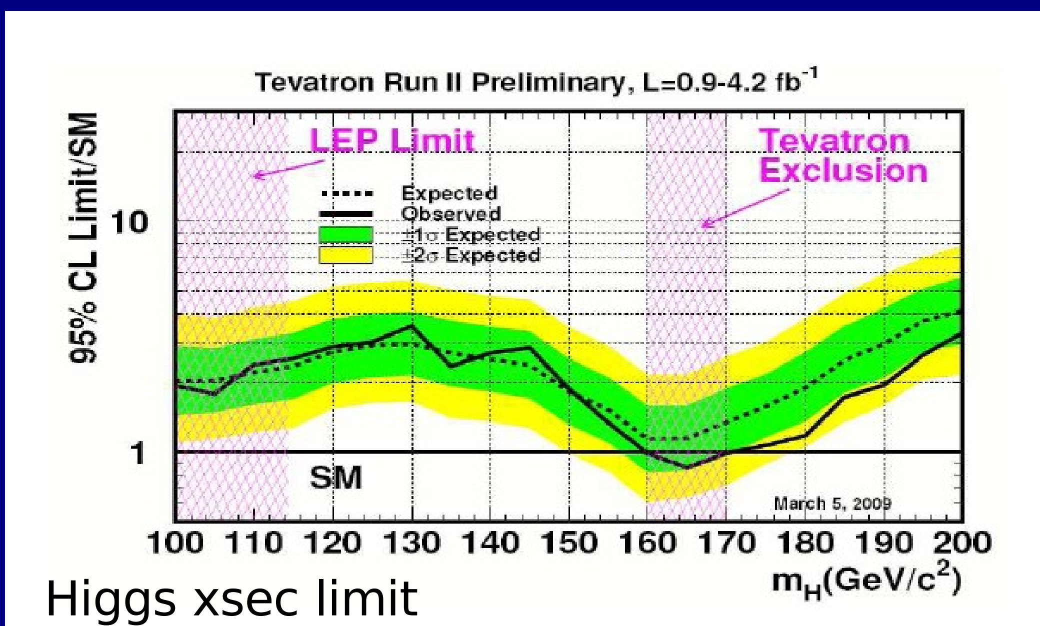
High-Pt and low-Pt leptons

Electron and muon triggers:
- Track
- EM cluster or muon stub

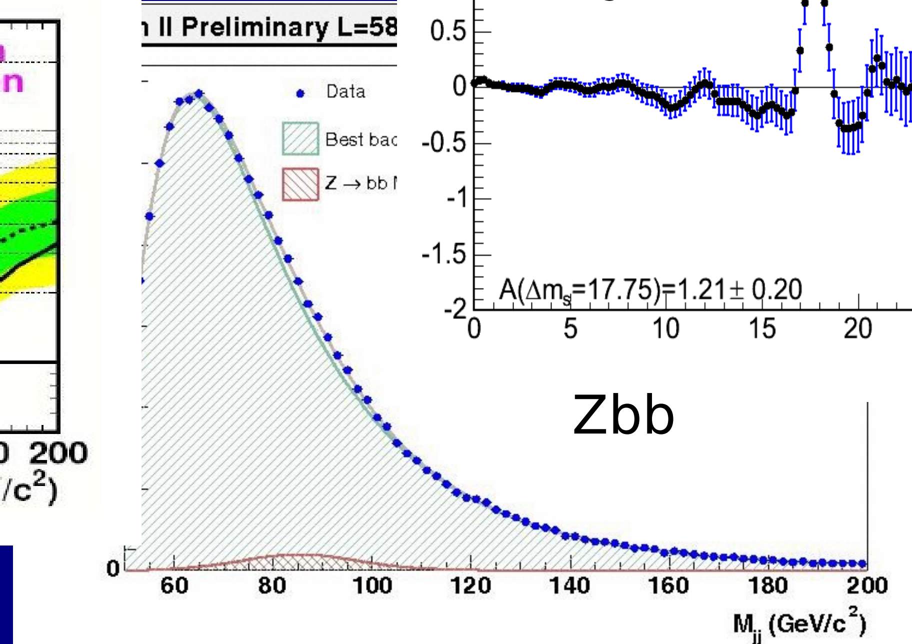
Level 1 → eXtremely Fast Tracker (**XFT**)

Level 2 → Silicon Vertex Trigger (**SVT**)

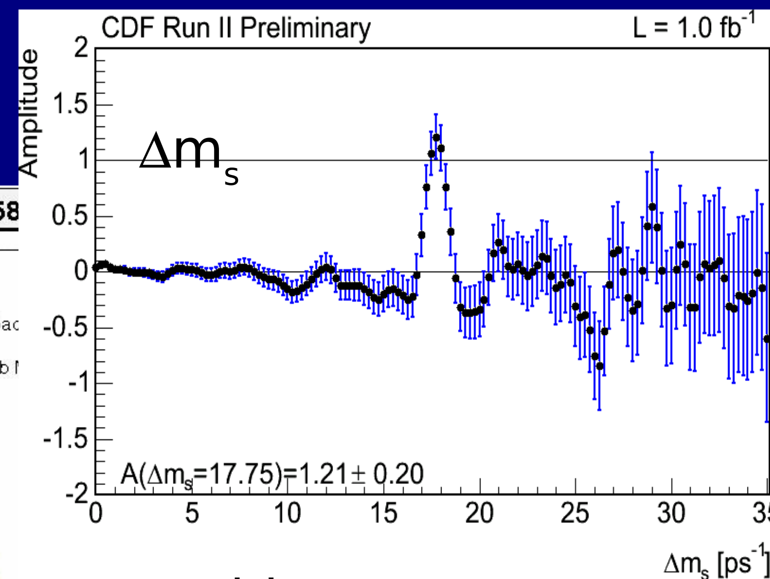
Displaced tracks:
- B-physics,
- Zbb



Higgs xsec limit



Zbb



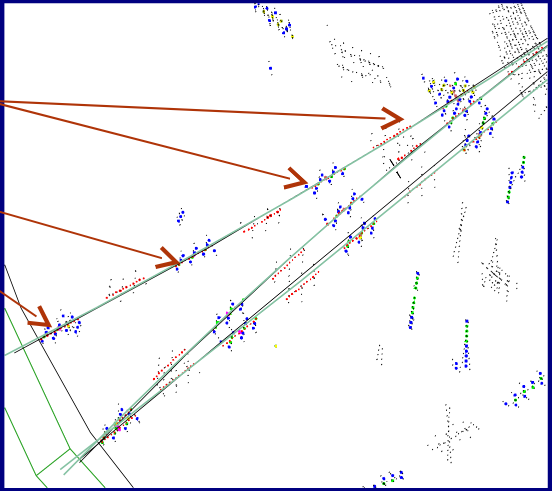
XFT

Drift chamber

8 layers (alternate **stereo** and **axial** wires)

Level 1

XFT **AXIAL** segments

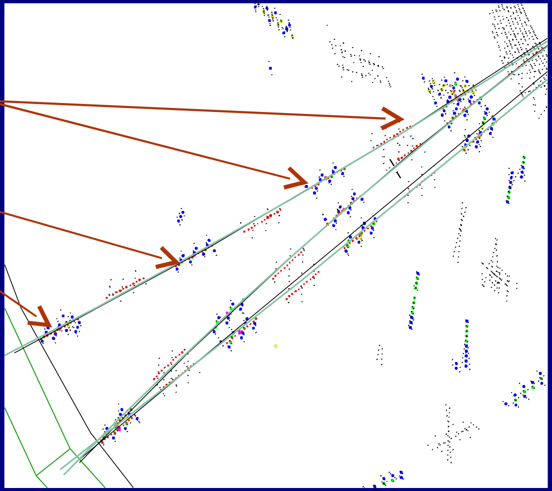


EXtremely Fast Tracker (XFT) processor

XFT

Level 1

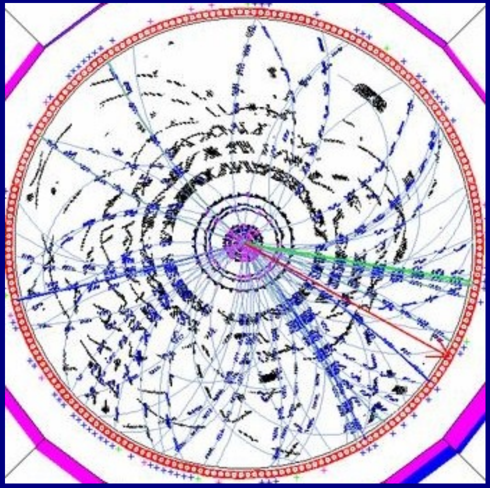
XFT **AXIAL**
segments



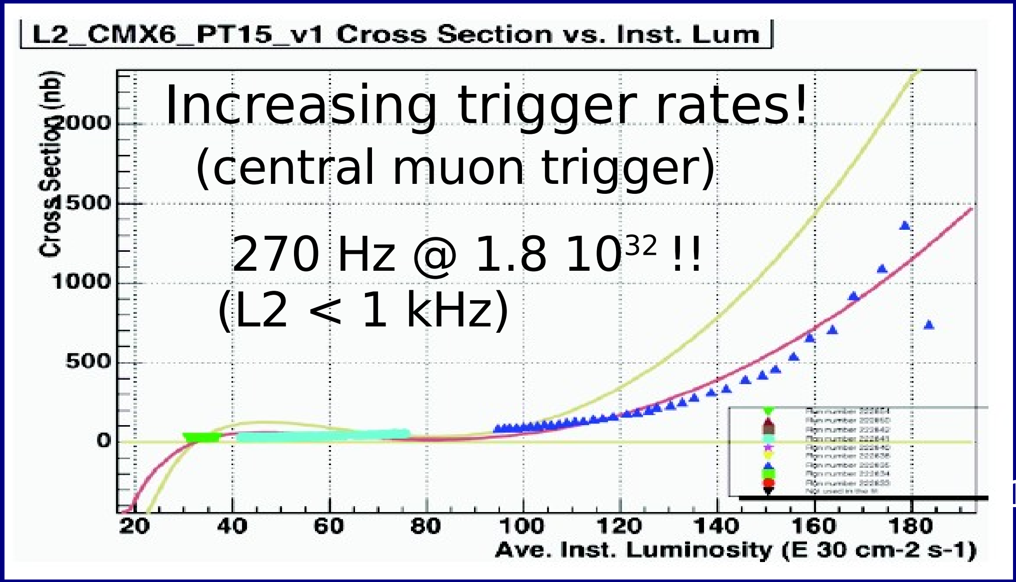
Drift chamber

8 layers (alternate **stereo** and **axial** wires)

EXtremely Fast Tracker (XFT) processor

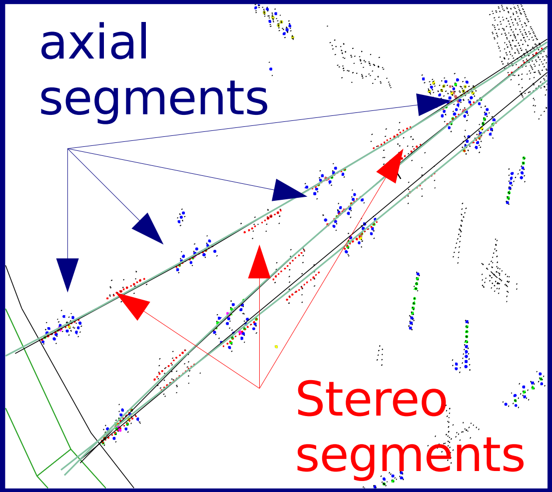


high lum
high occupancy



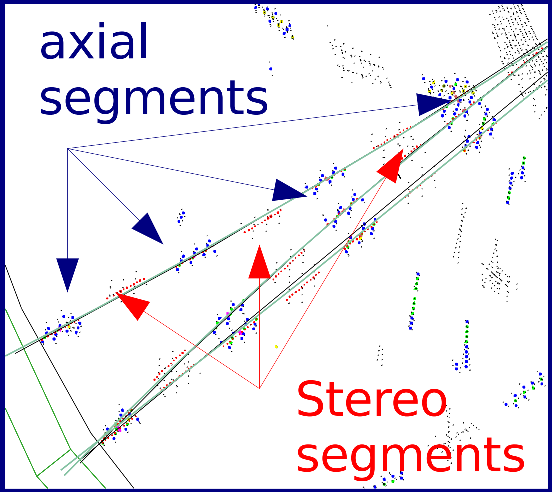
XFT upgrade – L1 & L2

Use data from wires in the outer 3 **stereo** layers to CONFIRM the presence of real tracks.

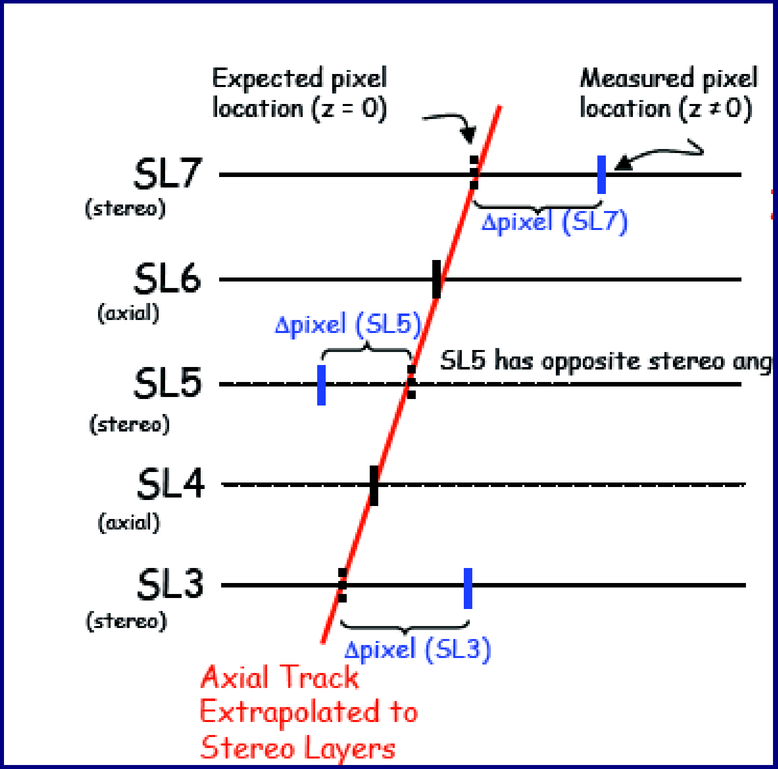


XFT upgrade – L1 & L2

Use data from wires in the outer 3 **stereo** layers to CONFIRM the presence of real tracks.

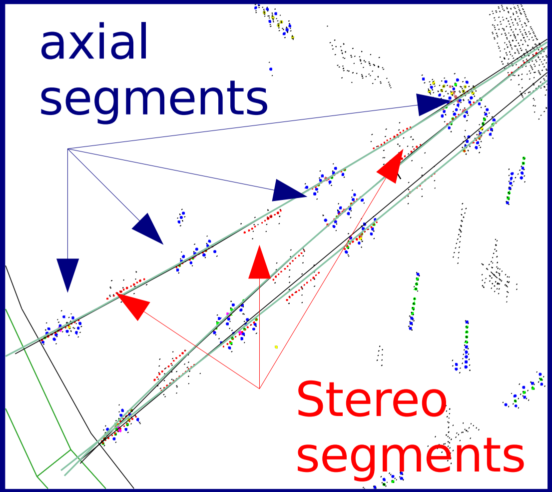


Correlation between
- azimuthal position of the axial track
- distance to the associated stereo pixel

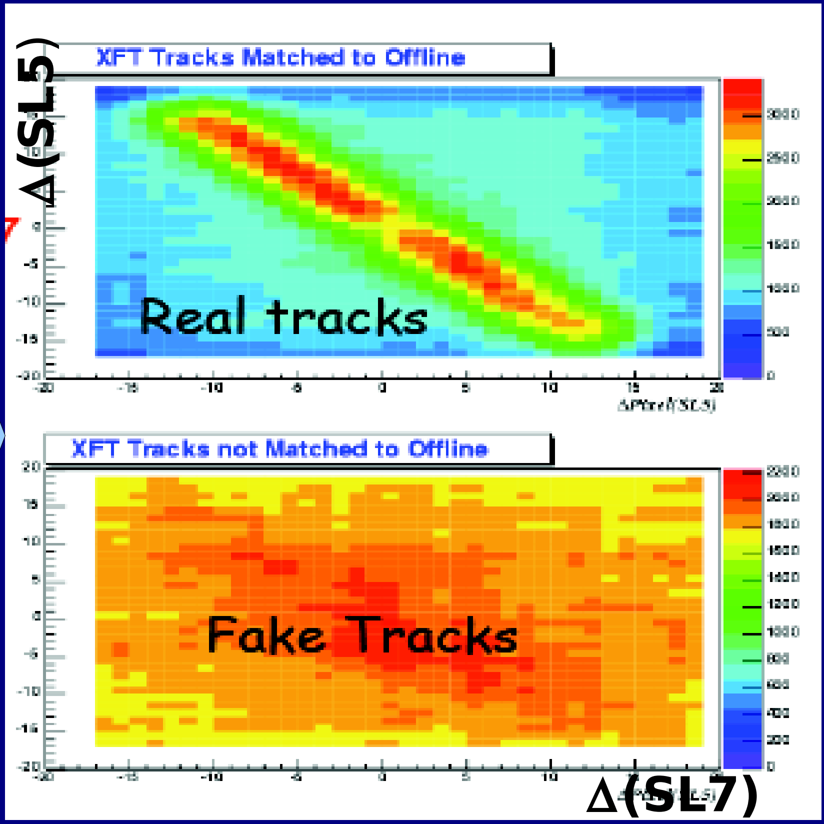


XFT upgrade – L1 & L2

Use data from wires in the outer 3 **stereo** layers to CONFIRM the presence of real tracks.



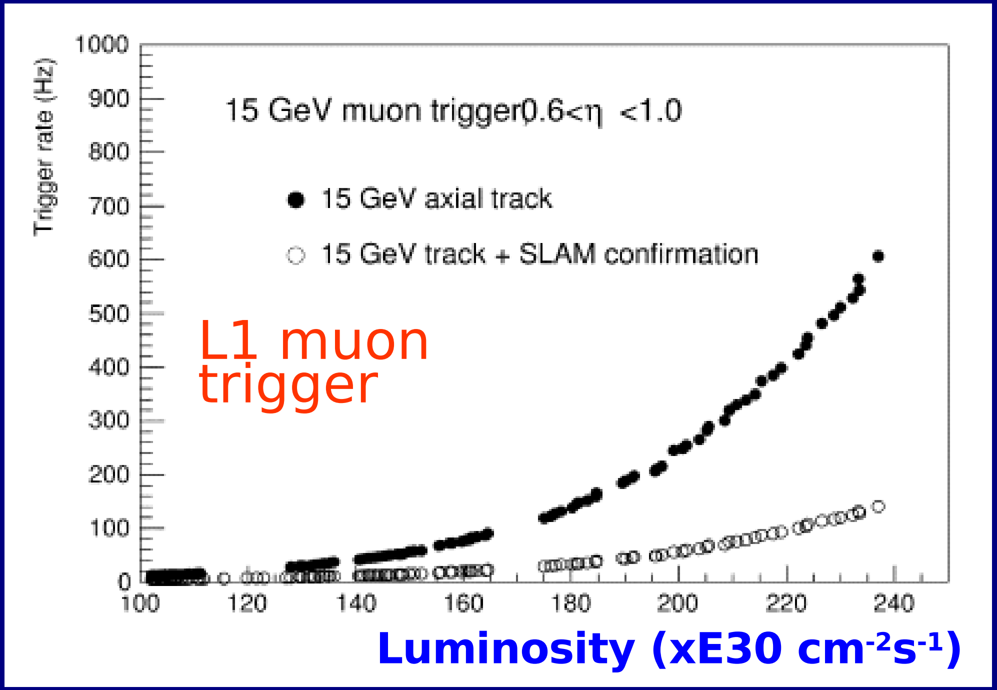
Correlation between
- azimuthal position of the axial track
- distance to the associated stereo pixel



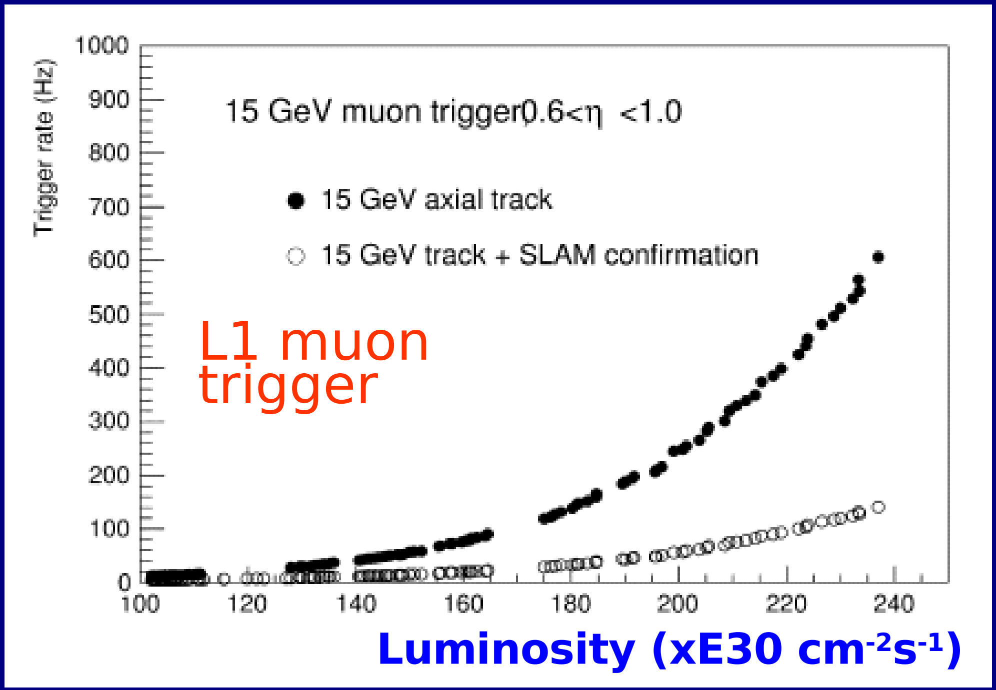
At L2

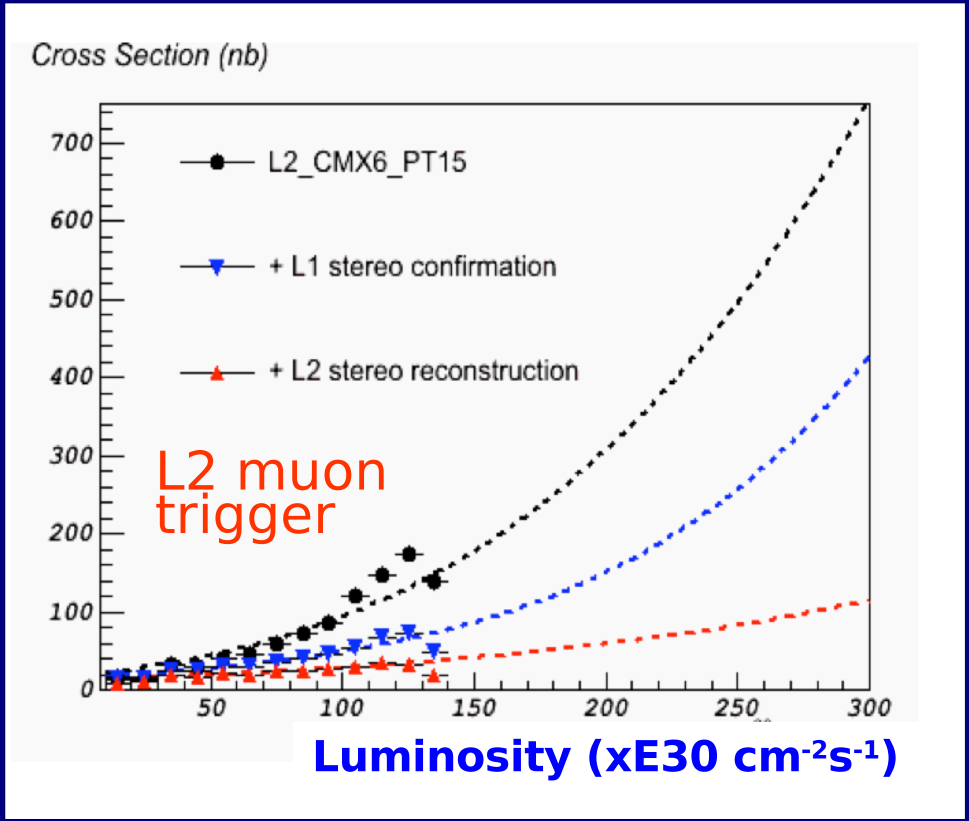
- more processing time available
- run stereo track reconstruction algorithm
- get z position and polar angle θ

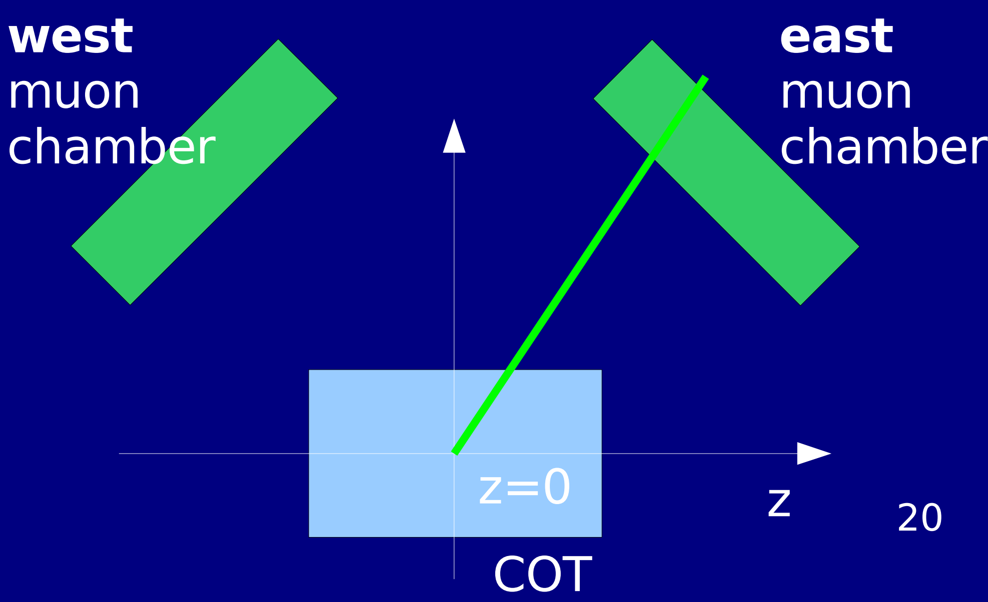
Impact on trigger rates



Impact on trigger rates







3-D tracks available at L2:

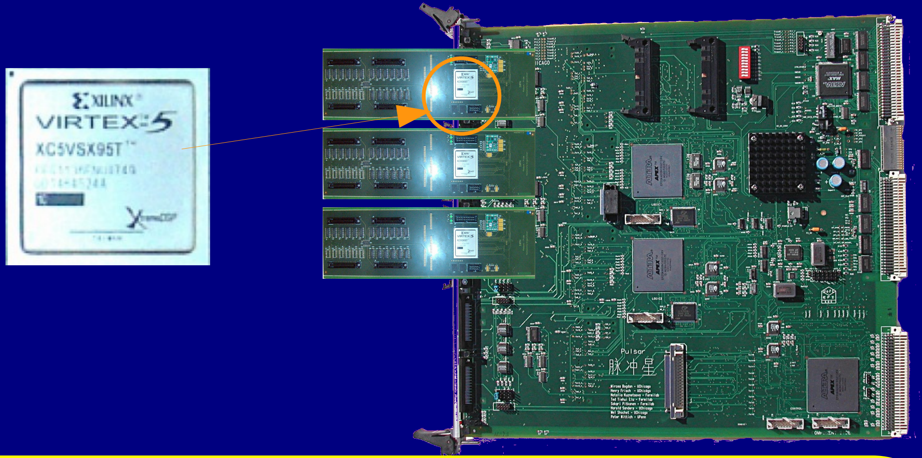
- tracks matched to muon chambers

the last CDF upgrade…

More details in M.Bucciantonio poster!

GigaFitter : **<u>online</u>** tracking processor developed as upgrade of CDF SVT track fitter to improve its performances at high luminosity

Pulsar + new mezzanine using modern FPGA (Xilinx V5)



High speed/parallelization/computation power → > 1 fit/ns

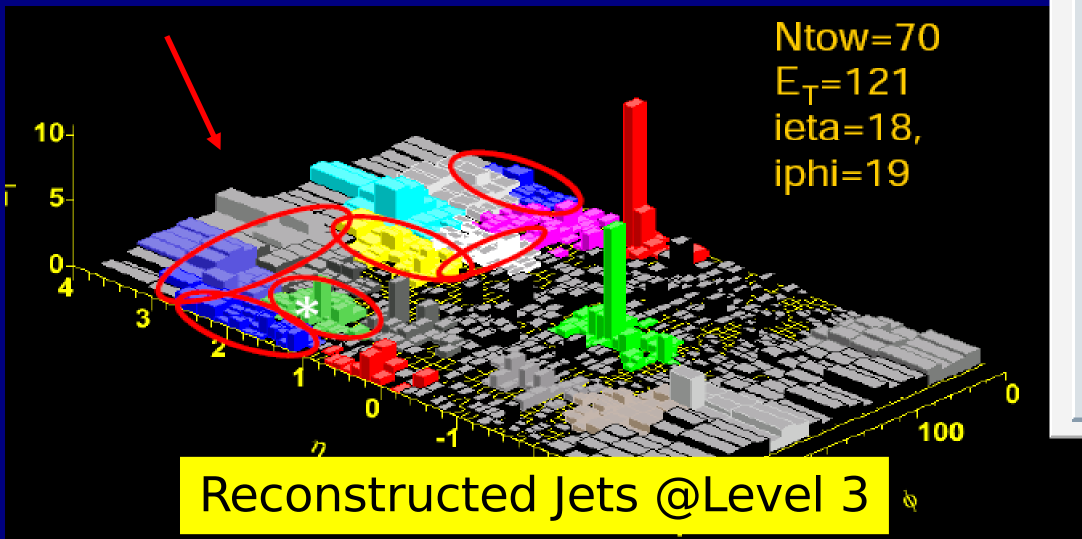
GF = 1 board ⟷ **Current system = 16 boards (12 Track Fitters + 4 merger boards)**

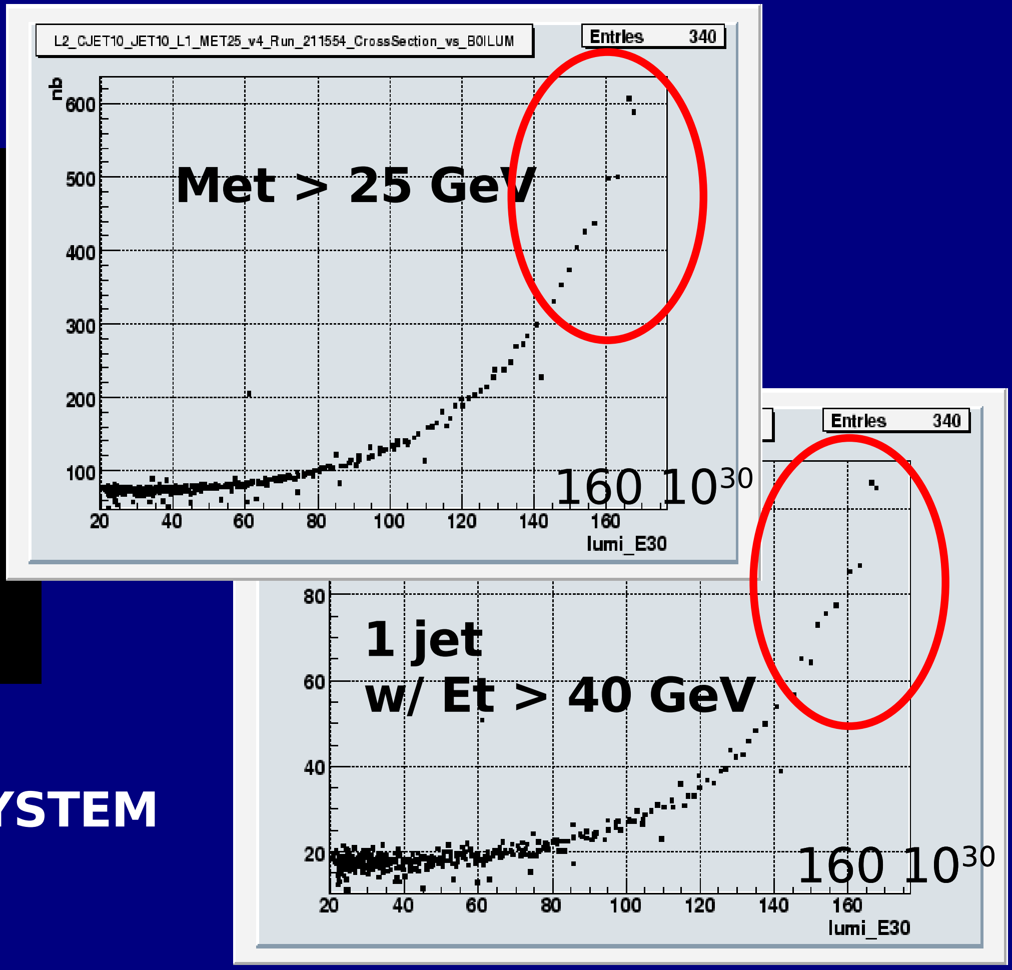
More memory available to store track candidates → increase track reconstruction efficiency

L1 & L2 calorimetric trigger upgrades

L2 calorimetric trigger

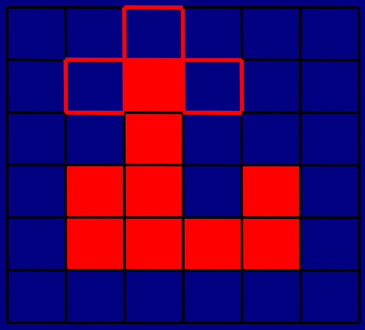
Merging of the jets @ L2





L2 cluster algo “Pac-Man” merged true / fake jets together

OLD SYSTEM



low Et jet → high Et jet

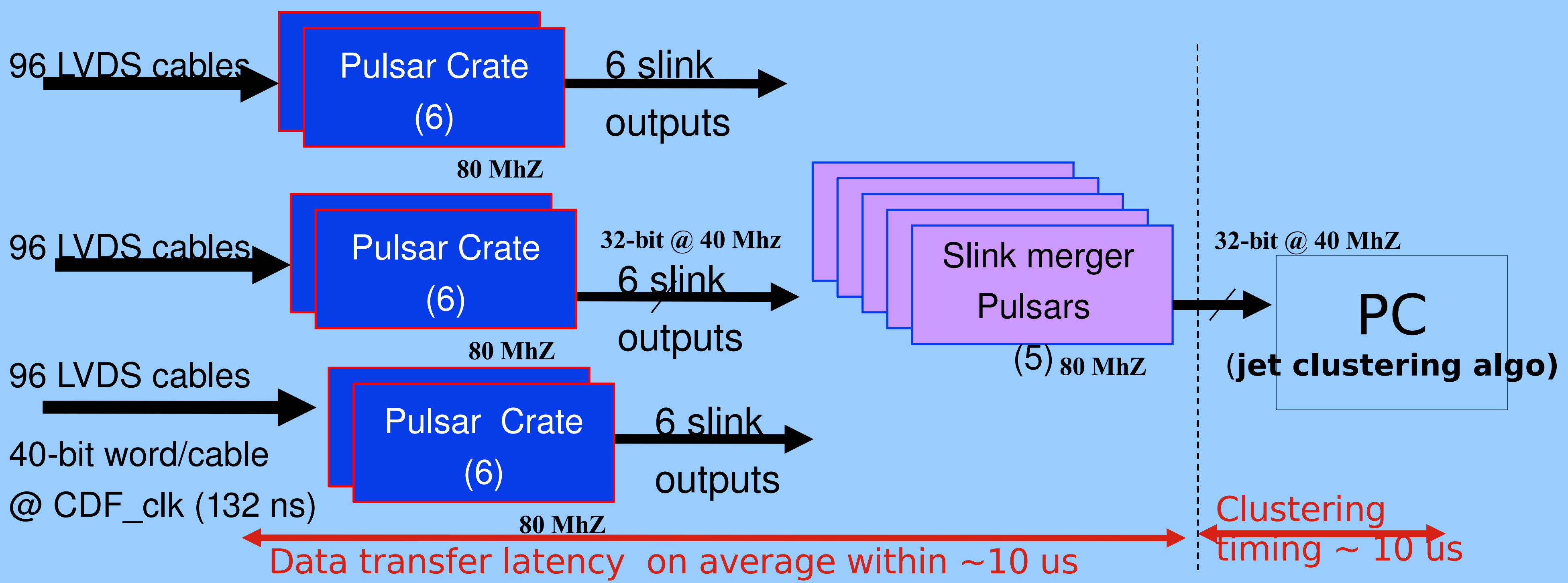
multi jet event → single jet event

... and used only 8-bit tower energy information (10-bit available)

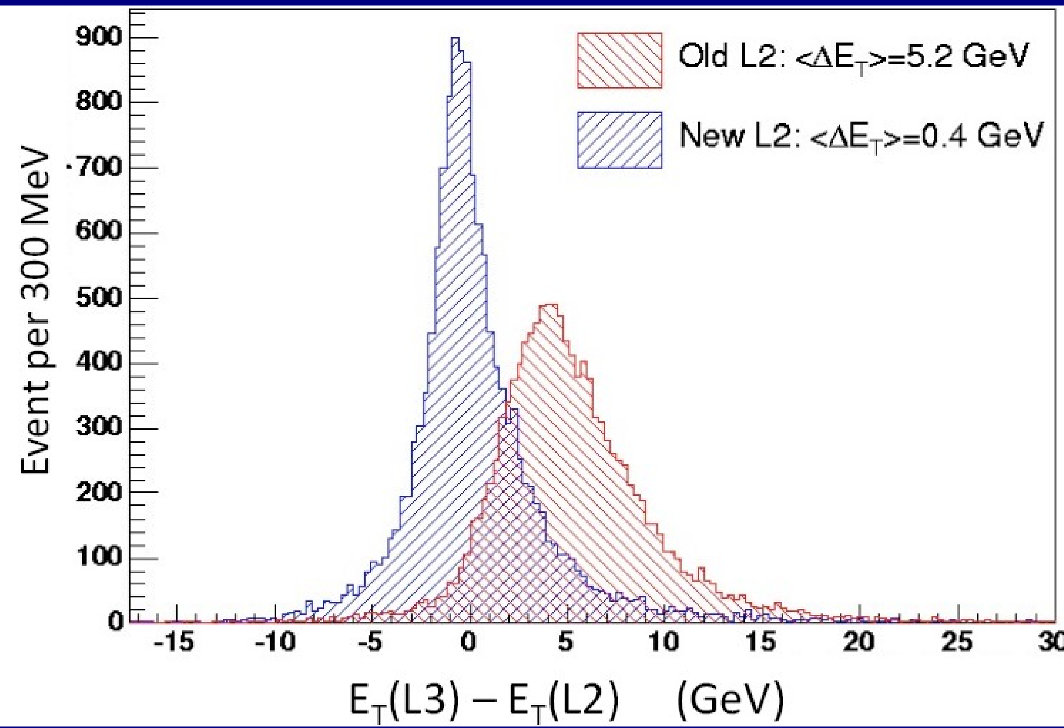
L2 calorimetric trigger upgrade

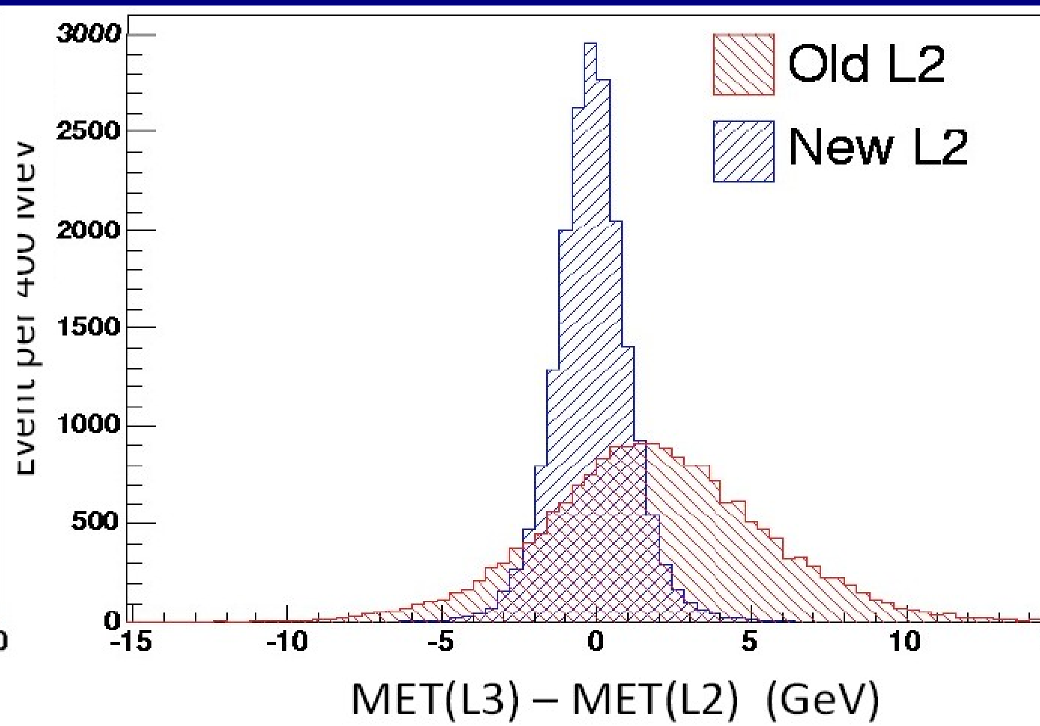
UPGRADE:

- fixed cone jet clustering algorithm
- full resolution (10 bits) for Sumet/Met calculation at L2



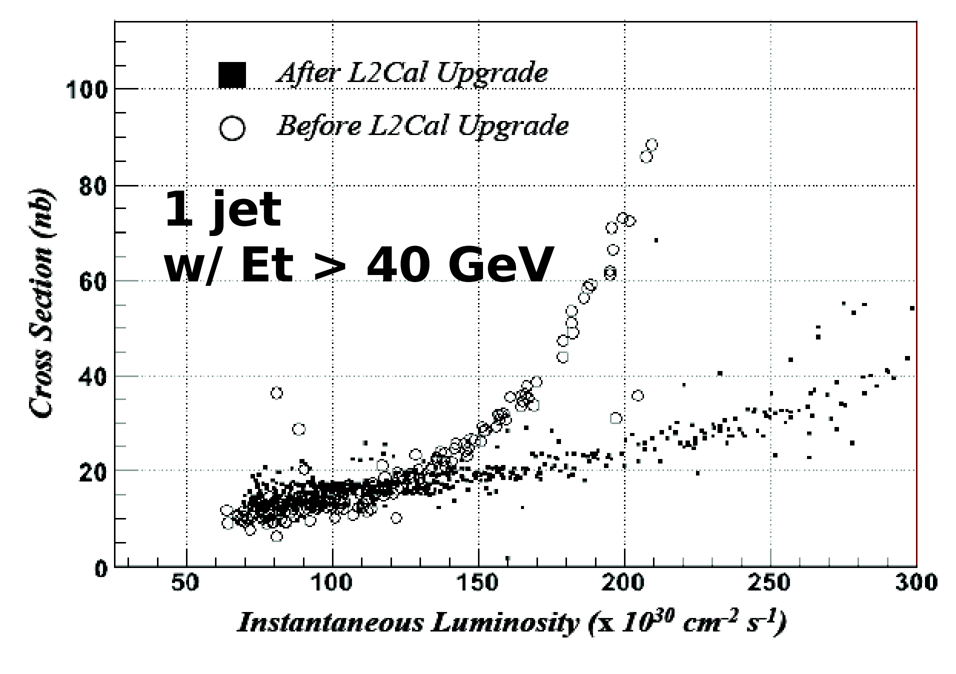
Trigger rates and resolutions





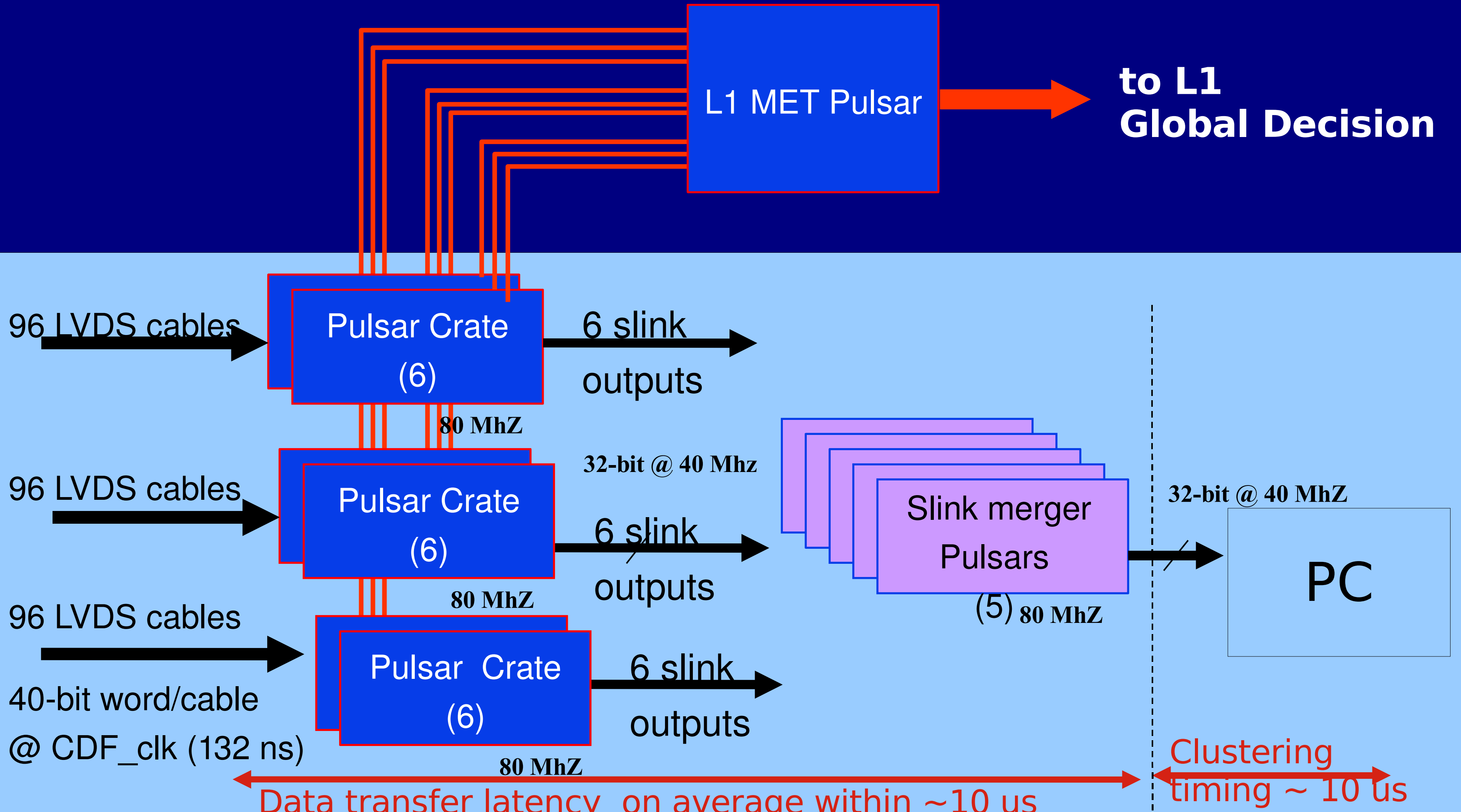
Difference between **L3** and **L2** Et/Met

Cross section under control



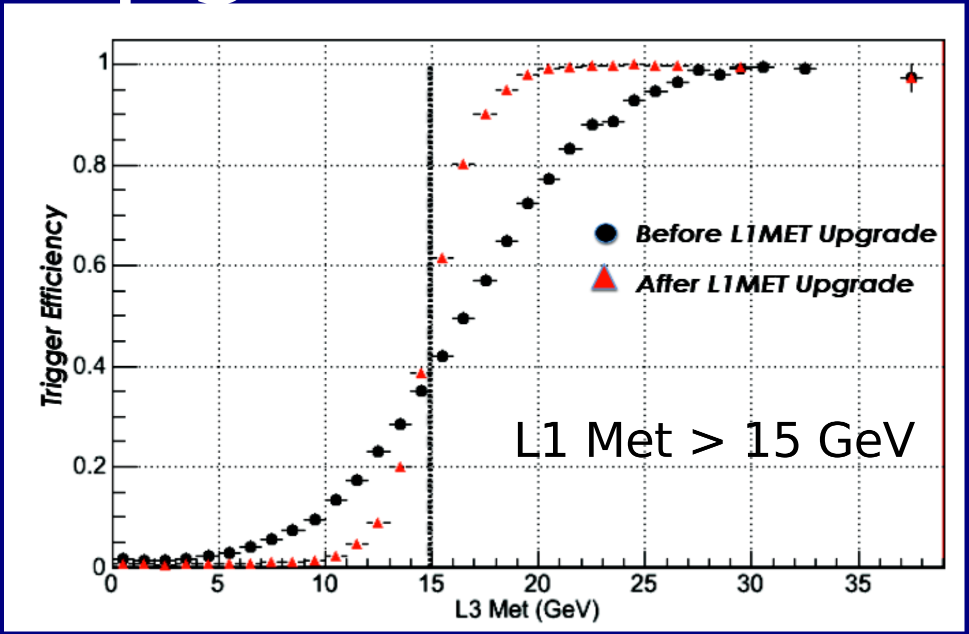
L1 Met upgrade

After L2CAL upgrade, push L2 Met resolution down to L1

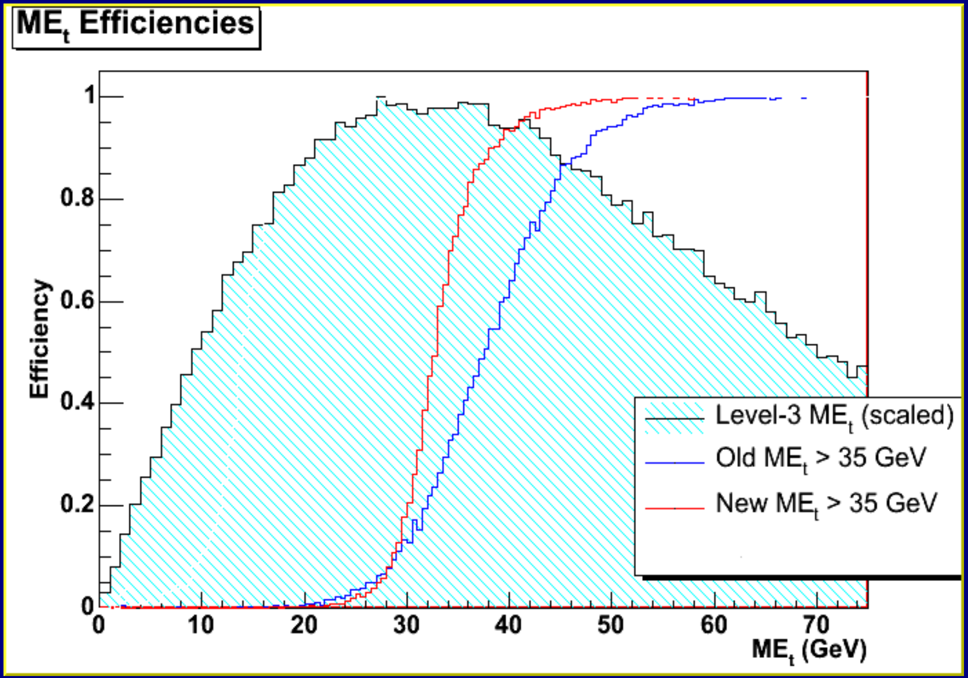


L1 Met upgrade

After the upgrade, at L1 same Met trigger capability of the L2



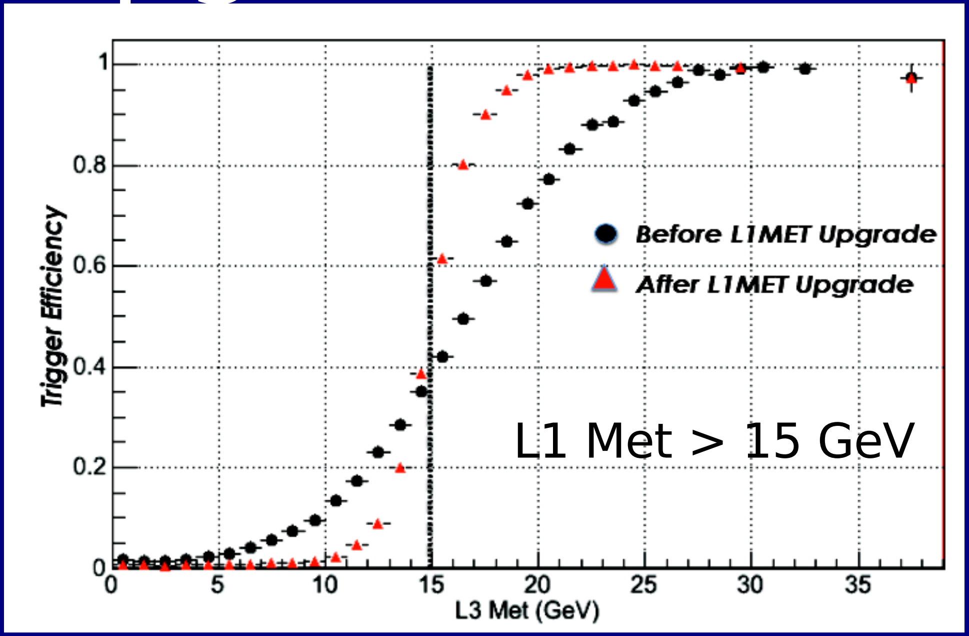
Increased flexibility of L1 Met based triggers



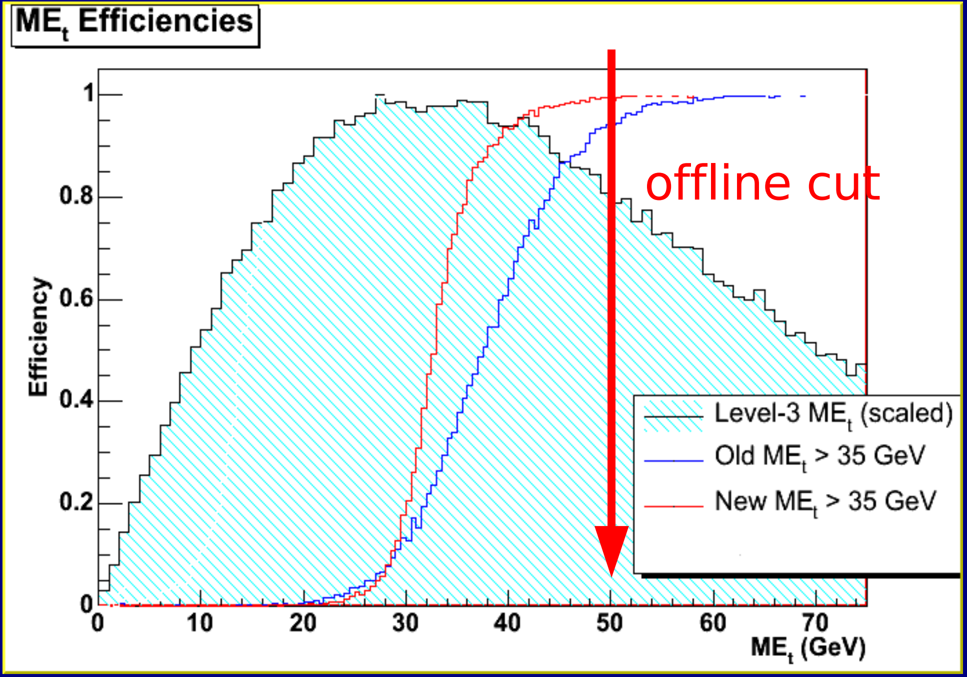
MET**35**_&_TWO_JETS trigger (used to select ZH→ννbb)

L1 Met upgrade

After the upgrade, at L1 same Met trigger capability of the L2



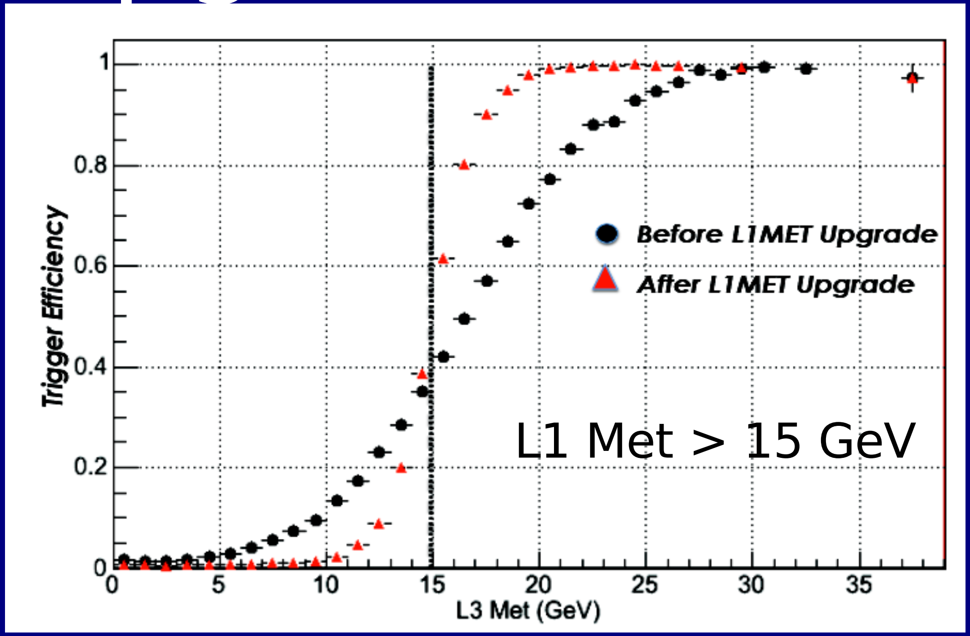
Increased flexibility of L1 Met based triggers



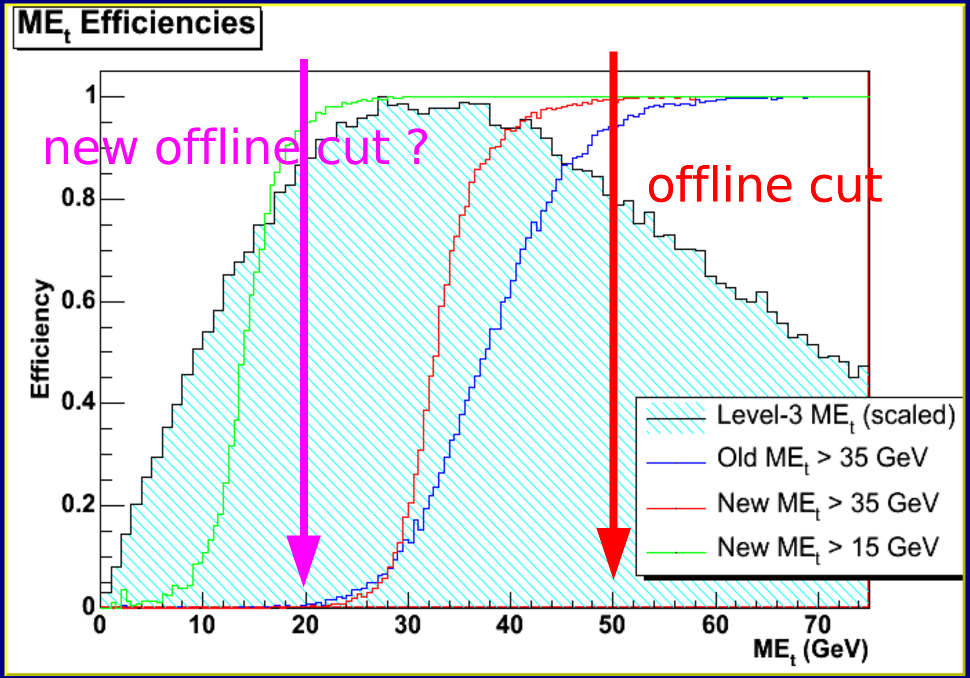
MET**35**_&_TWO_JETS trigger (used to select ZH→ννbb)

L1 Met upgrade

After the upgrade, at L1 same Met trigger capability of the L2



Increased flexibility of L1 Met based triggers



MET**35**_&_TWO_JETS trigger (used to select ZH→ννbb)

Applications

Met-dijet trigger

very simple architecture

L1 Met > 28 GeV

L2 Met > 28 GeV, 2 jets

A single trigger for WH and ZH channels

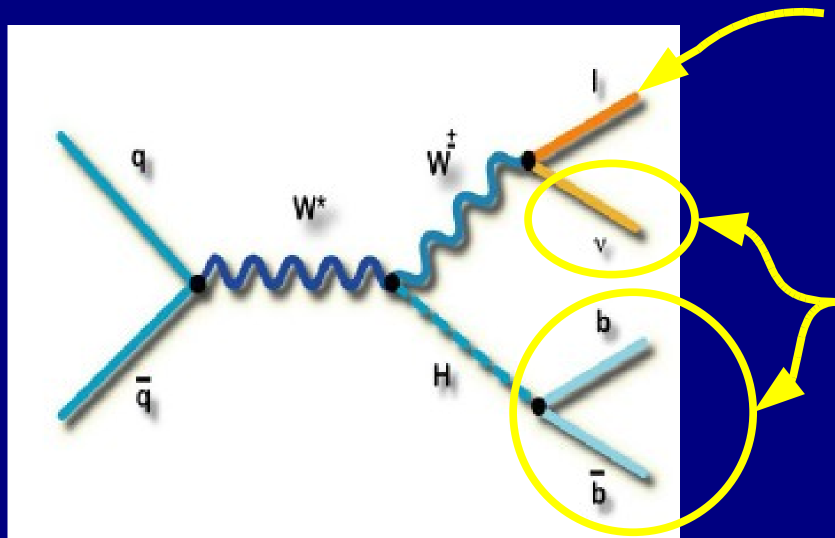
High efficient

	WH			ZH	
	$e\nu_e b\bar{b}$	$\mu\nu_\mu b\bar{b}$	$\tau\nu_\tau b\bar{b}$	$\nu\bar{\nu}b\bar{b}$	$\mu\mu b\bar{b}$
L1 eff.	91.8%	85.5%	84.5%	86.9%	85.8%
L2 eff.	75.8%	71.2%	66.9%	73.2%	71.6%
L3 eff.	66.3%	65.7%	59.5%	68.3%	66.2%

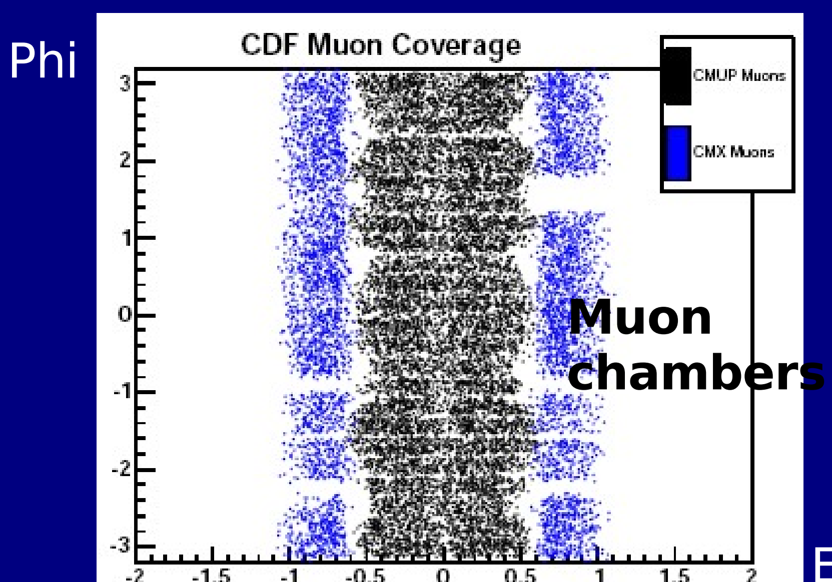
Excellent complement to leptonic triggers

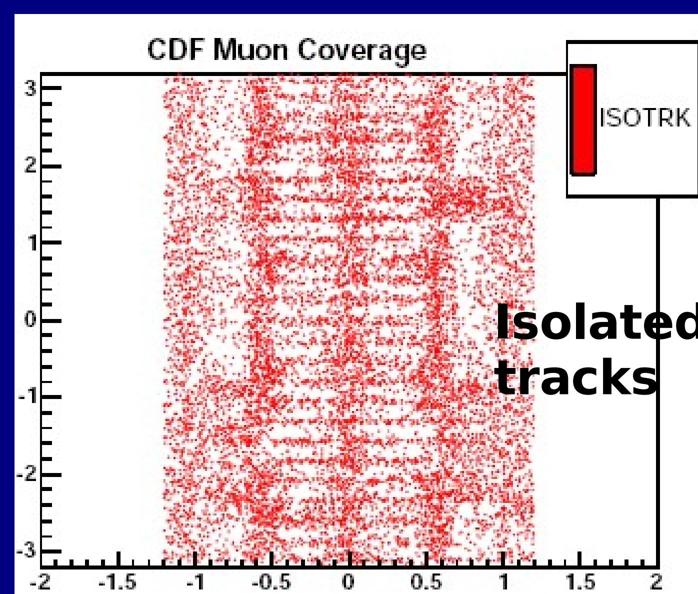
	WH acceptance	
	lepton-based triggers	cumulative with MET_DIJET
e	61.2%	85.4%
μ	22.1%	74.5%
τ	11.3%	62.8%

Increased WH acceptance



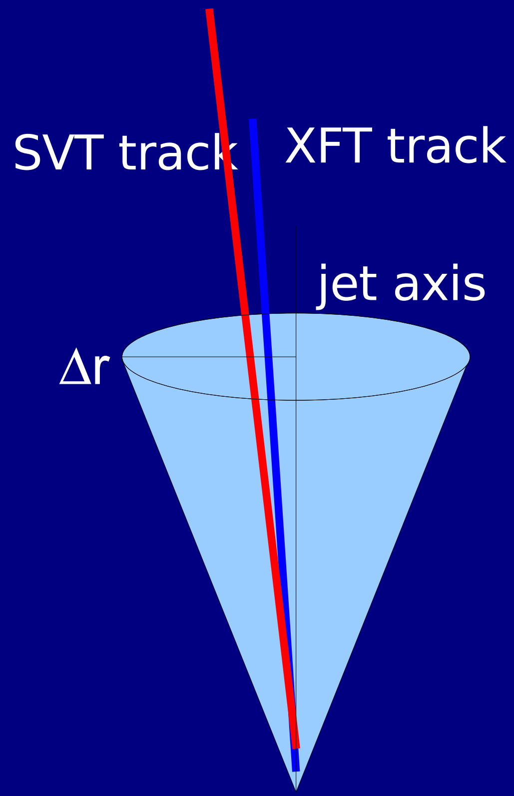
The addition of the non-triggered lepton increases WH → lν b-bbar acceptance by ~ 25% (recovers Eta and Phi gaps in muon detectors)





dijet- btag trigger

Trigger optimized for the selection of events rich of **b-jet**s (H→ b-bbar)

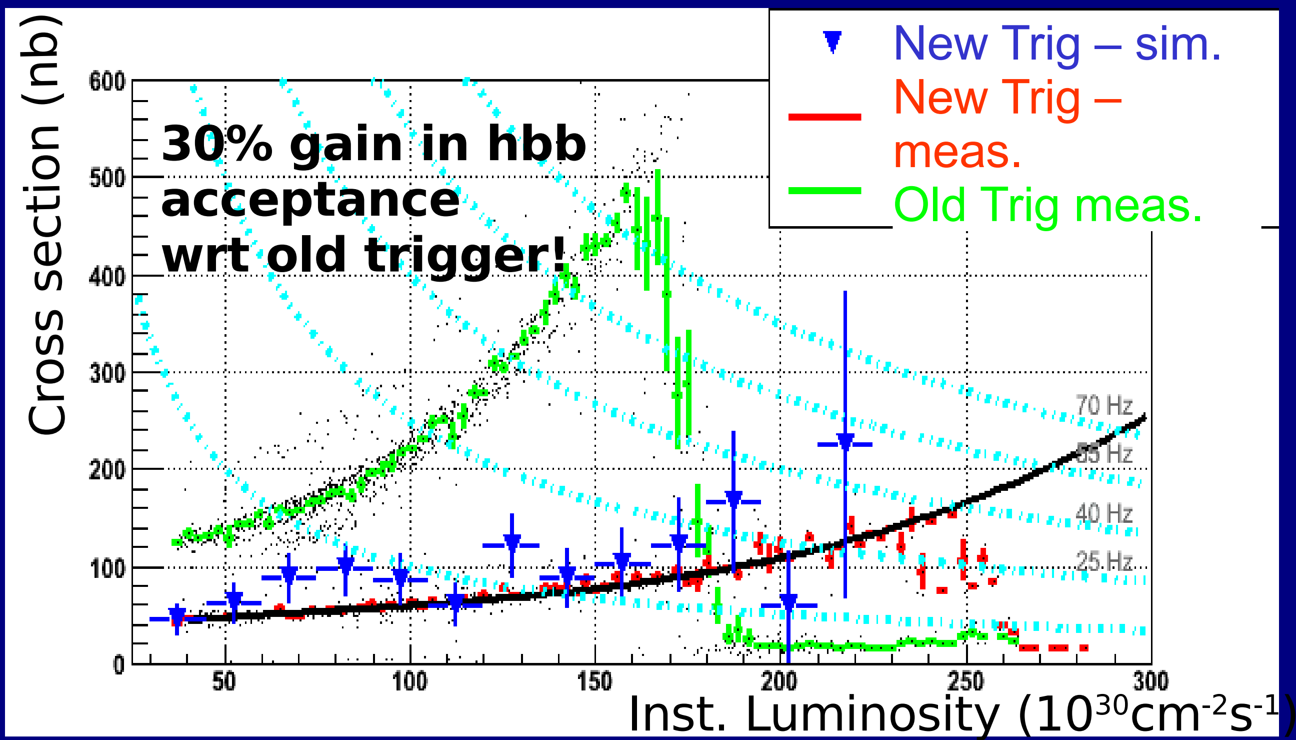


3D match al L2 between
- 3D track
- L2 Jet

Complementary to Met based triggers (ZH → ννbb)

Efficiency on signal events

H → bb	12.7%
φ → bb	11.2%
Z → bb	5.4%



Conclusions

CDF trigger has undergone **many upgrades** to cope with Tevatron increasing luminosity

Pulsar board: common tool, very flexible

Increase trigger variables quality

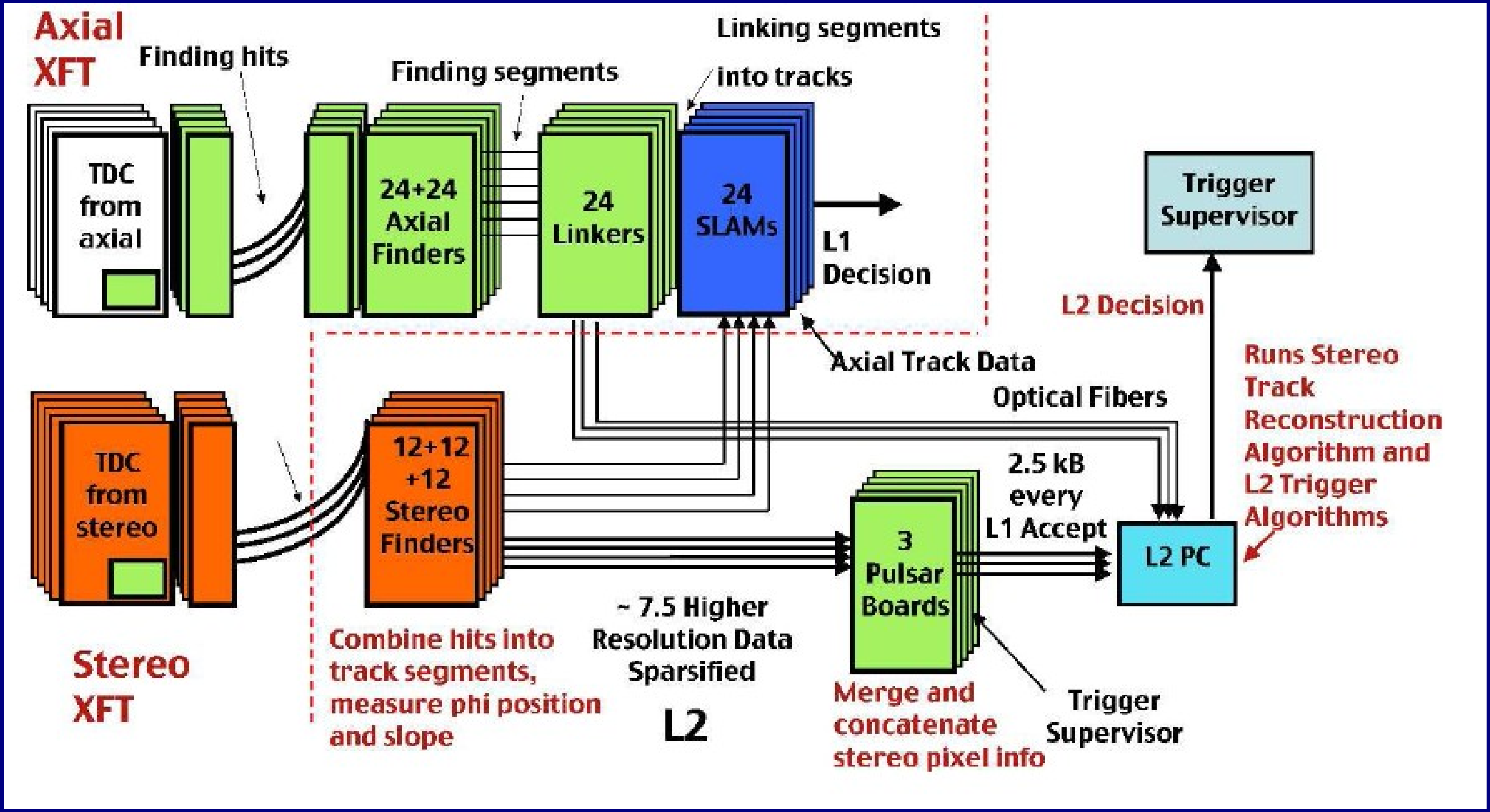
- 3D tracking
- offline-like jet clustering algorithm

Up to 2010 (2011) more than **2.5 fb^{-1} (5 fb^{-1})** will benefit of the upgrades

Online selection with **offline-quality** variables can greatly improve the physics reach of the experiment.

BACKUP

XFT upgrade



L1 upgrade improves fake rejection by a factor 3 to 5 and is 97% efficient

L2 further reduces the trigger rate by a factor of 3 and is over 99% efficient

XFT upgrade

Merging and transmission of the Stereo Data

The Pulsar board merges the Stereo segments and re-formats them into a S-LINK 32 bit word standard packet.

The S-LINK data format allows the comunication between the Pulsar and the FILAR card (Four Input Links for Atlas Readout) to the L2 PC

FILAR = high bandwidth S-LINK-to-PCI interface card

L2 decision PC: Dual Core AMD Opteron 290 2.8 Ghz (4 cores), 2 GB RAM, gentoo Linux

XFT stereo data volume = 1.5 to 3 kB per event (> 50% of the data volume transferred through the PCI bus)

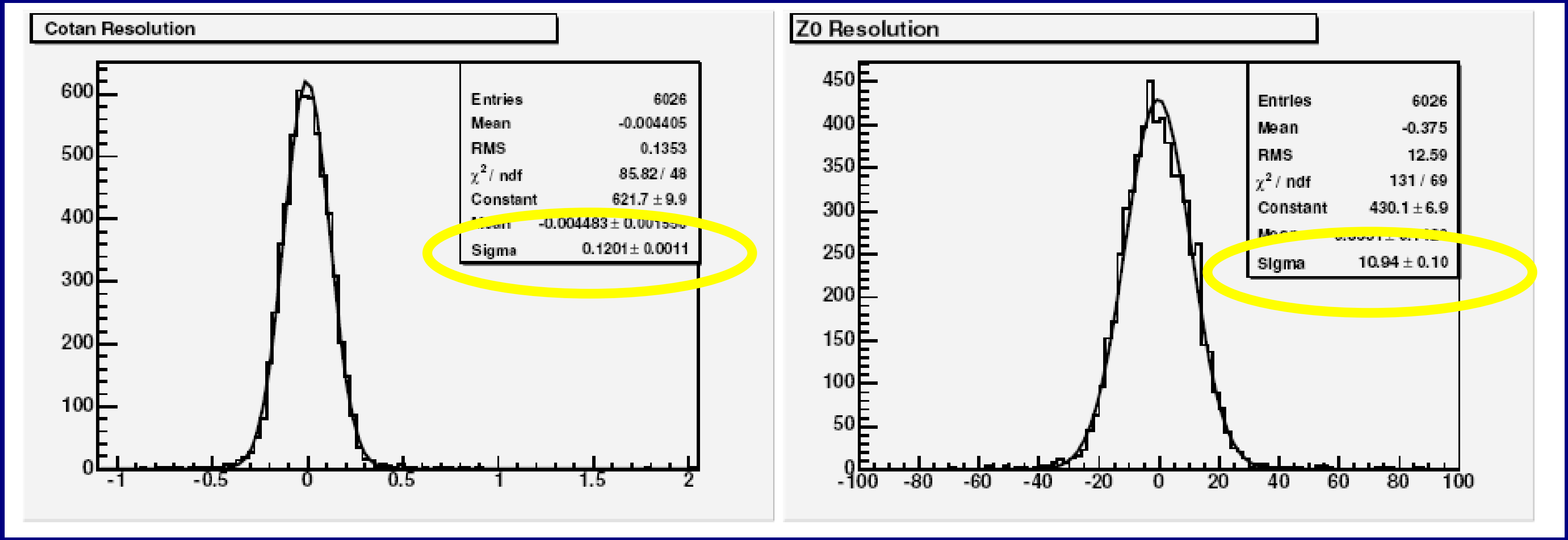
XFT upgrade

Stereo reconstruction algorithm

- each axial track is extrapolated to each of the 3 outer stereo layers
- at each layer, the track segments corresponding to ± 3 cells centered near the extrapolated ϕ position of the track are unpacked
- the slopes of the extrapolated track are obtained at each stereo layer
- the stereo pixel across different stereo layers are combined into triplets and z and cotan(θ) are measured (chi2 likelihood minimization)

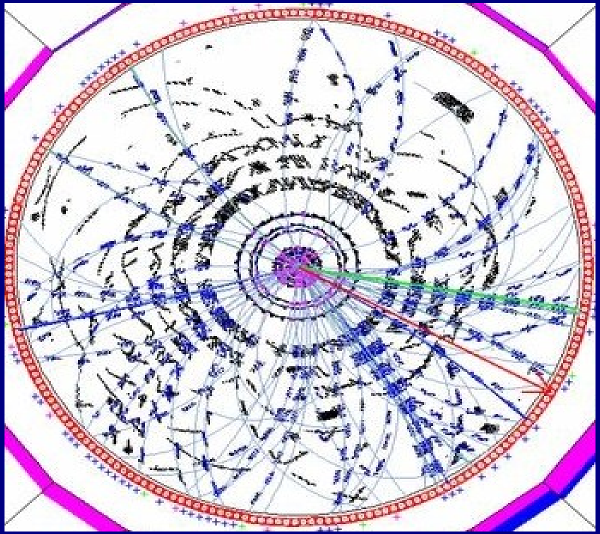
$$Z_0 = -4.606\,\Delta SL7 + 1.032\,\Delta SL5 + 6.444\,\Delta SL3$$

$$\cot(\theta) = 0.0589\,\Delta SL7 + 0.0008\,\Delta SL5 - 0.0581\,\Delta SL3$$

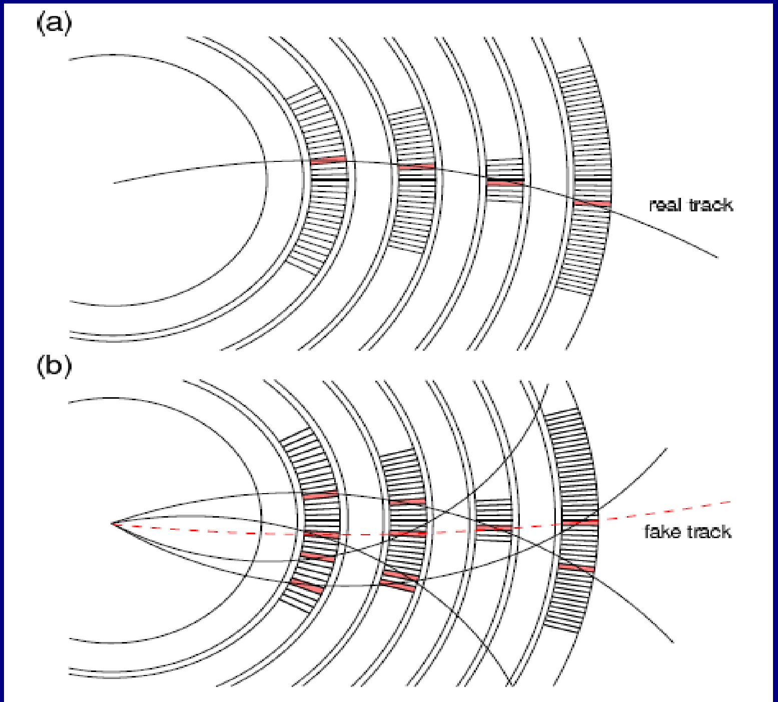


XFT fake tracks at High Lum

L > 200 10^{30} $cm^{-2}s^{-1}$ → ~ 6 pp interactions per bunch crossing, high COT occupancy



overlapping patterns of hits incorrectly identified as high momentum tracks



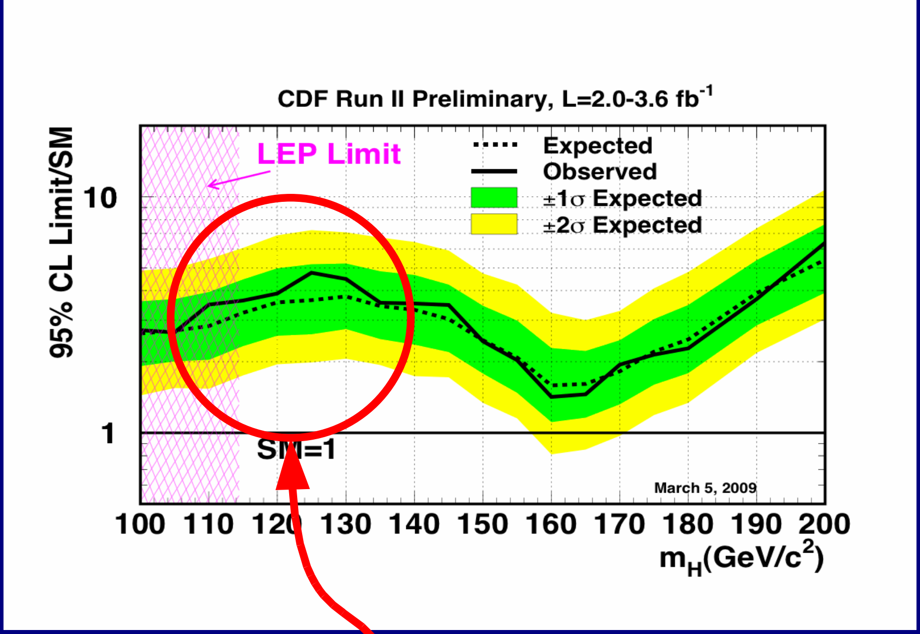
XFT and SVT resolutions

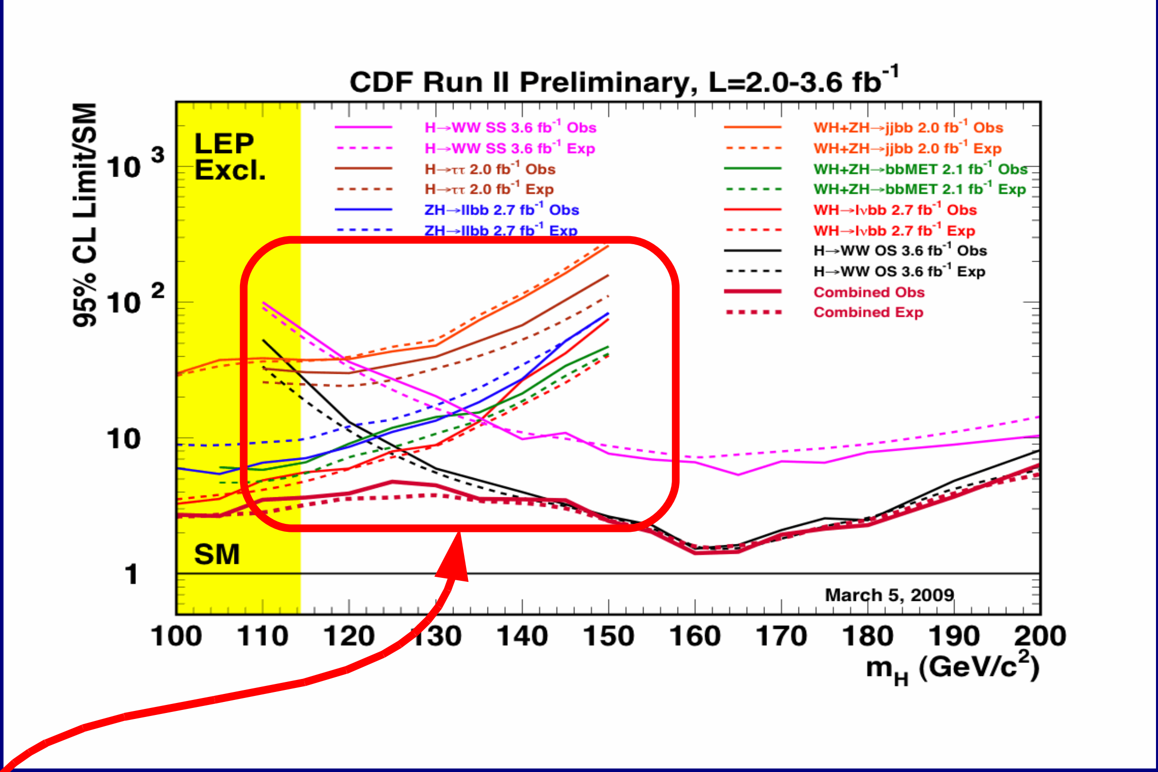
XFT

- eff > 96% (p_T > 1.5 GeV)
- $\sigma_{pT}/p_T^2 \sim 2\%$
- $\sigma_\phi \sim$ 2 mrad
- $\sigma_{\cot\theta} = 0.11$
- σ_z = 11 cm

SVT

- eff ~ 90% (p_T > 2 GeV, d_0 < 1 mm)
- $\sigma_{d0} \sim 35\ \mu m$
- $\sigma_{pT} \sim 0.003\ p_T^2$
- $\sigma_\phi \sim$ 1 mrad



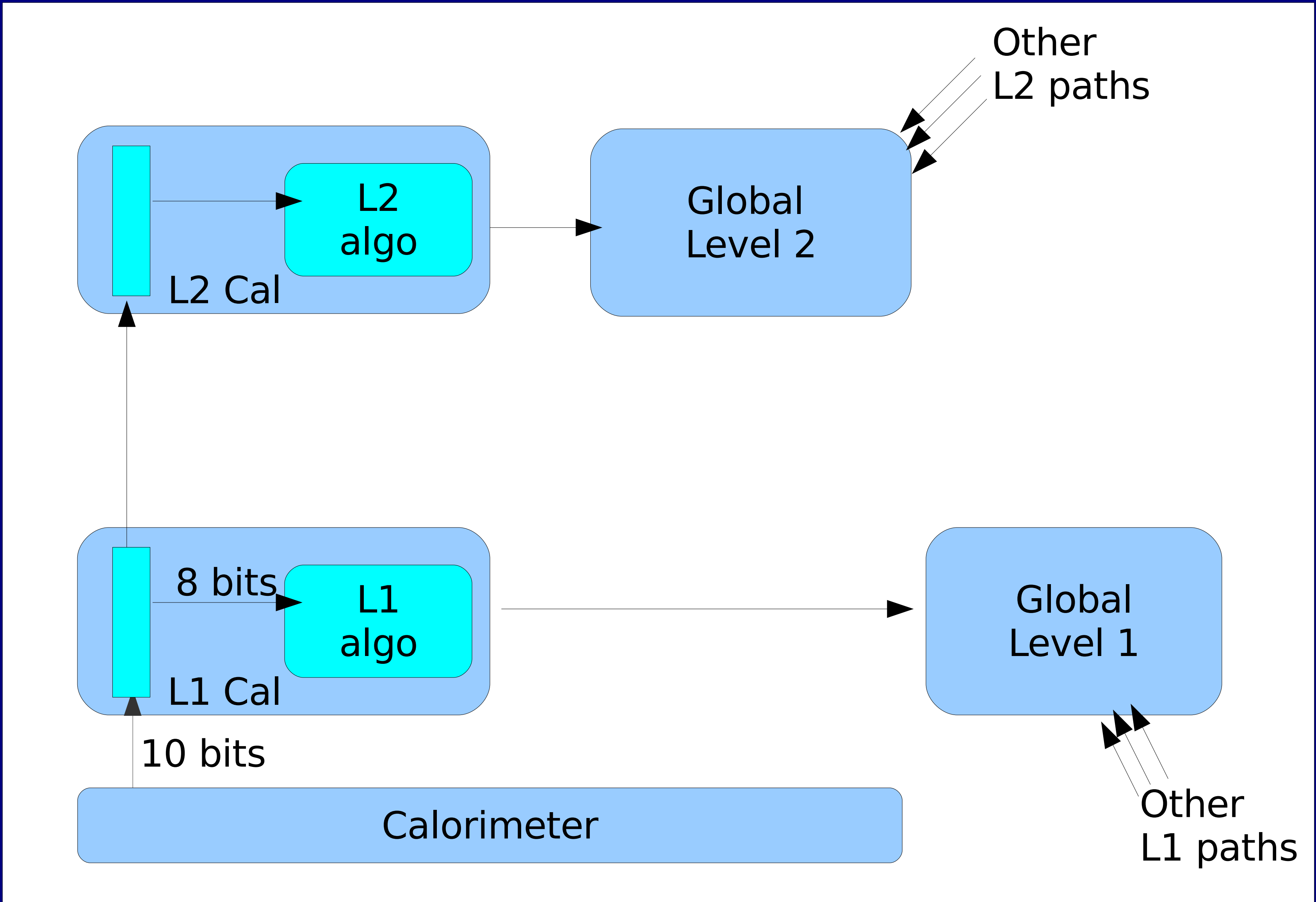


Low mass region difficult

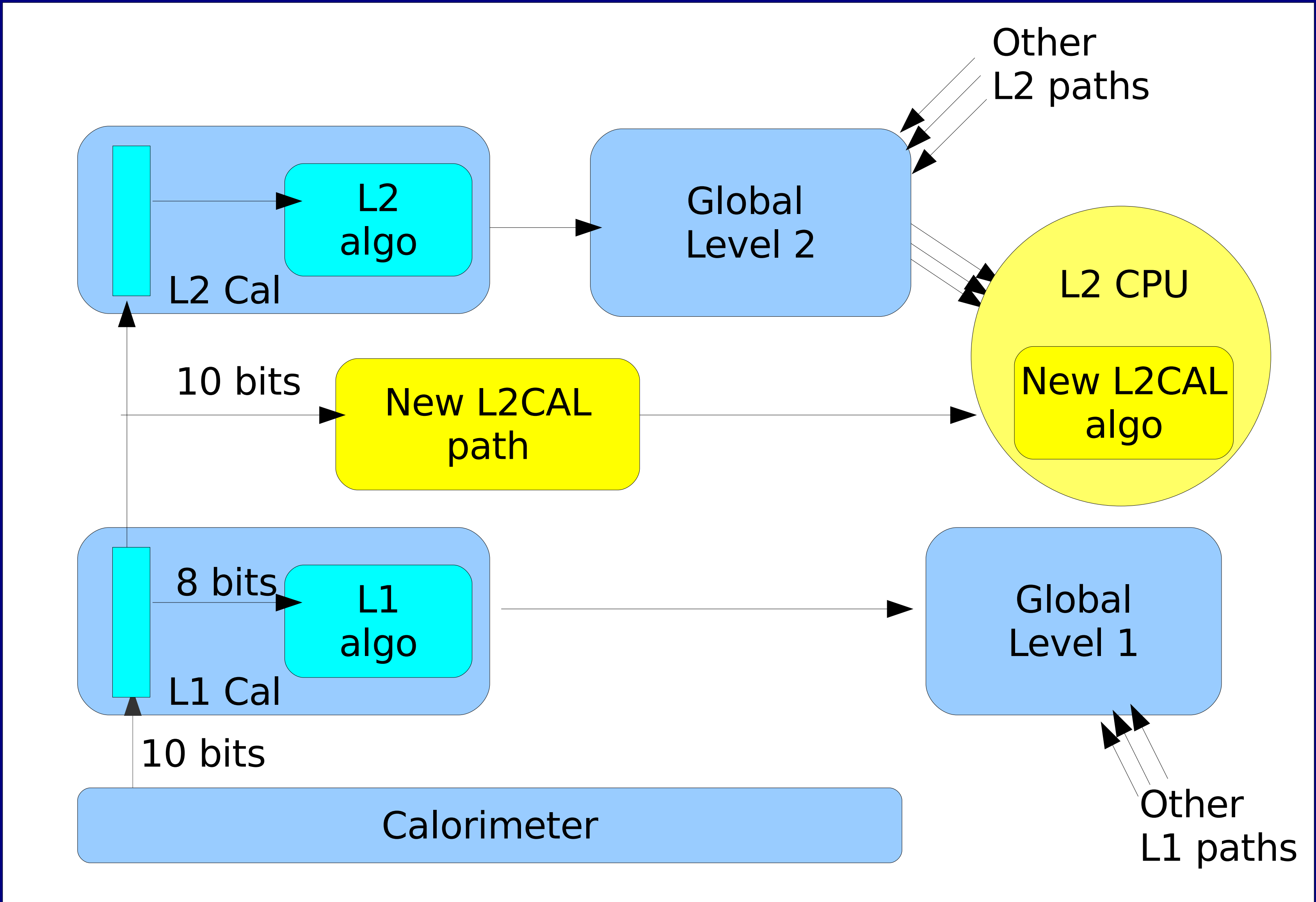
Search for **H → b-bbar** in association with **W → l** ν or **Z →** νν, **ll**

fundamental **b-tagging** **lepton ID** **Met**

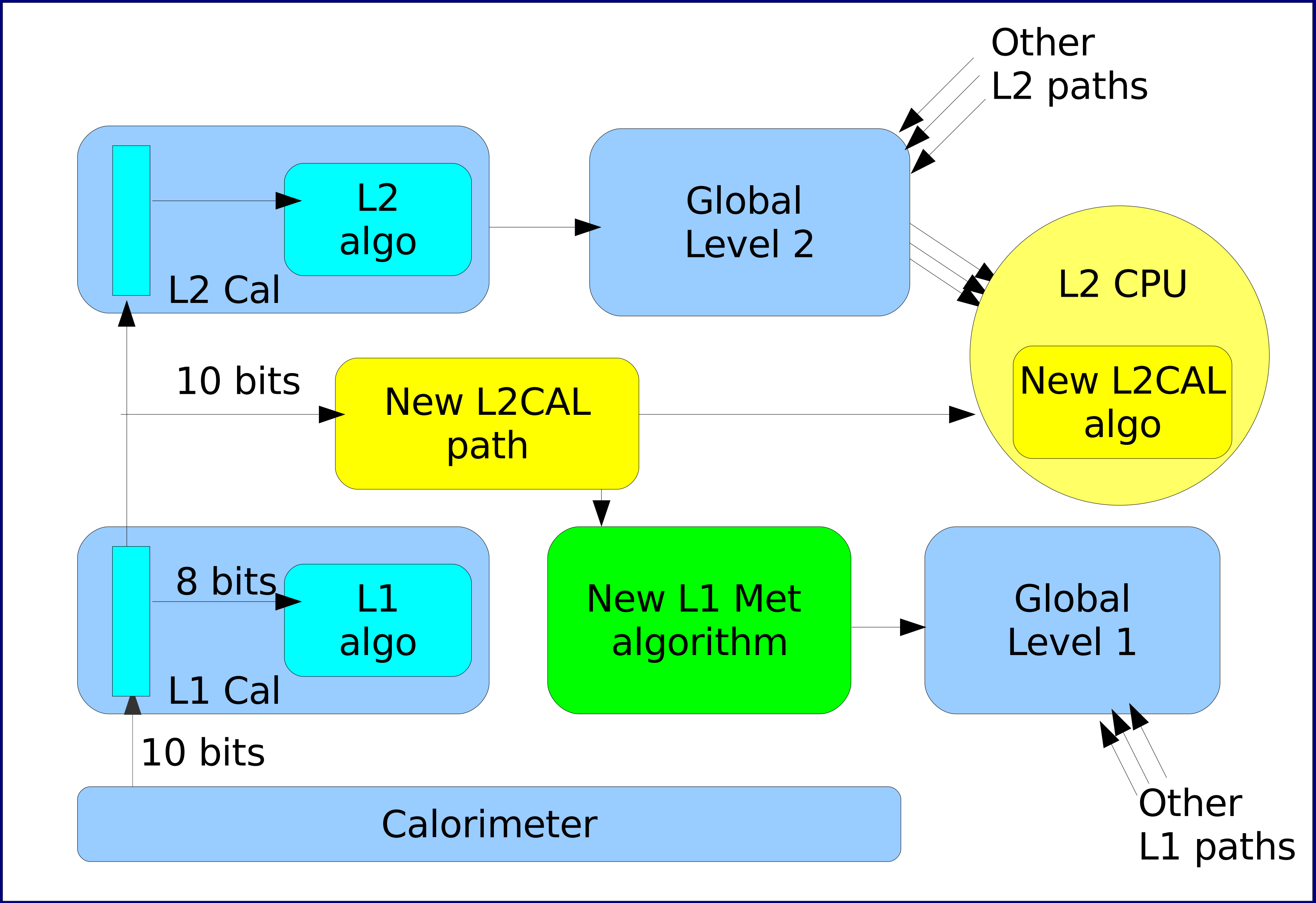
L1/L2 CAL upgrades



L1/L2 CAL upgrades



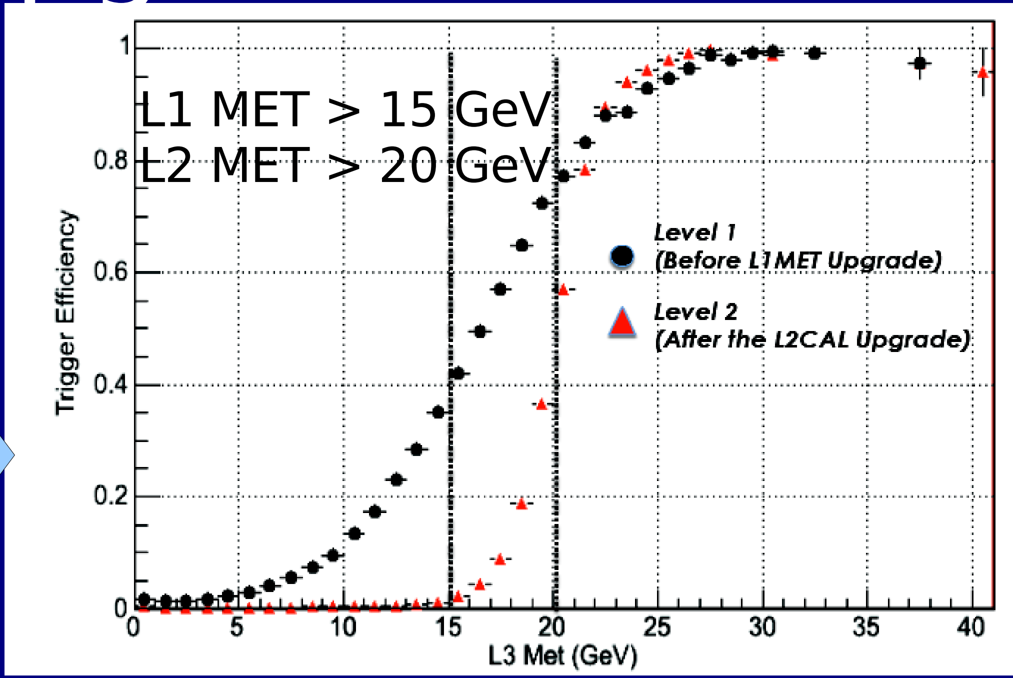
L1/L2 CAL upgrades



L1 Met upgrade

Different MET resolutions at L1 and L2 → cannot lower MET threshold at L2

L1 turn-on curve slower than L2



Calorimetric trigger – some details

It triggers on **electrons, photons, jets, SumEt and MEt**

Calorimeters are divided in towers (EM and HAD)
Information from towers id **digitized every 132 ns**
Physical towers are summed into **trigger towers,** weighted to yield transverse energy

15° $\Delta\phi$, 0.2 $\Delta\eta$

Calorimeters = 24 x 24 map in η–ϕ plane (576 trigger towers)

10-bit energy resolution (LSB = 125 MeV, full scale 128 GeV)

OLD SYSTEM

L1CAL used only 8-bit trigger tower energy (LSB = 250 GeV, full scale 64 GeV)

L2CAL, hw based system, used SumEt and Met information directly from L1CAL

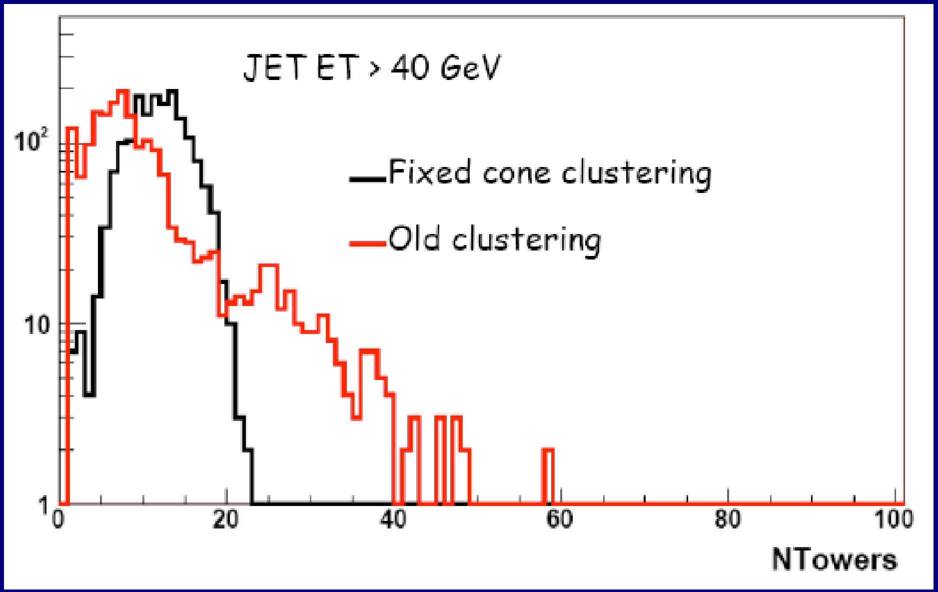
Calorimetric trigger – some details

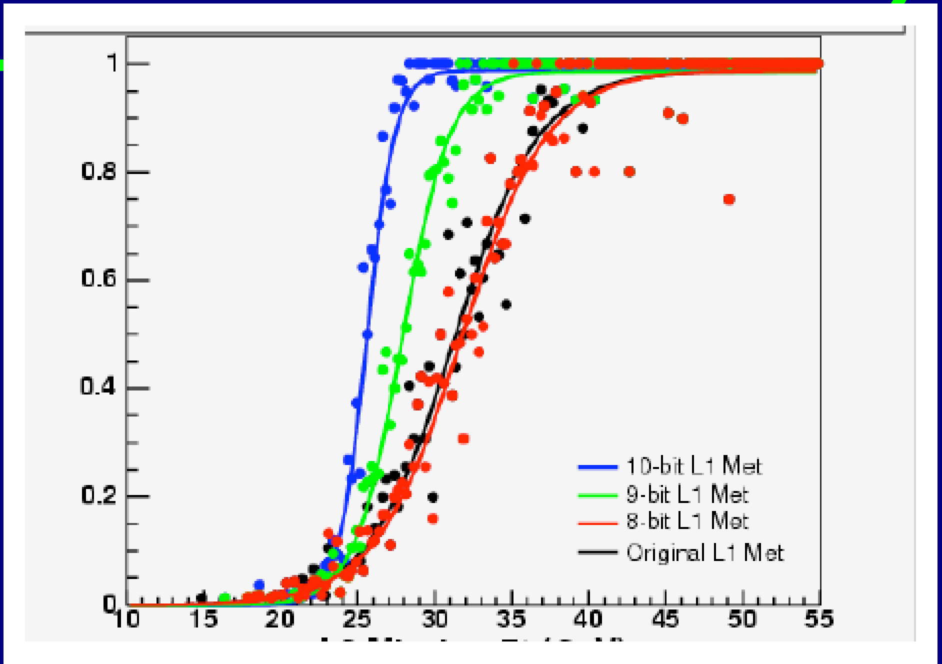
NEW SYSTEM

Fixed cone algorithm:
- finds and orders the seed trigger towers in Et
- it clusters in Et in a fixed cone arouund the largest seed (no iteration)
- it flags used towers
- it repeats until all seeds are used
- it orders the found clusters
- cluster η and φ are weighted by Et

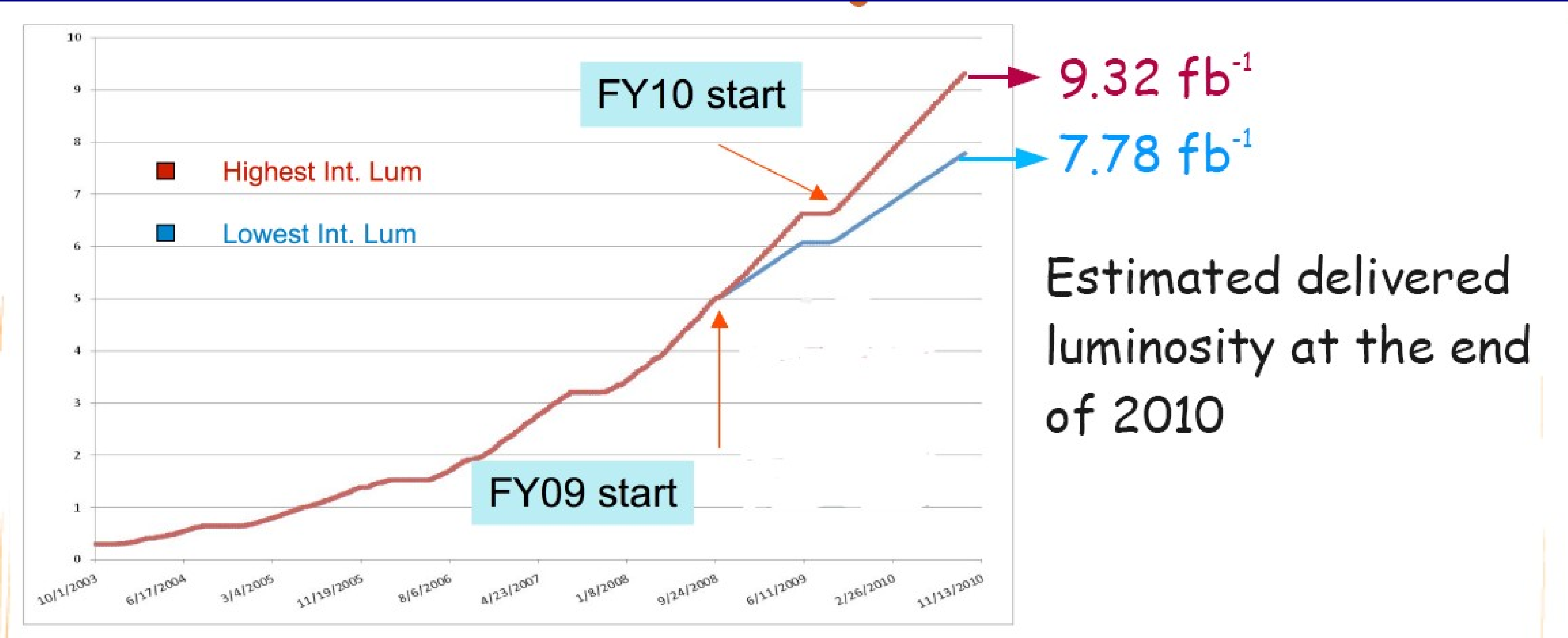
Seed threshold = 3 GeV
Shoulder threshold = 1 GeV

SumEt and Met are recalculated using the full 10-bit resolution





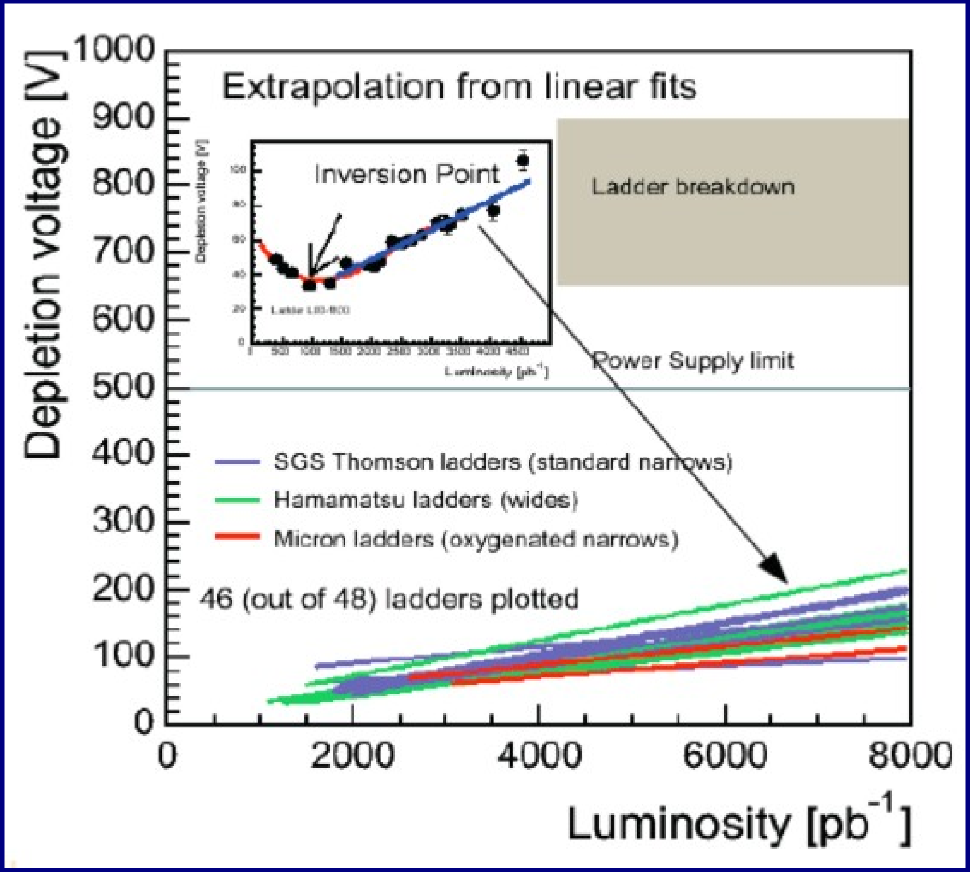
Tevatron projections

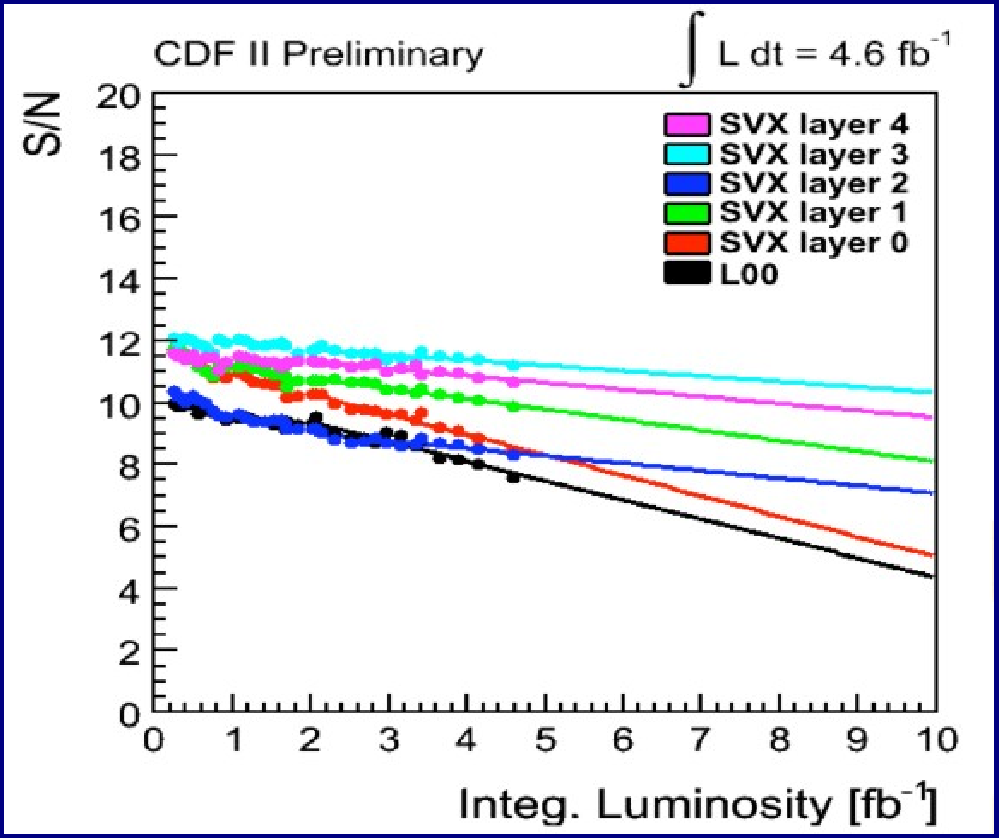


if running in 2011 -> 11.8 fb^{-1}

expect at least doubled luminosity by the end on 2011

CDF status





- S/N ~ 5/6 good for physics
- S/N ~ 3 goof for high-Pt b-tagging