Trigger Studies with Tracking, Calorimeter and Muon Triggers at CMS

Overview of this talk:

- CMS Calorimeter Trigger at SLHC
- Stacked Tracker for Triggering at the SLHC
- Algorithms for Calorimeter and Tracking Triggers
- Studies using Tracking and Muon Triggers
- Outlook for the next two years

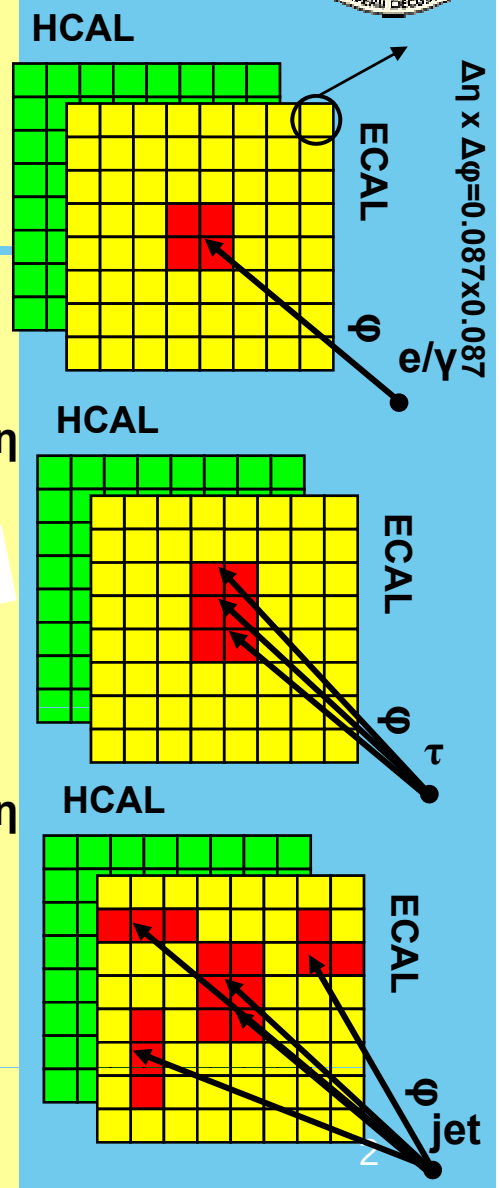
The Calorimeter Trigger at SLHC

At SLHC Phase-I: Increase Calorimeter Trigger Granularity:

- LHC Jets: Regions (4x4 towers); 1 jet = 12x12 Towers
- LHC e/γ trigger: Trigger Towers ($\Delta\eta \times \Delta\varphi = 0.087 \times 0.087$)
- SLHC: Both e/γ and jets in towers
- SLHC: Clustering and filtering precedes algorithms

- **Electrons/Photons**
  - Spatially confined in a cluster of 2x2 trigger towers
  - Significantly higher ECAL contribution
  - Isolated e/γ should have low energy deposits in the surrounding area
- **Taus**
  - Confined in 2x3 Clusters
  - 3 prongs/1 prong + π0s have wider φ profile
  - Small energy leak in surrounding towers
- **Jets**
  - Most of the energy confined in a central core
  - For jets over 20 Gev the energy is included in a 8x8 region

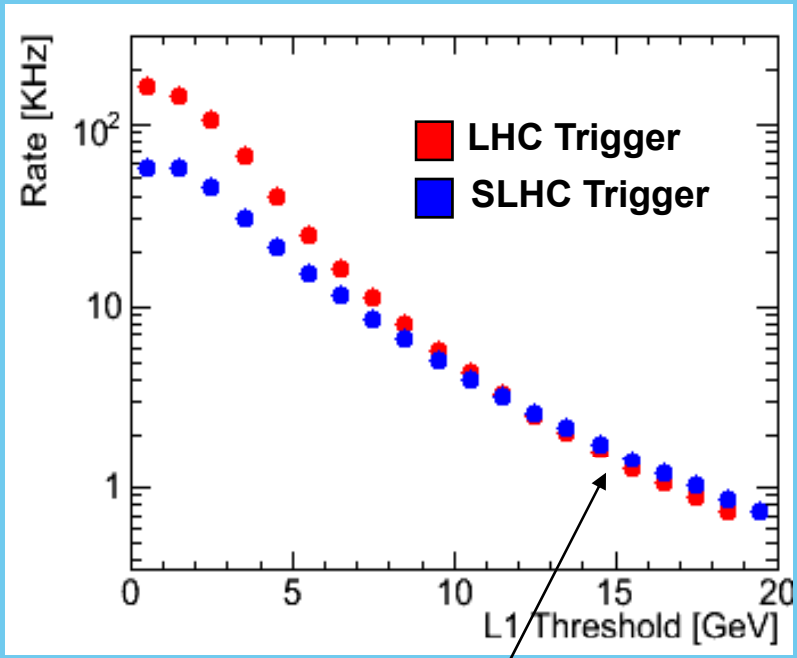
Big gain for tau-triggers !!!



Dasu/Bachtis-Wisconsin

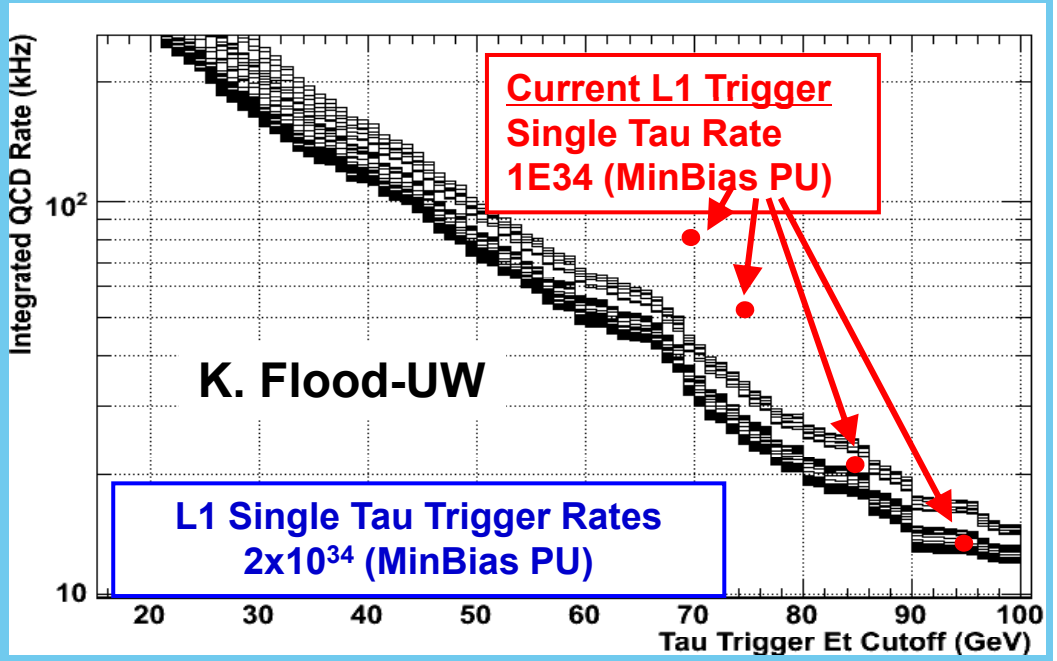
Rates at 2×10^{34}

Isolated e/γ Trigger



At high Et the isolation in SLHC Trigger relaxes So the rate slightly increases. Isolation cuts need to be tuned tighter for high luminosity

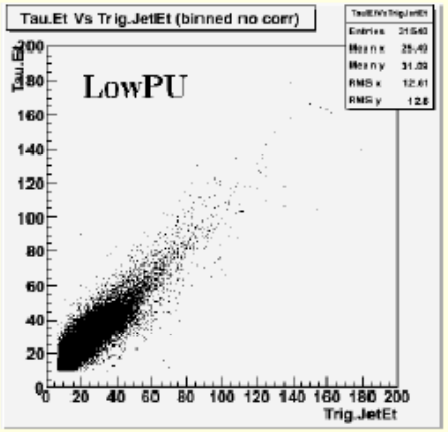
Single τ Trigger

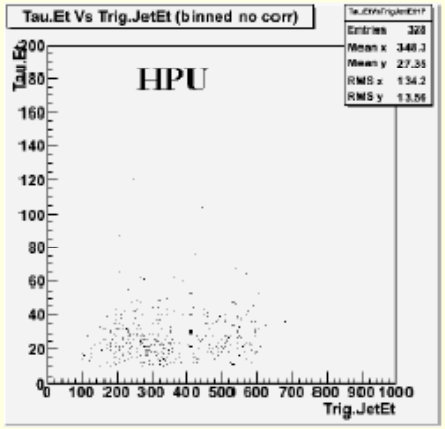


Significant improvement for taus ! The single Tau Threshold could be <1/2 the value we have now

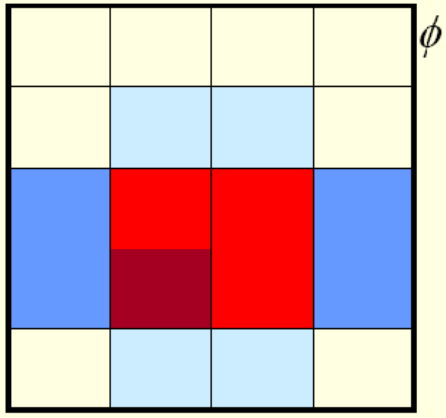
- As expected tau triggers improve dramatically.
- Electron/photon triggers need better isolation cuts which inevitably will decrease efficiency.
- Even with improved calorimeter trigger the rate is unsustainable and tracking information is needed to reduce it

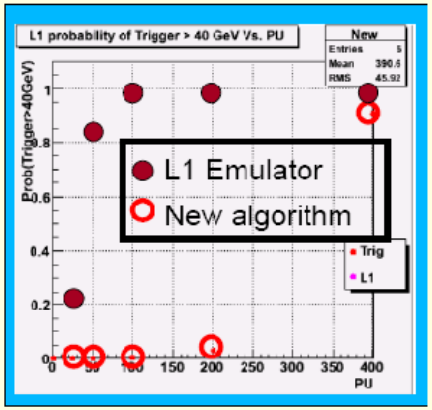
High Pileup Tau Trigger Studies



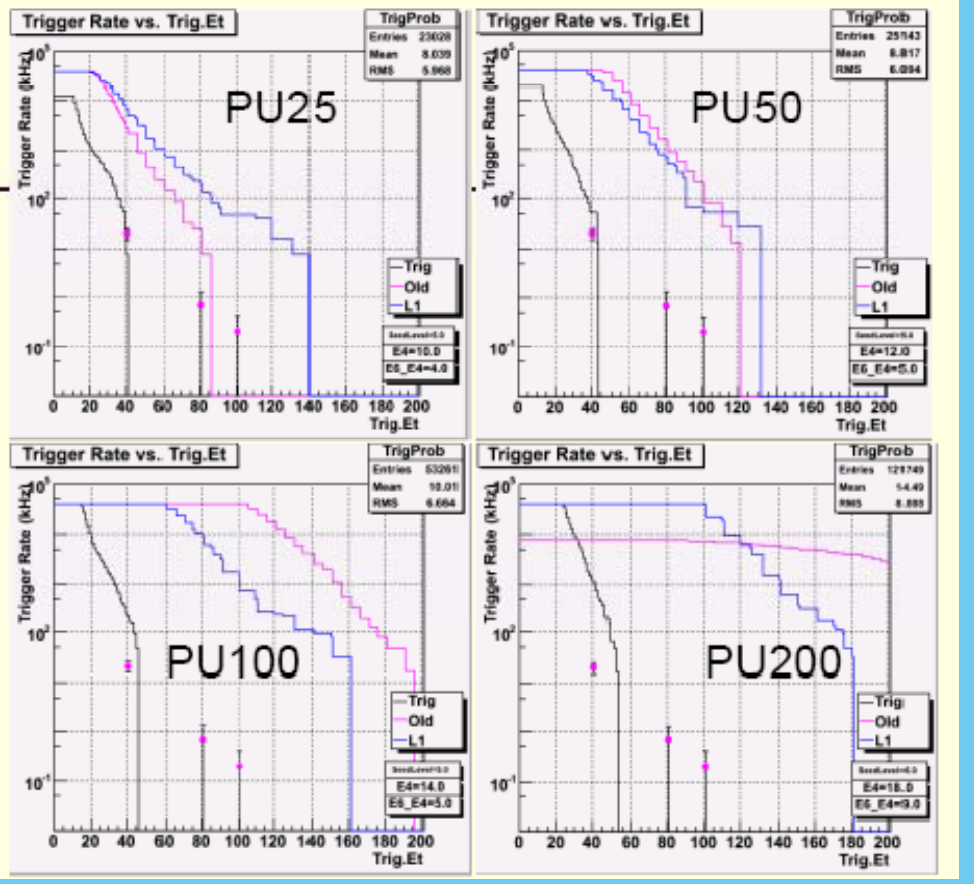


Michael Mason
Vadim Khotilovich
Alexei Safonov
(Texas A&M University)



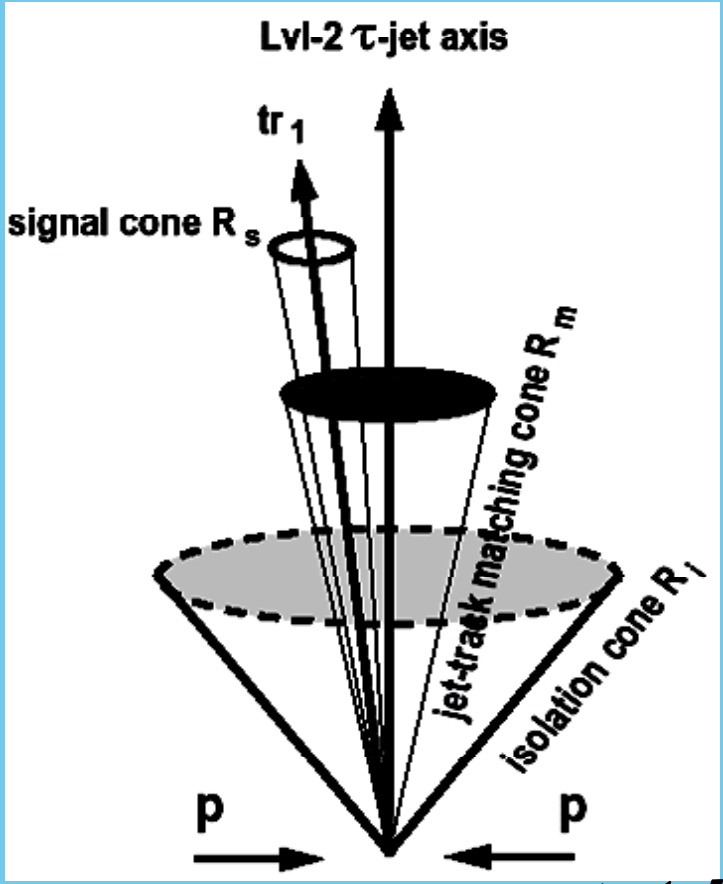


Probability of triggering for a 40 GeV tau in a crossing with i_{PU} PU events vs i_{PU}. L1 emulator "as is" from 1.6.X

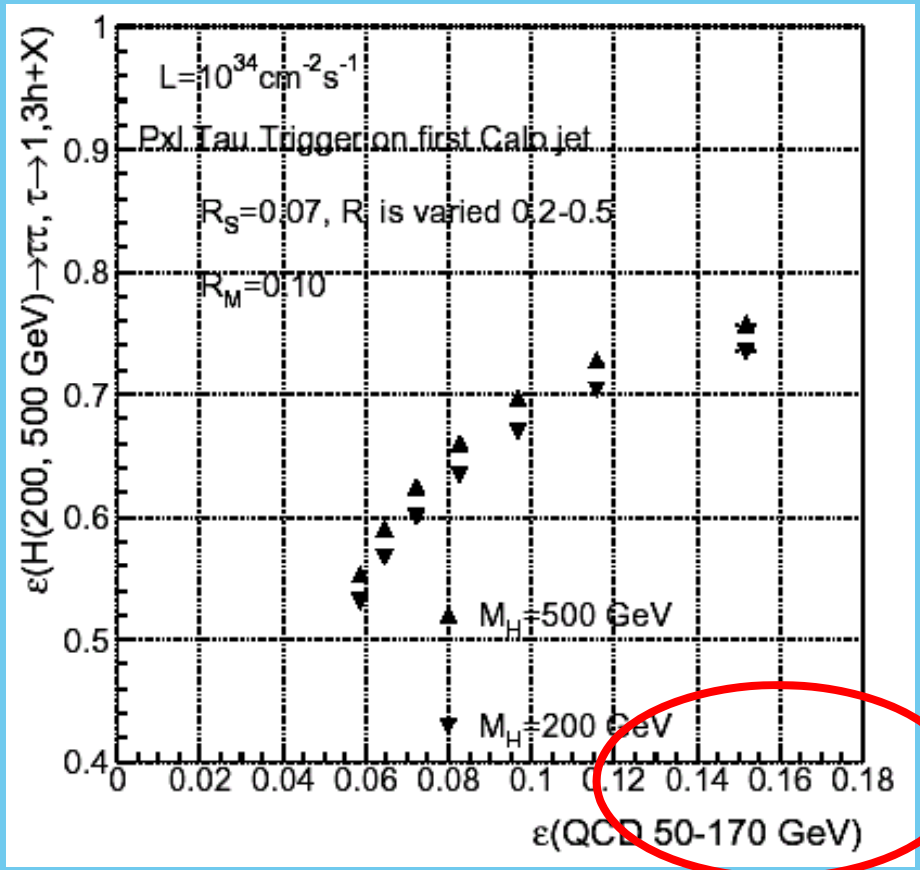


- **Current 12x12 tower tau finder will not work at high pileup.**
- **Cluster based tau finder do better and we may survive phase-I but not phase-2**

Tau Triggers with tracking



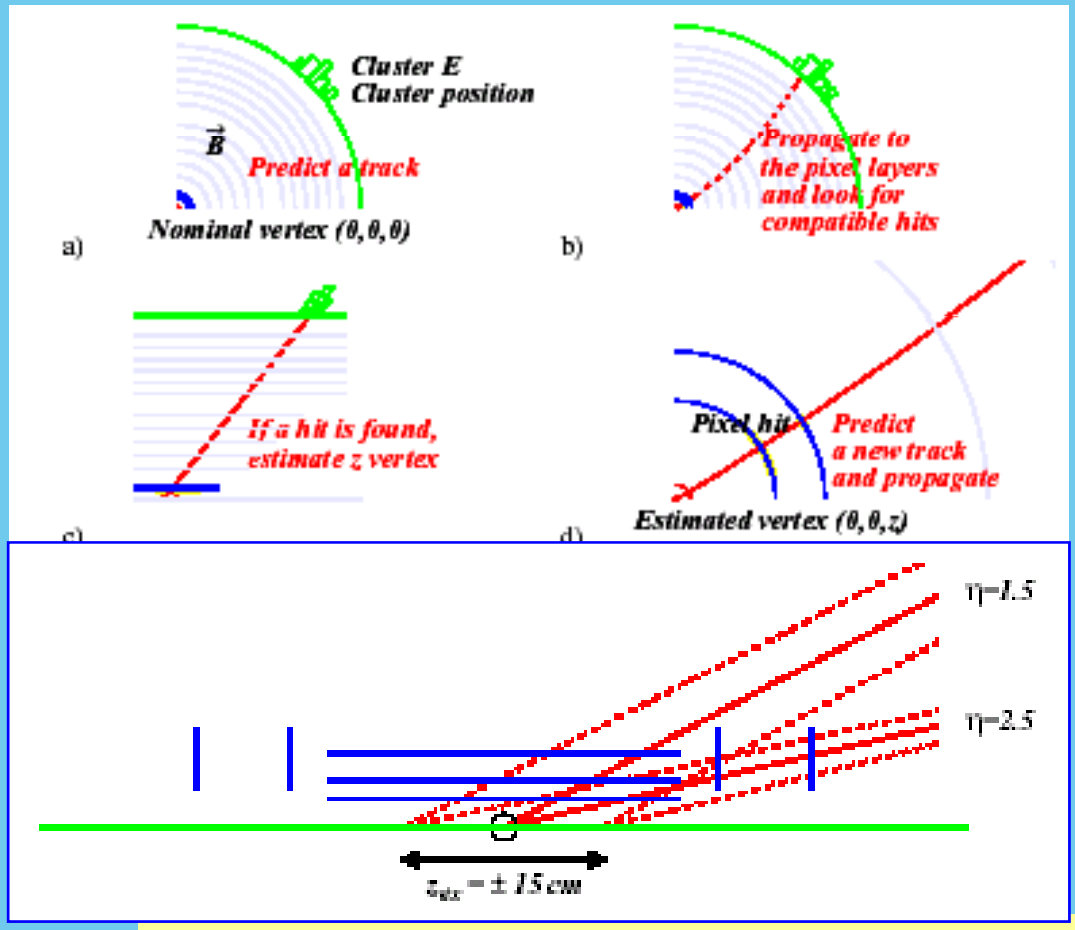
Inner tracker high Pt stubs

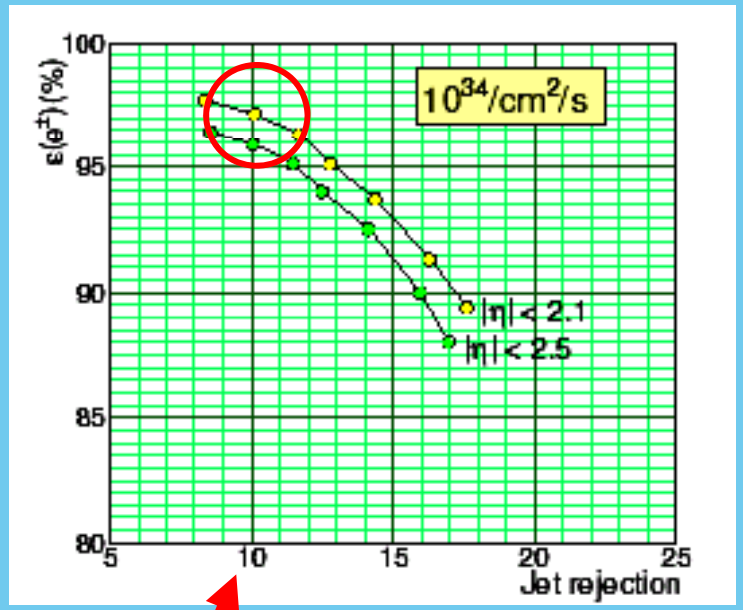


Efficiency for QCD events

- **Tau Triggers also require isolated high p_t stubs in the inner tracker to detect hadronic decays of taus (65%).**
- **The QCD jet efficiency can be reduced by a factor of 10 while tau jet efficiency rises to 75 %.**

Reducing the e/γ trigger rate for Phase-II

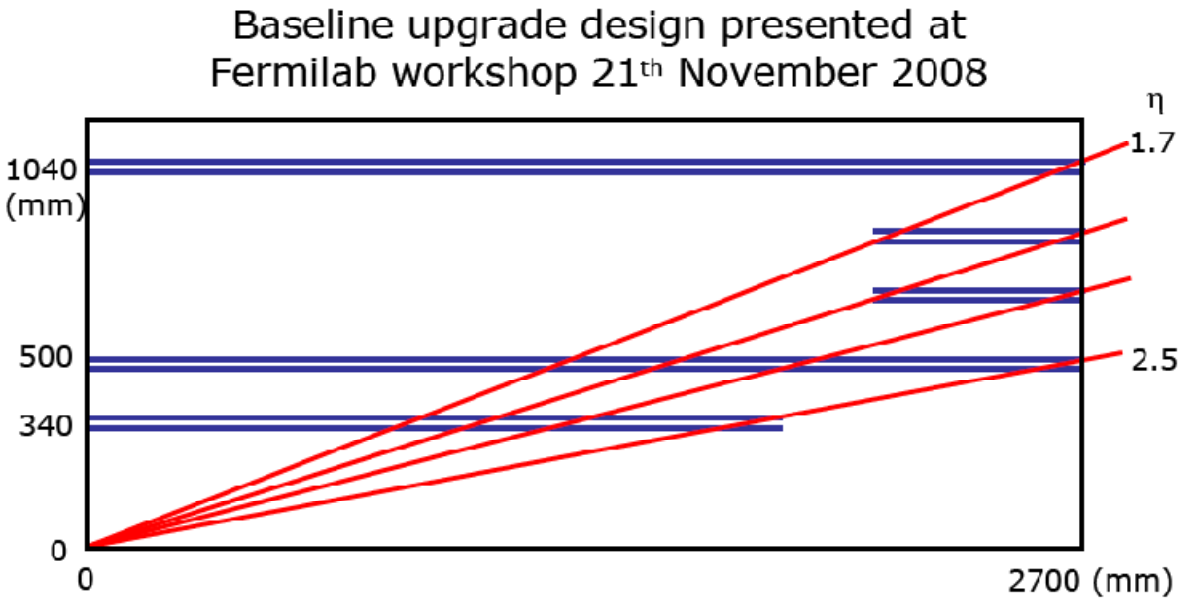




G. Daskalakis CMS Note 2002-39

- Gain a factor of 10 by requiring a hit in the inner tracker
- Another factor of 3 from using the outer tracker.
- Inner Tracker is absolutely essential for a tracking trigger.

A stacked detector for triggering

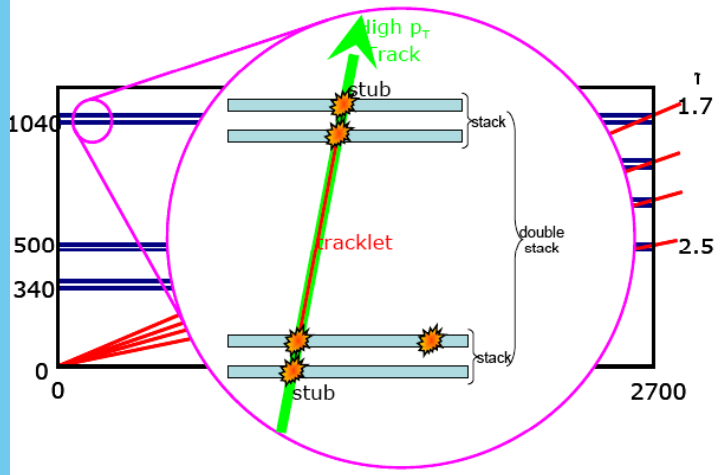


1mm x 10 μm pixels

R=34,38,50,54,66.3,70.3,
82.3,86.2,100.5,104.5 cm

- **Stack: pair of closely spaced (~1mm) sensors.**
- **Stub: Correlated pair of hits in a stack**
- **Double stack: Two stacks separated by few cm.**
- **Tracklet : Matched pair of stubs**

Terminology



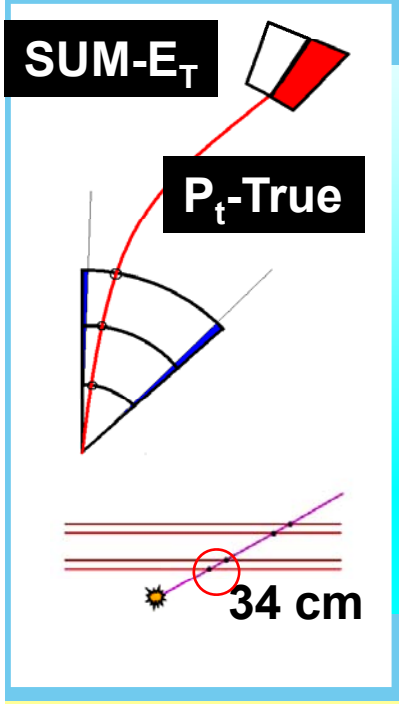
Stack:pair of closely spaced sensors (~1mm)
Stub:correlated pair of hits in stub
Double stack:Two stacks separated by few cm. Also referred to as a beam.
Tracklet A matched pair of stubs.

A layer is one stack in this talk.

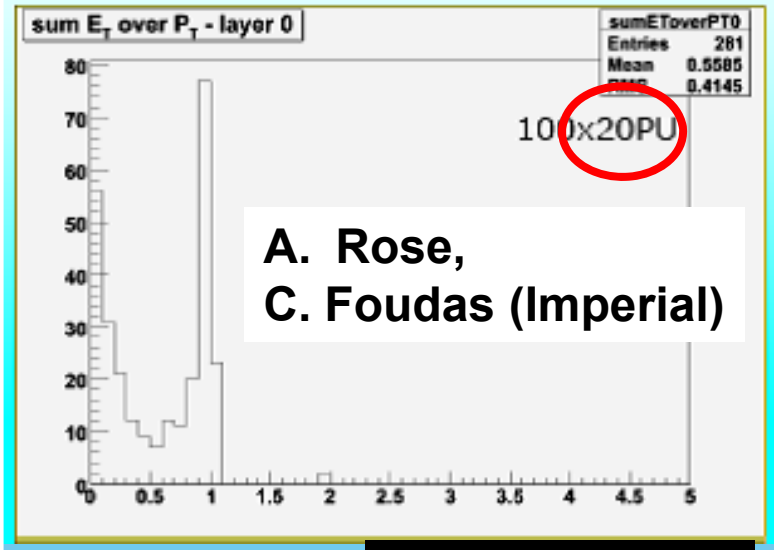
https://twiki.cern.ch/twiki/bin/view/CMS/SLHCTrackerTerminology

Costas Foudas, Imperial College London

Combining e/γ with tracker stubs: 1-Stack

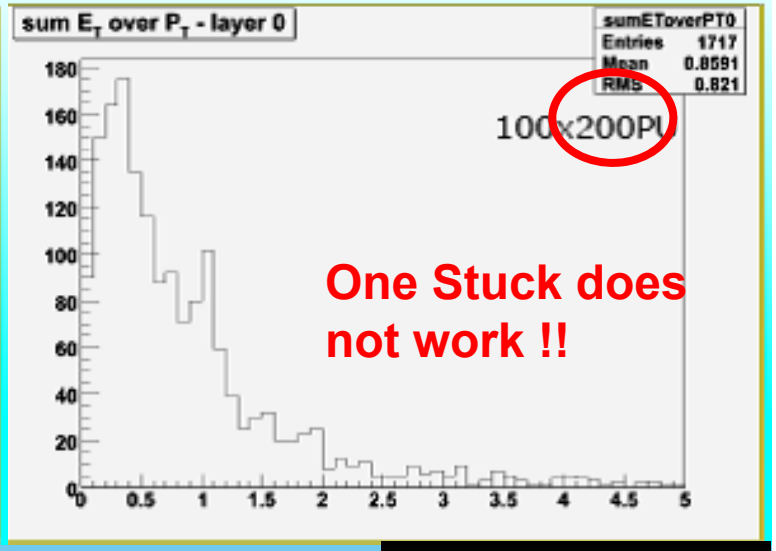


Results from one stack (1 mm apart) at Radius=34.0 cm



A. Rose,
C. Foudas (Imperial)

SUM-E_T/P_t-True



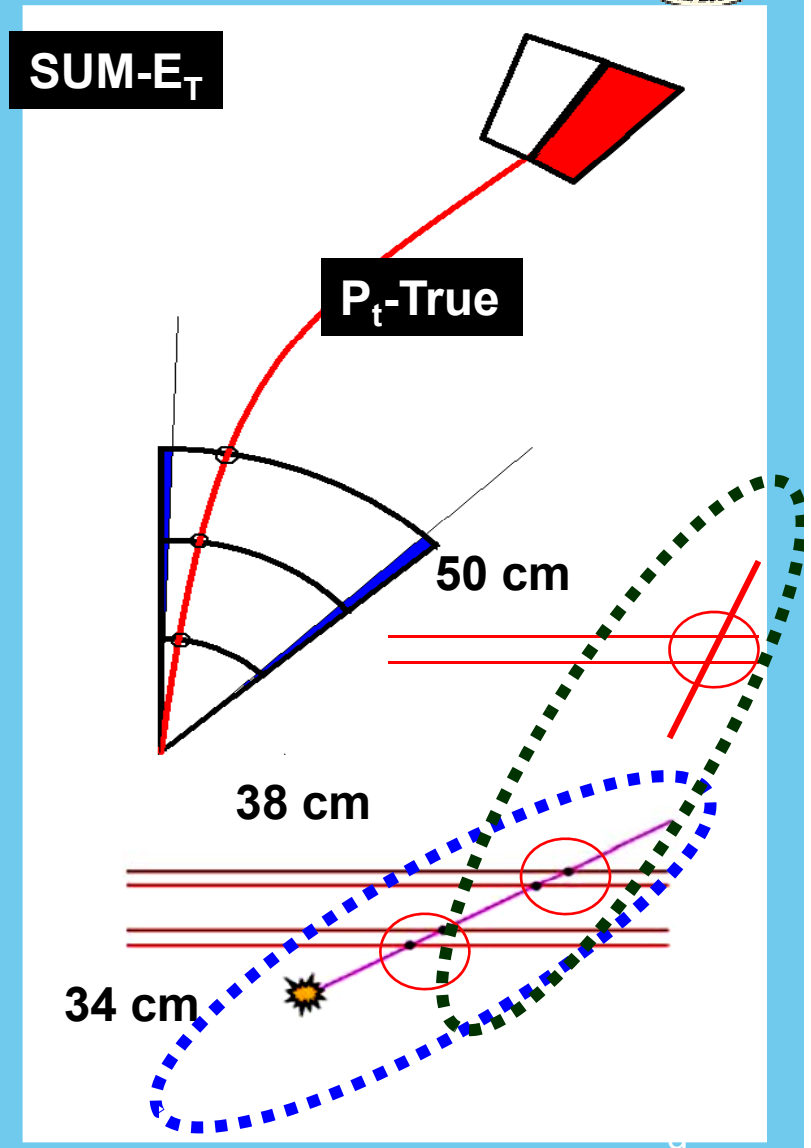
One Stuck does not work !!

SUM-E_T/P_t-True

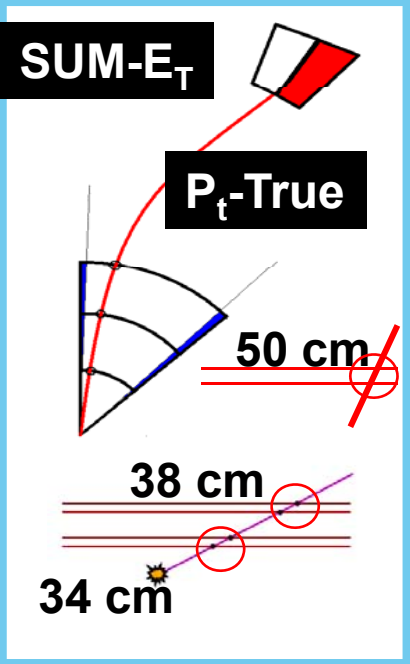
- **Method:**
  - Use single electron events + different number of pile-up events (20, 200).
  - Use one stacked detector at R=34 cm and stack members at 1 mm apart
  - Extrapolate to the calorimeter using the nominal vertex and search for the maximum E_T tower within a window.
  - Compute the calorimetric energy deposition by taking the sum of the energy of the maximum tower plus the highest of the 4 neigboughrs, SUM-E_t (current RCT method)

Combining e/γ with tracker stubs: 2-Stacks

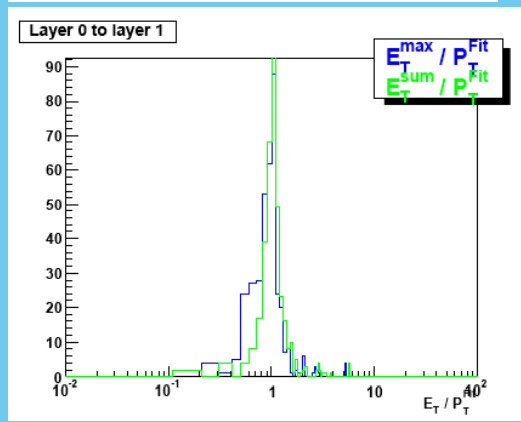
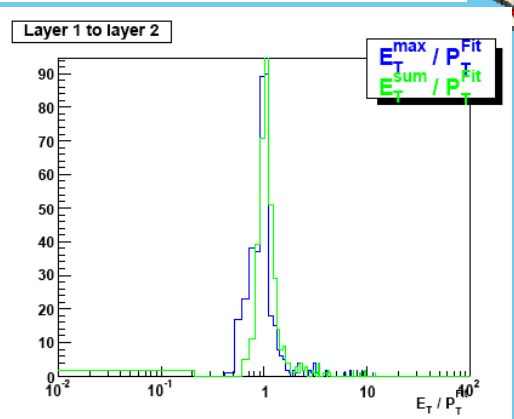
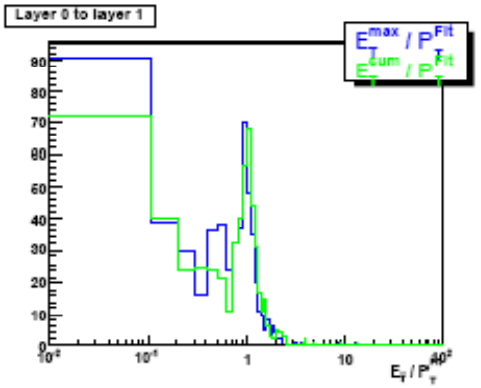
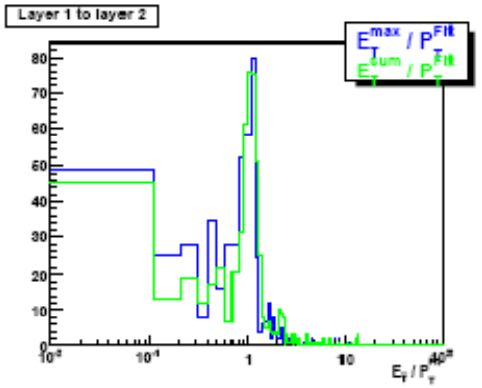
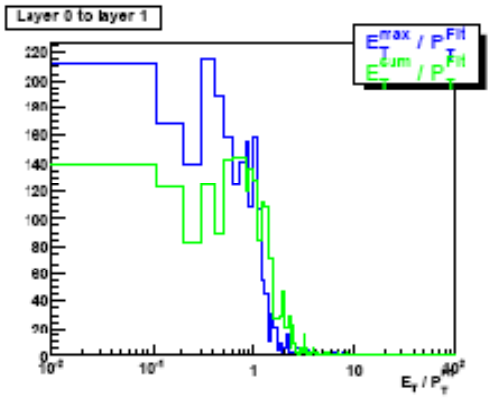
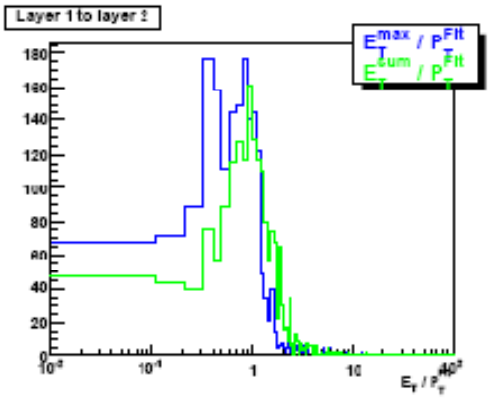
- **Method:**
  - Use single electron events and different number of pile-up events (0, 20, 200).
  - Use stubs in two different stacks and fit for a helix to crate a tracklet
  - Extrapolate the tracklet to the calorimeter and compute the calorimetric energy deposition using two methods:
    - Electron energy is the energy of the maximum tower (E_T^{max})within a window from the impact point (less sensitive to pileup)
    - Electron energy is the energy of the maximum tower plus the highest SUM-E_t of the 4 neigboughrs (current RCT method)



Combining e/γ with tracker stubs: 2-Stacks



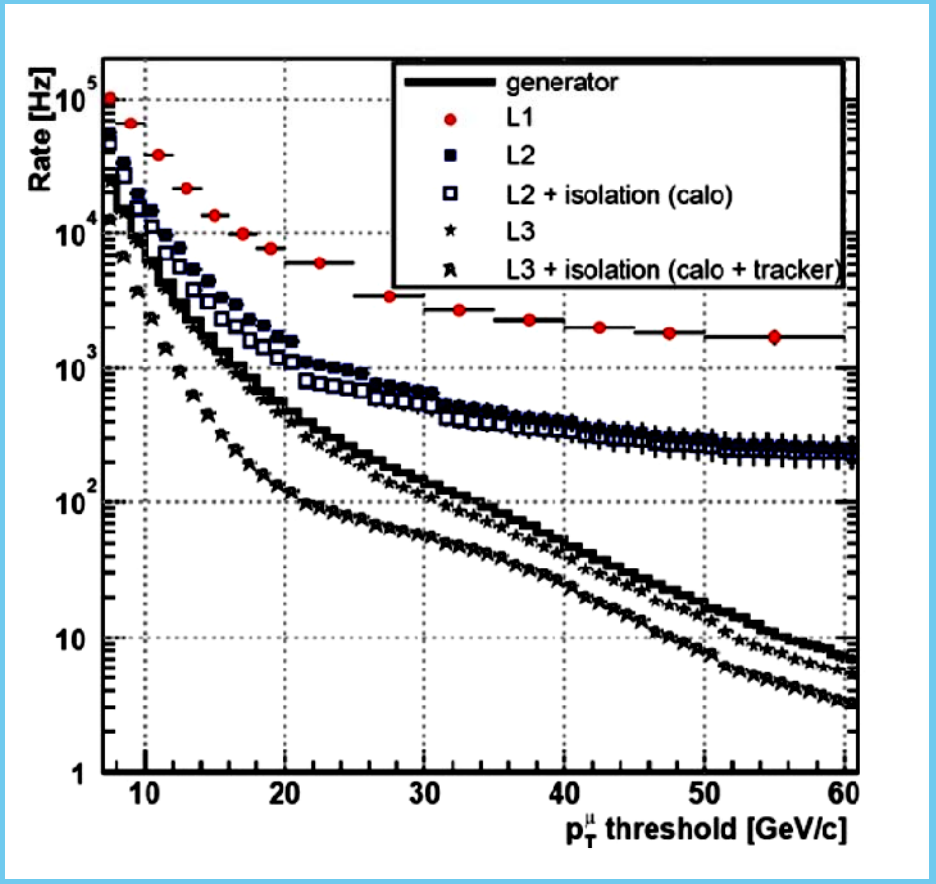
- Without pileup the method works and Sum-Et is better.
- As pileup increases evidence of incorrect extrapolation appears at zero Et.
- Detectors placed far apart in R perform better.
- Calorimeter energy also suffers from pileup

	2 Stacks at 34 – 38 cm	2 Stacks at 38 – 50 cm
0 PU - Check		
20 PU LHC		
200 PU SLHC		

A. Rose,
C. Foudas (Imperial)

Muon Triggers

Level	Rate (Hz) Single	Double
Level-1	6200	1700
Level-2	700	35
Calo isolation	590	25
Level-3	100	10
Level-3+calo +tracker isolation	50	5
Total	55	



- Large Factors to be gained also for muons.
- Outer tracker subs may be important here.

Correlating Muon/Tracking Trigger data

P. Zotto

Muon rates at 10^{35} cm^2s^{-1}

The muon trigger rates at the LHC p_T thresholds will largely exceed the reserved 12.5 kHz rate bandwidth.

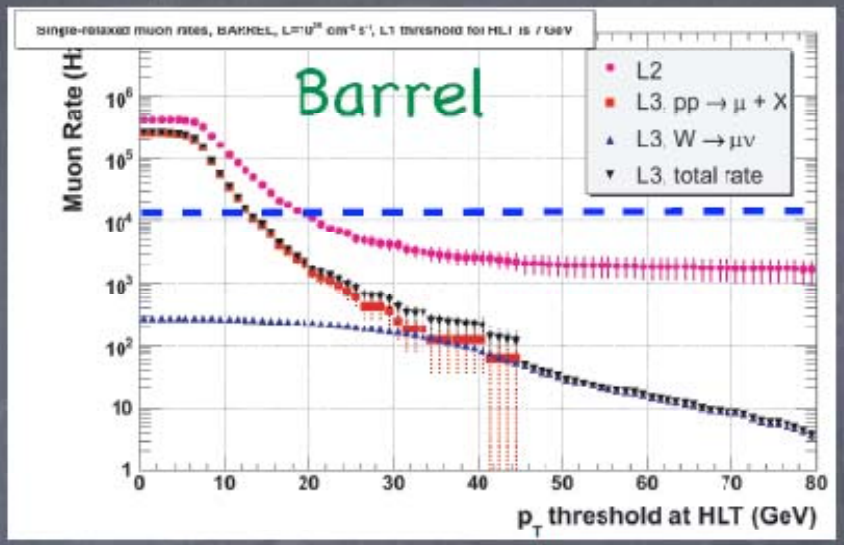
This is not due to the true muon rate, but rather to insufficient p_T resolution allowing high p_T assignment of low energy muons

The solutions are an increase of the threshold or a resolution improvement.

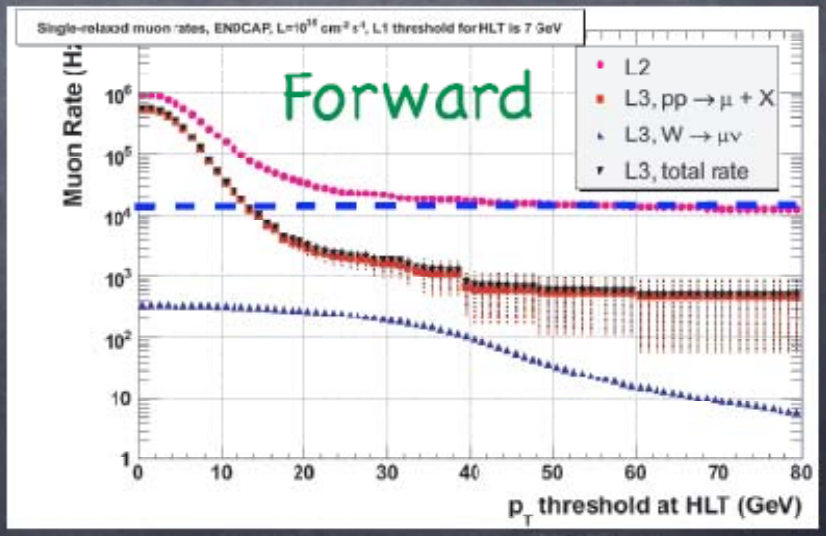
Increasing thresholds is unacceptable.

Simulation of HLT trigger algorithms at SLHC luminosity shows that even using the full detector resolution will be barely sufficient for the barrel and still insufficient for the forward detectors.

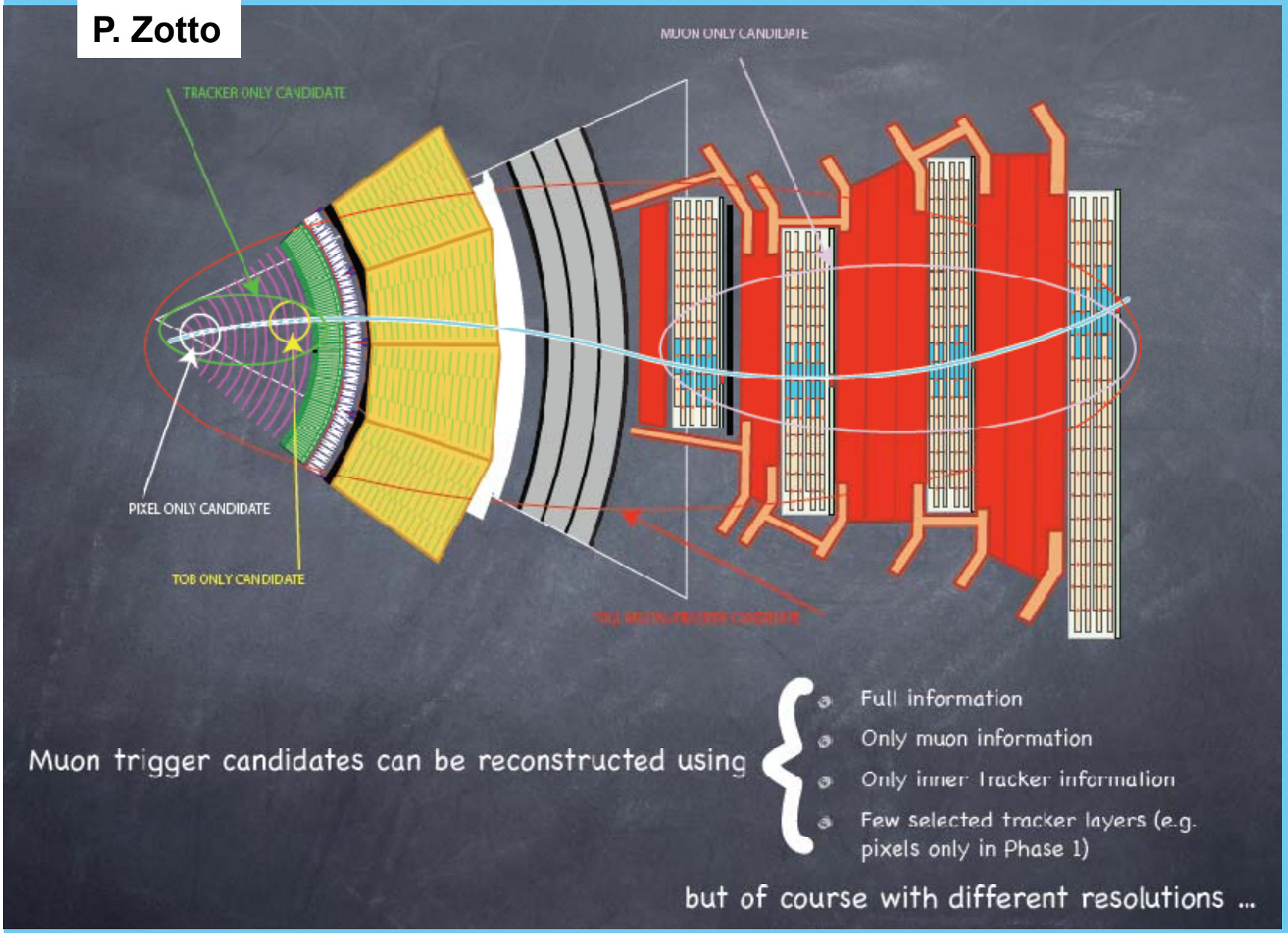
Hence the only possibility for a sensible resolution improvement is providing access to the Tracker hits



FROM J. ALCARAZ



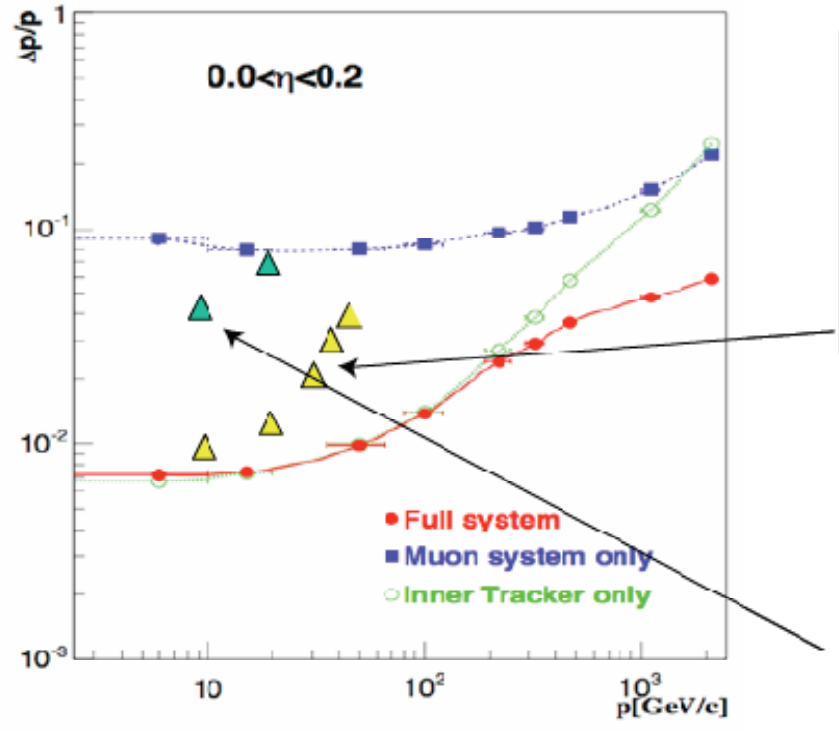
P. Zotto


MUON ONLY CANDIDATE
TRACKER ONLY CANDIDATE
PIXEL ONLY CANDIDATE
TOB ONLY CANDIDATE
Muon trigger candidates can be reconstructed using
Full information
Only muon information
Only inner Tracker information
Few selected tracker layers (e.g. pixels only in Phase 1)
but of course with different resolutions ...

Improved Resolution using tracker data

P. Zotto

Achievable resolutions



fit of 2 points (in two TOB layers) and the vertex constraint, strip pitch of 200 μm

Radius (cm) of two layers	Δ Pt / Pt (%) for different Pt (GeV/c)				
	10	20	30	40	50
61.0-108.0	0.8	1.1	1.6	2.1	2.6
61.0-86.8	1.1	1.8	2.8	3.5	4.4
86.8-108.0	0.9	1.5	2.3	3.0	4.0

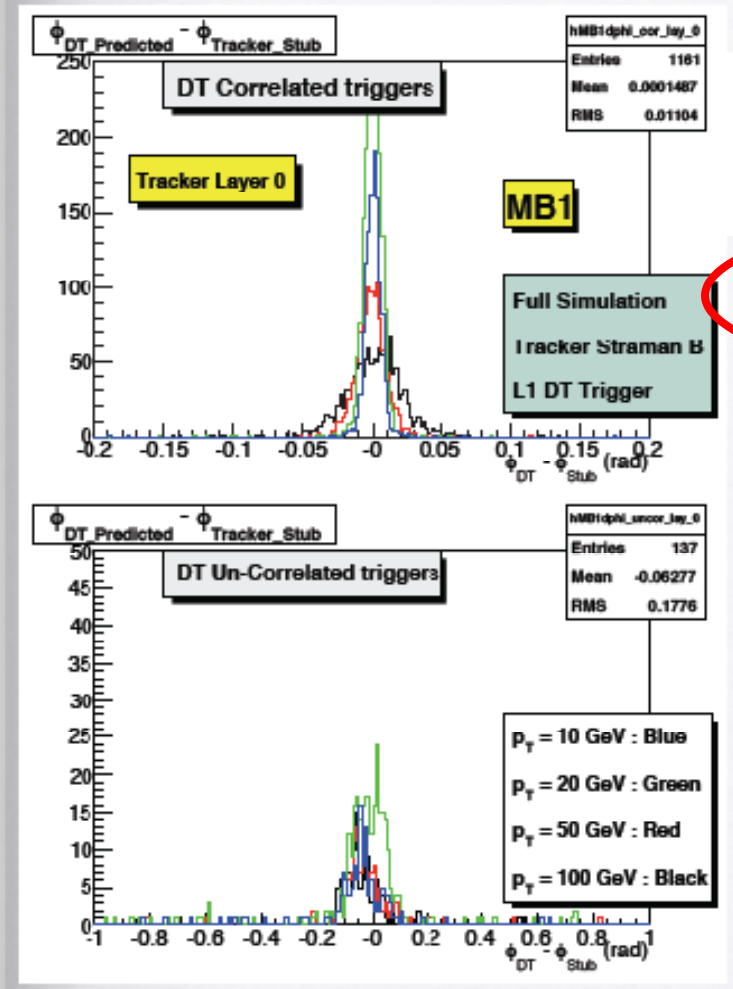
Radius (cm) of 3 layers: 4.4, 10.2, 25.0
No vertex constraint

Pixel pitch	Δ Pt / Pt (%) for different Pt (GeV/c)	
	10	20
100 μm	7.5	14.5
50 μm	4.3	7.2
20 μm	2.7	3.2

Partial Tracker information (even pixels only with digital readout) could provide a rate reduction already at Phase 1

FROM BOLOGNA GROUP: G. ABBIENDI, C. BATTILANA, A. MONTANARI, A. PERROTTA

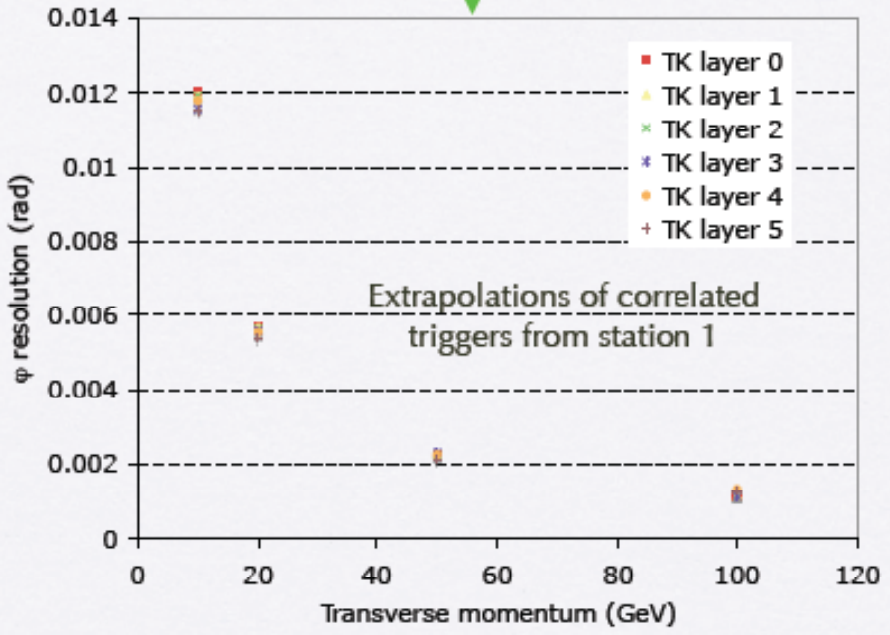
Extrapolation: φ dependence on TP quality



Search in two possible tracker layers position
R = 25 cm
R = 35 cm
and compute windows for DT station 1 position

p_T (GeV)	$\Delta\eta$	$\Delta\varphi$ (degrees)	
		MTT	DTTF
10	±0.114	±14	±7
12		±11.5	±5.5
15		±9	±4.5

φ resolution is independent of tracker layer
(is tracker material description realistic?)



Summary and Outlook

- We finally have some critical mass and a plan in the trigger group.
- Optimizing the stacked tracking detector is under way:
  - Electron and Muon trigger studies with tracking information are progressing well.
  - Need to optimize the algorithms and take in to account the new HCAL design (work started on this but no results yet)
- Calorimeter based trigger studies for taus are at an advanced stage.
  - Need to understand the taus in the calorimeter first before introducing tracking
- A considerable amount of work is still needed to optimize pixel-sizes, radii and in general detector configurations.

- We should have results before the July-09CMS trigger workshop which should give a strong indication as to which tracker design is optimum for triggering.