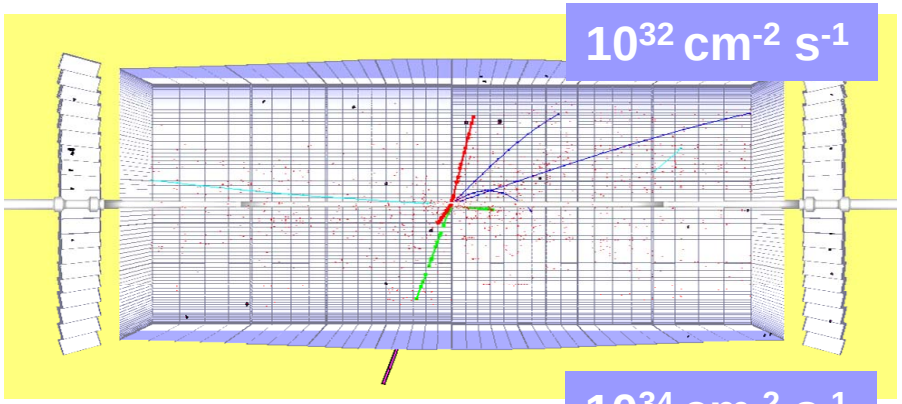
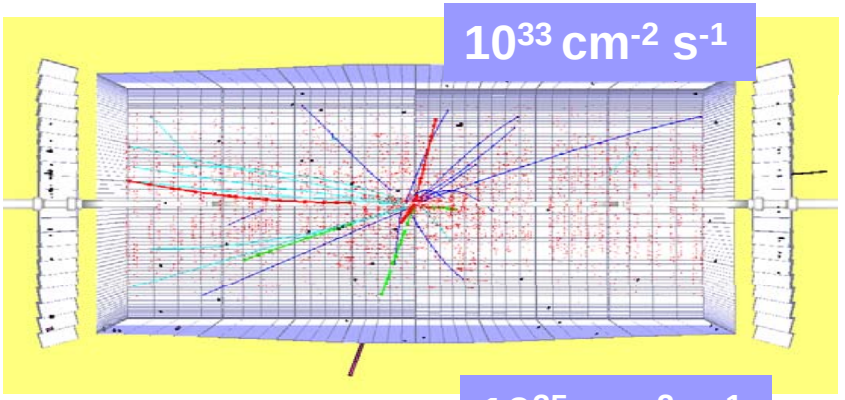
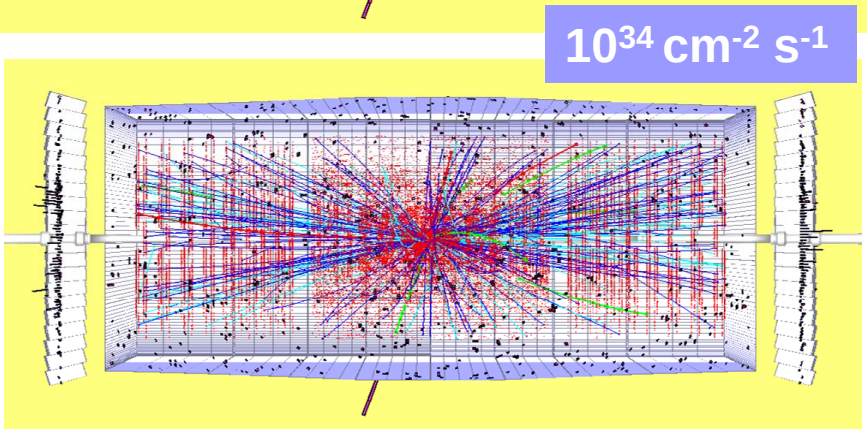
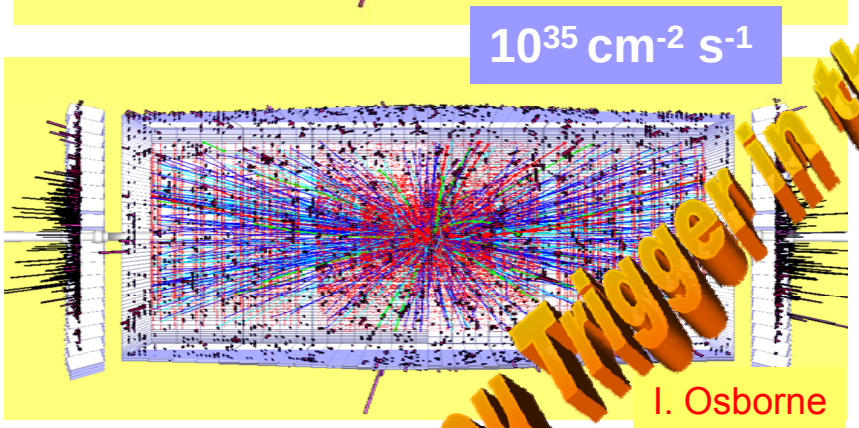
Lv-1 Tracking Triggers with CMS at SLHC









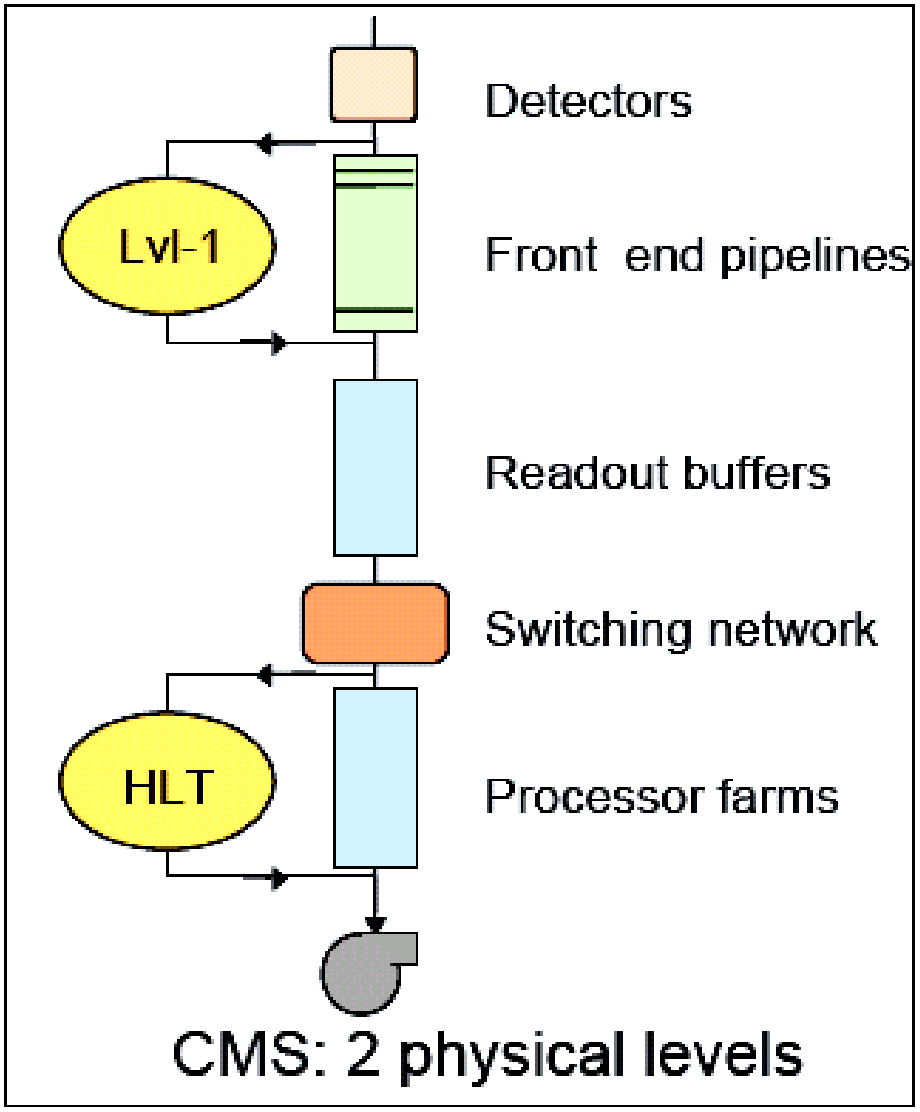
Outline:

- **The CMS Lv1 Trigger System**
- **Trigger Rates at SLHC**
- **Tracking Trigger Upgrades**
- **Organization and Plans**

Minimum Bias Events

- SLHC (10^{35} ; 80 MHz): 110
- **SLHC (10^{35} ; 40 MHz): 220**
- SLHC (10^{35} ; 20 MHz): 440

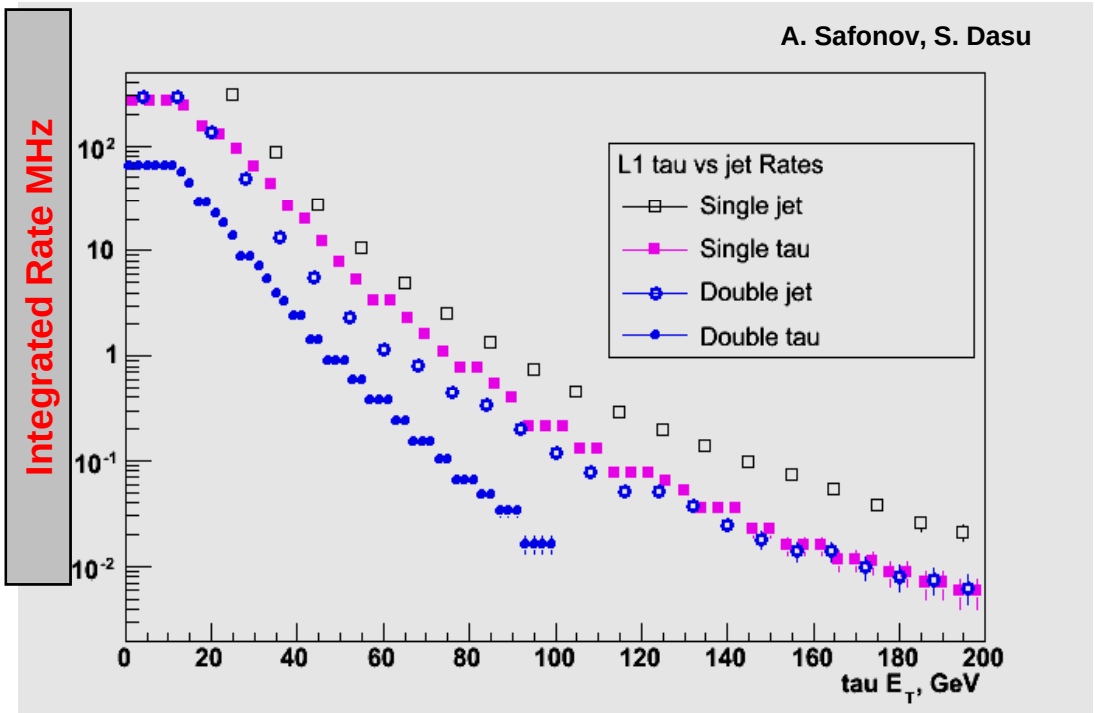
The Current CMS Lv1 Trigger

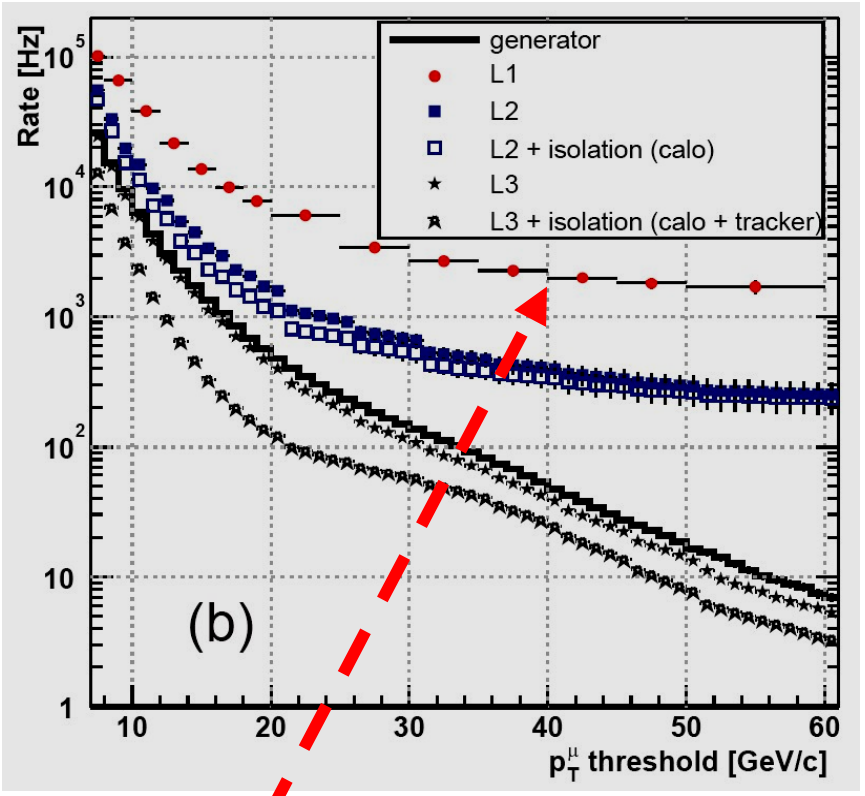


- 40 MHz Lv1 input rate
- 100 KHz Lv1 output rate
- 3.2 μsec latency
- Event Size 1-2 Mbytes
- Level-1 Trigger: Custom made hardware processor using data from the calorimeter and muon systems.
- High Level Trigger: PC Farm. Uses data from the calorimeter, muon as well as the Si-Trackers. Reconstruction software and event filters similar to the offline analysis.

Trigger Rates at SLHC

Jet and τ-triggers at SLHC

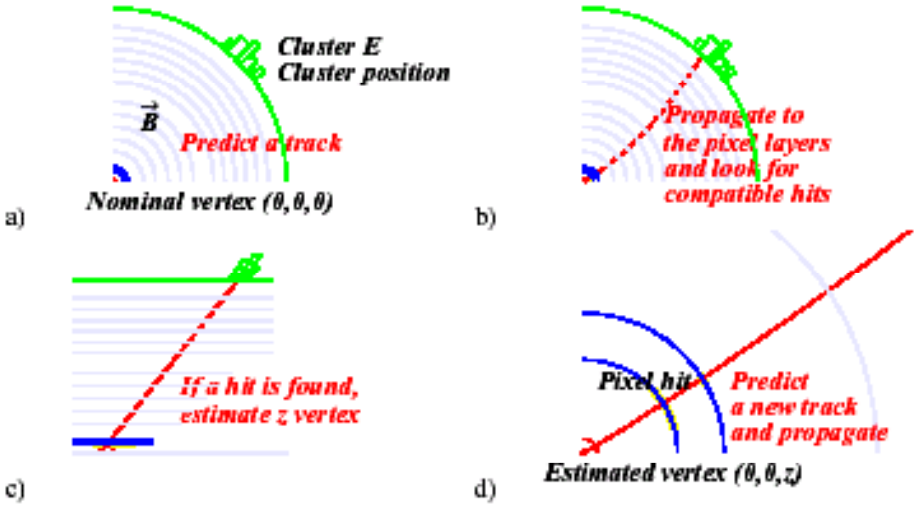


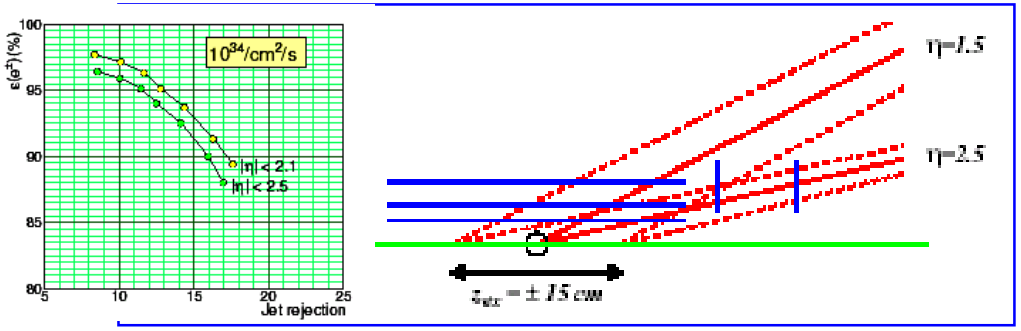


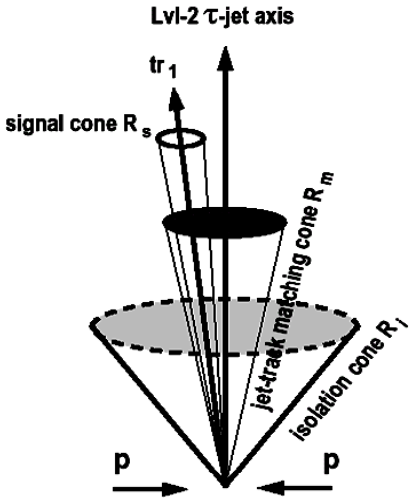
- At SLHC Electron, tau, muon and jet triggers will fire in the 10^6 Hz region (LHC Thresholds)
- Keeping the same thresholds as at LHC may be desirable if one wants to study possible LHC signals with more statistics.
- Even if one wished to raise threshold it would not help as shown here in the muon trigger case.

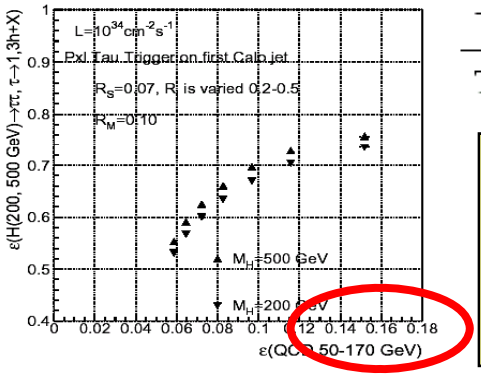
What is to be done ??

Getting Trigger Ideas for SLHC from the CMS HLT









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	

- **Muon Trigger:**
  - Outer tracker
  - Large rejection

Efficiency for QCD events

- **Electron Triggers**:
  - A factor of 10 reduction using hits in the pixels
  - A factor of 3 using the outer tracker

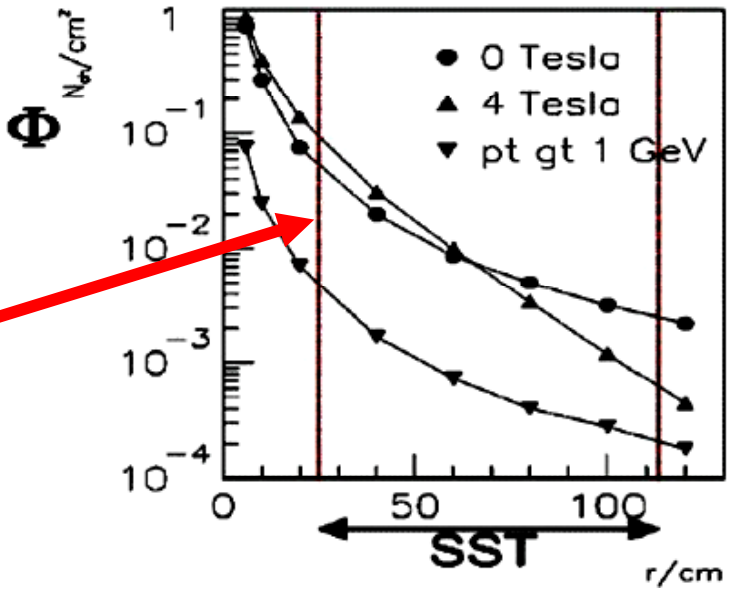
- **Tau Trigger:**
  - Uses isolated stubs in the pixels
  - A factor of 10 in QCD jst rejection

Triggering Challenges at SLHC

R (cm)	Hits/ bin in plateau	Hits /bin /event	hits/bin /electron	Occup. (2×10^{33}) hits/cm^2/ 25 nsec	Occup. (1×10^{35}) hits/cm^2/ 12.5 nsec
4	2500	0.250	0.0625	0.35	8.8
7	1100	0.110	0.0275	0.15	3.8
10	650	0.065	0.0162	0.09	2.3

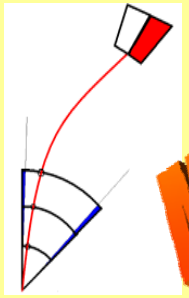
Occup. (10^{35}) hits/cm^2 / 25 nsec
17.6
7.6
4.6

- Expected data rates from the Inner tracker are very large resulting to ~10^1 TBytes/sec/cm^2
- This rate needs to be reduced on the detector.
- 90% of the rate comes from particles below 1 GeV in Pt



Proposals/Ideas for Tracking Trigger

- **Stacked Tracker:**
  - Coincidences between two layers of pixels placed ~ mm apart.
  - Amounts to a low Pt cut.
  - Advanced FPGAs on uTCA cards execute off detector algorithms.
  - Requires sophisticated electronics on Si-Tracker
- **Selective Readout:**
  - Requires identification of objects first with the calorimeter/muon triggers
  - Extrapolation and readout only of the relevant sections of the Si-Tracker
  - Latency could be a problem
- **Associative Memories:**
  - Relies on cluster width to reduce the data on detector
  - Associate memories are used to process the data off detector



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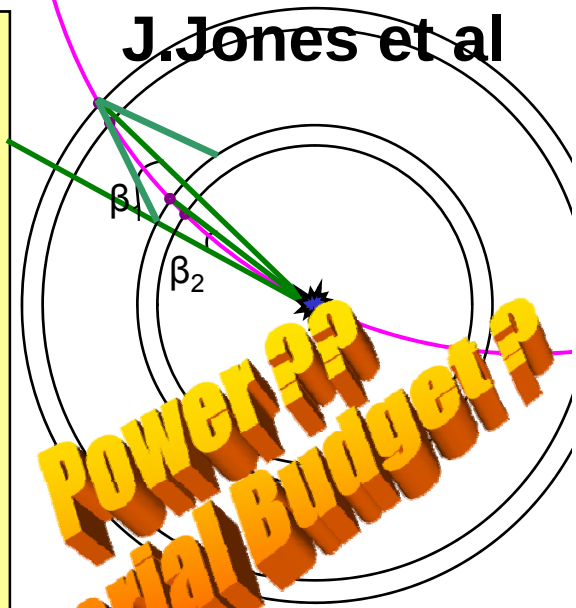

Power ??
Material Budget ?

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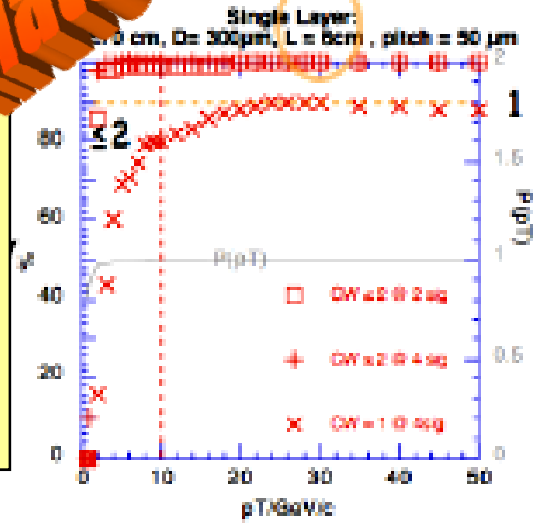
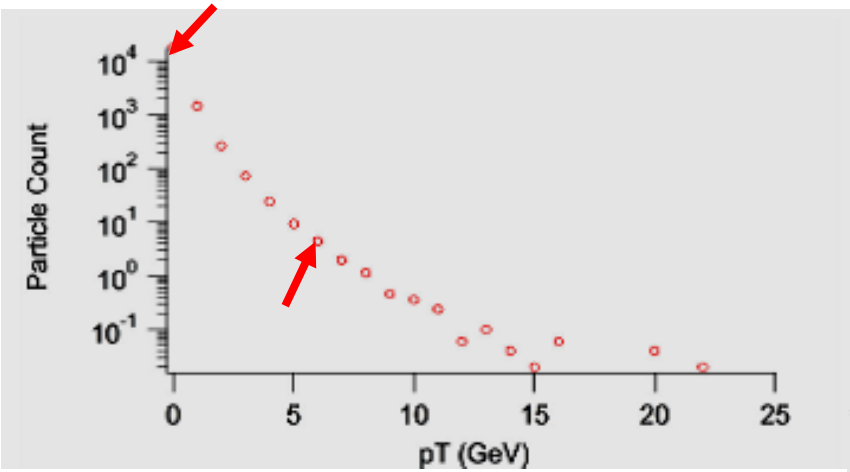
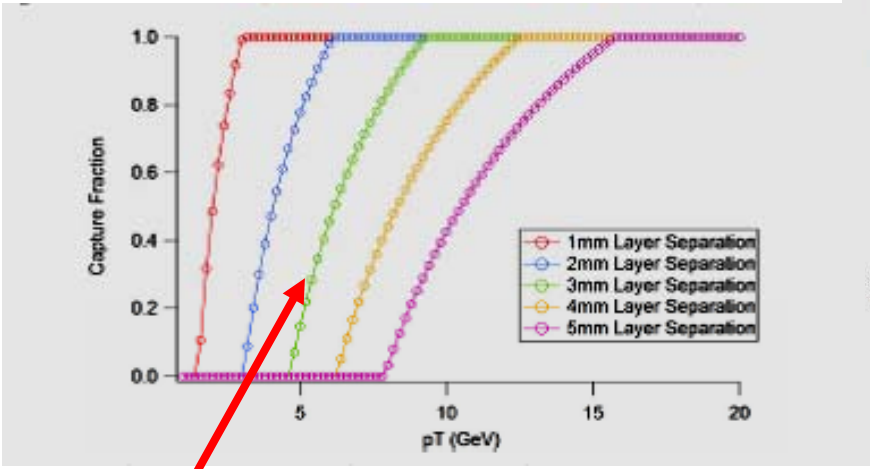


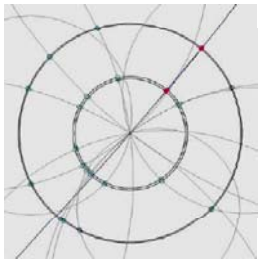
Example: Stacked Tracker Approach

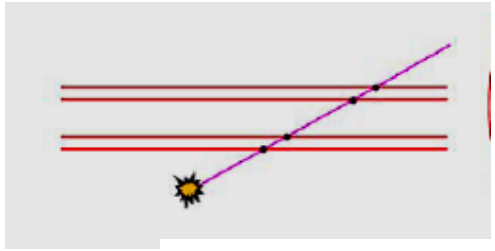
Singe Stacked Detector

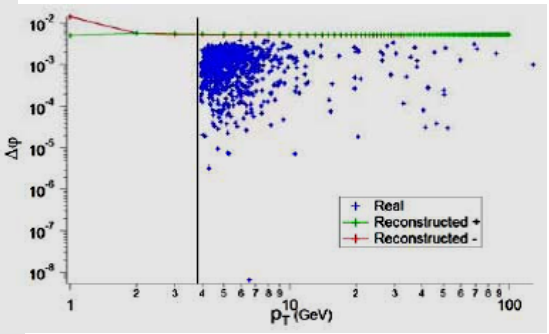




Double Stacked Detector







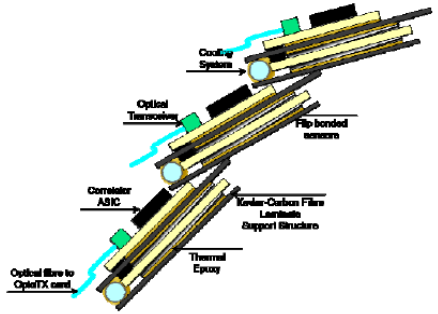
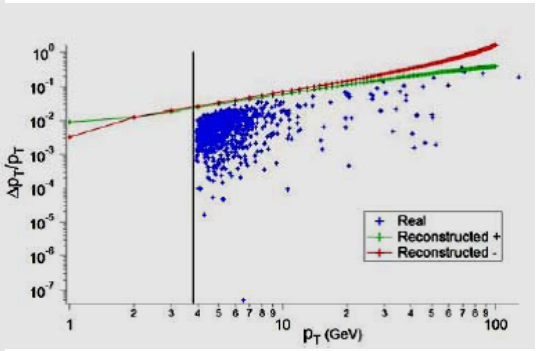
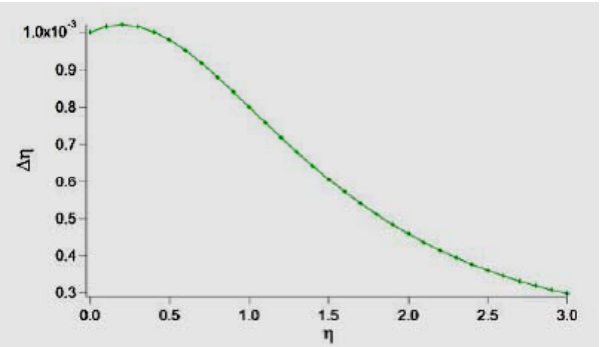


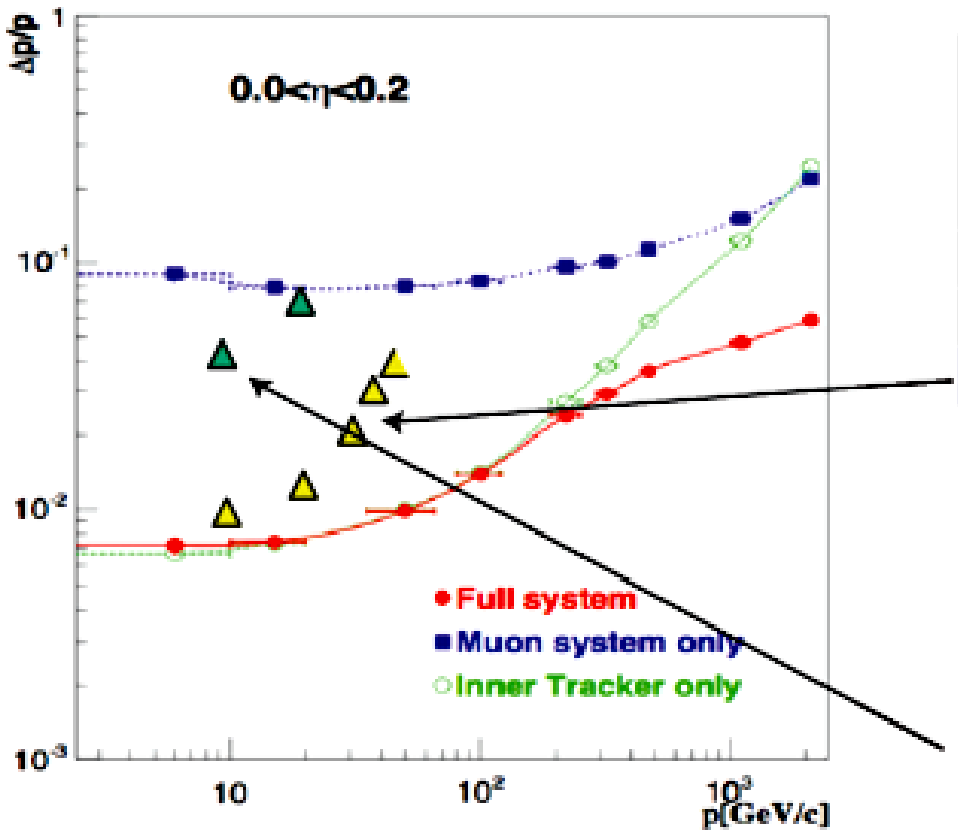
Figure 8: Possible detector structure for a stacked pixel array





- **A 2 mm separation cuts Pt<5 GeV**
- **Double Stack would allow extrapolations to the calorimeter and muon systems**

Improving the Resolution of the CMS Muon System



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

- **The CMS muon system trigger resolution will improve dramatically if one includes information from the Si-Tracker**

Off-Detector Electronics for SLHC

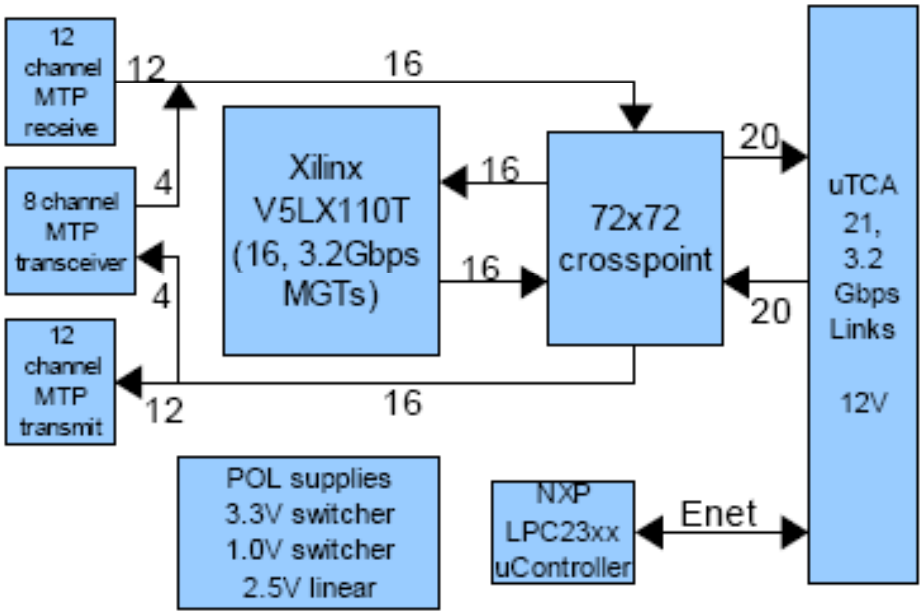
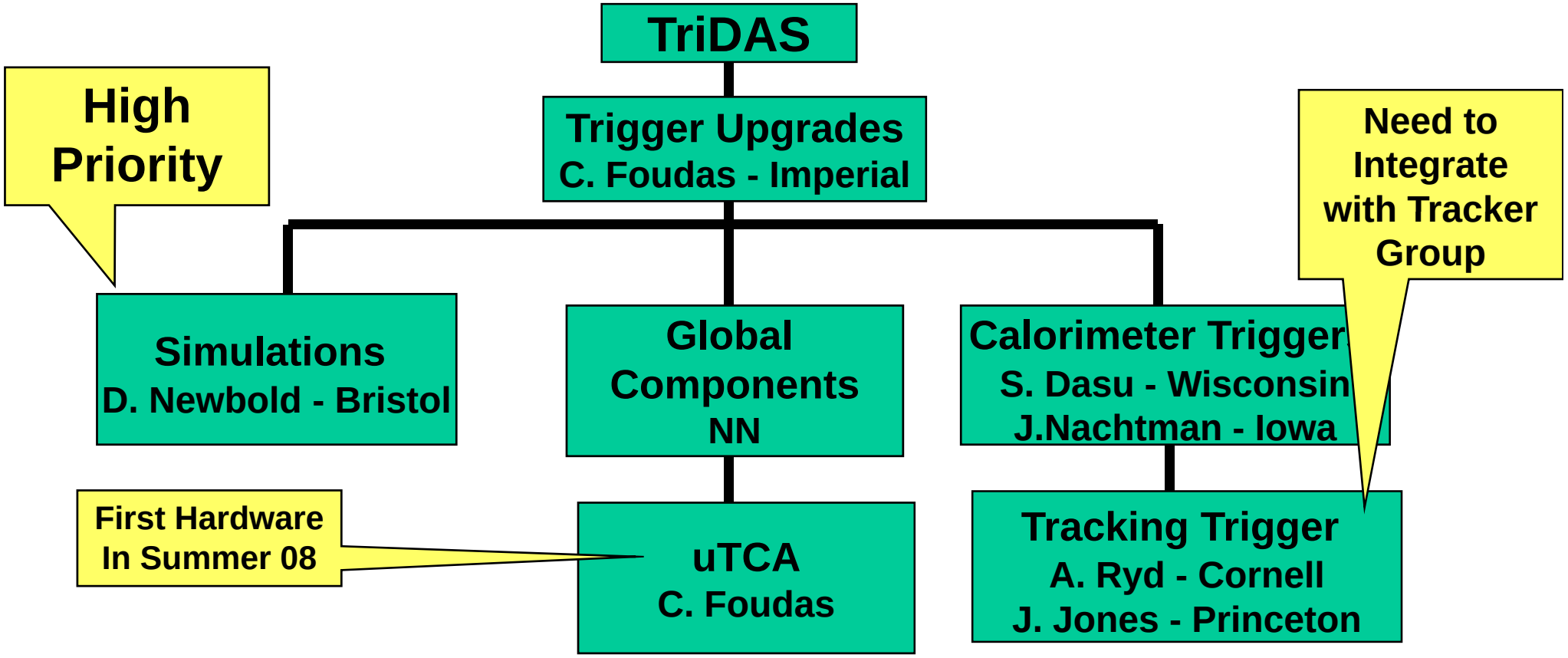


Figure 2: Processing module block diagram

Figure 1: micro TCA crate with single high backplane

- **A standard trigger platform is under development based on the uTCS telecom Standard.**
- **This platform is designed to accept data from different detectors to support a Lv1 tracking trigger.**
- **We wish to investigate the question whether this platform can replace all Lv1 trigger off detector electronics and become a CMS-wide standard.**
- **This would reduce significantly manpower and R&D costs**

CMS SLHC Trigger Project



- May 21st workshop signalled the start of the project
- First results should come during a planned workshop this fall.

Summary

- CMS has an active group to pursue future Lv1 Trigger upgrades.
- Simulation Studies have already started in collaboration with the tracker upgrades group and this is a priority at the moment.
- Hardware demonstrators in uTCA will be available soon and may be useful in LHC also.
- An enormous amount of work is ahead of us…