Geometry Implementation for CMS Tracker at SLHC

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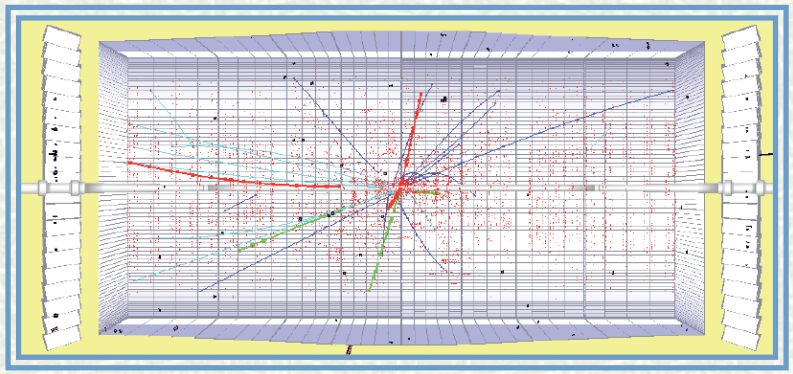
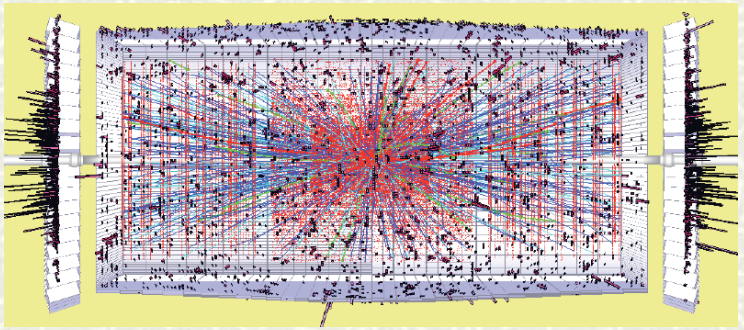
Outline

- Simulation group priorities
- Trigger Layer
- Stawman 0
- Strawmen A & B, and Long Barrel
- Status of move to 2_2_3
- Converging with detector hardware group
- Plans for the immediate future and goals

Accelerator Upgrade Plan

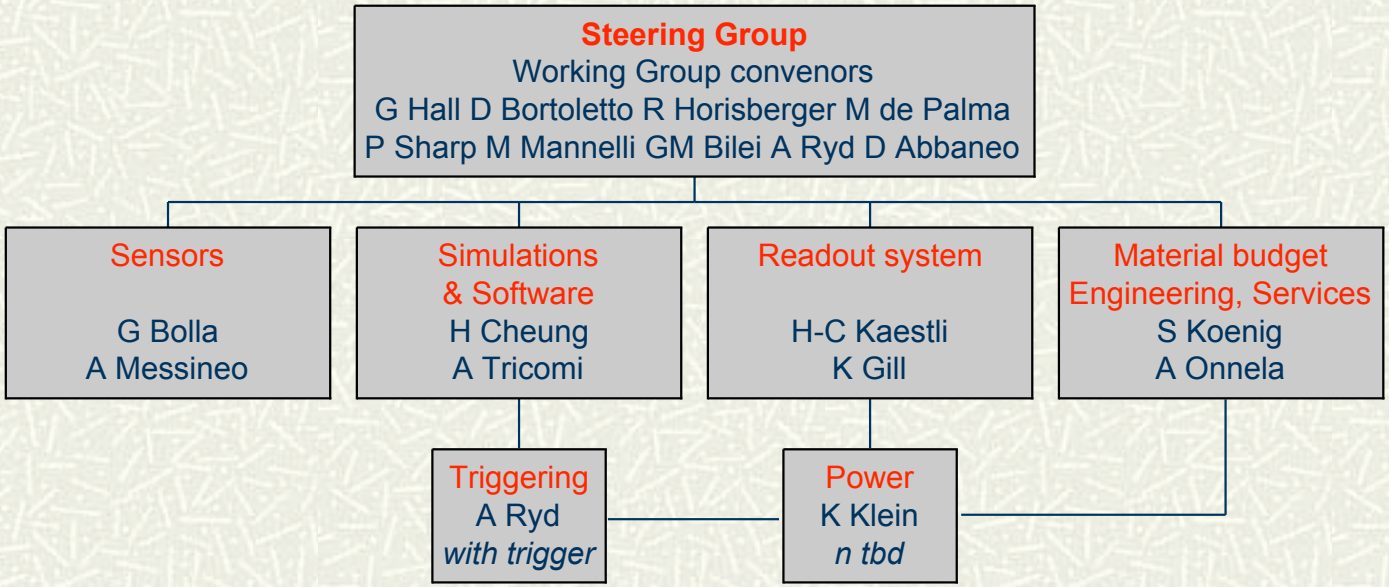
- Done in two phases
- Phase 1
  - Upgrade luminosity to $2x10^{34}cm^{-2}s^{-1}$ by 2013
  - Able to replace Pixel Detector at this point
- Phase 2
  - Increase luminosity to $1x10^{35}cm^{-2}s^{-1}$ by 2018
  - Replace entire Tracker
  - Would go from 20 pileup events at 10^{34} to ~200
  - Need tracker information to be included in trigger





SLHC Simulations Task

- https://twiki.cern.ch/twiki/bin/view/CMS/SLHCTrackerSimuSoftTools
- Group's Mission is to do the simulations studies to help design a new tracking system
- Coordinators
  - Harry Cheung (FNAL) and Alessia Tricomi (Catania)
- Technical meeting every Monday at 10am [Fermi]
- General meeting every 1-2 months at CERN
- Priorities
  - Perform studies and to provide input to other WG



Current Group Priorities

Simulation Studies

- Whether a (buildable) trigger stack would work, how many we need, where it (they) would go in radius, and what should the pixel stack parameters be (granularity and separation)? Does the stack idea work for the forward region?
- An extra 4th barrel pixel layer (and 3rd pixel disk) for both Phase 1 and 2.
- If a realistic strawman A has as good of a tracking performance at high pileup (10^{35}) as the standard CMS geometry at design pileup (10^{34}). Studies of the forward region should be included.
- If a realistic strawman B has superior features compared to strawman A. Studies of the forward region should be included.
- The viability of a very long barrel mini-strip or strixel layers.
- Roland's option 1 to 4 for Phase 1 (discussed later).
- The tracking performance for the standard CMS geometry at Phase 1 luminosities ($2x10^{34}$).
- Investigate the effect of other L1 tracking trigger ideas on the tracking system geometry.

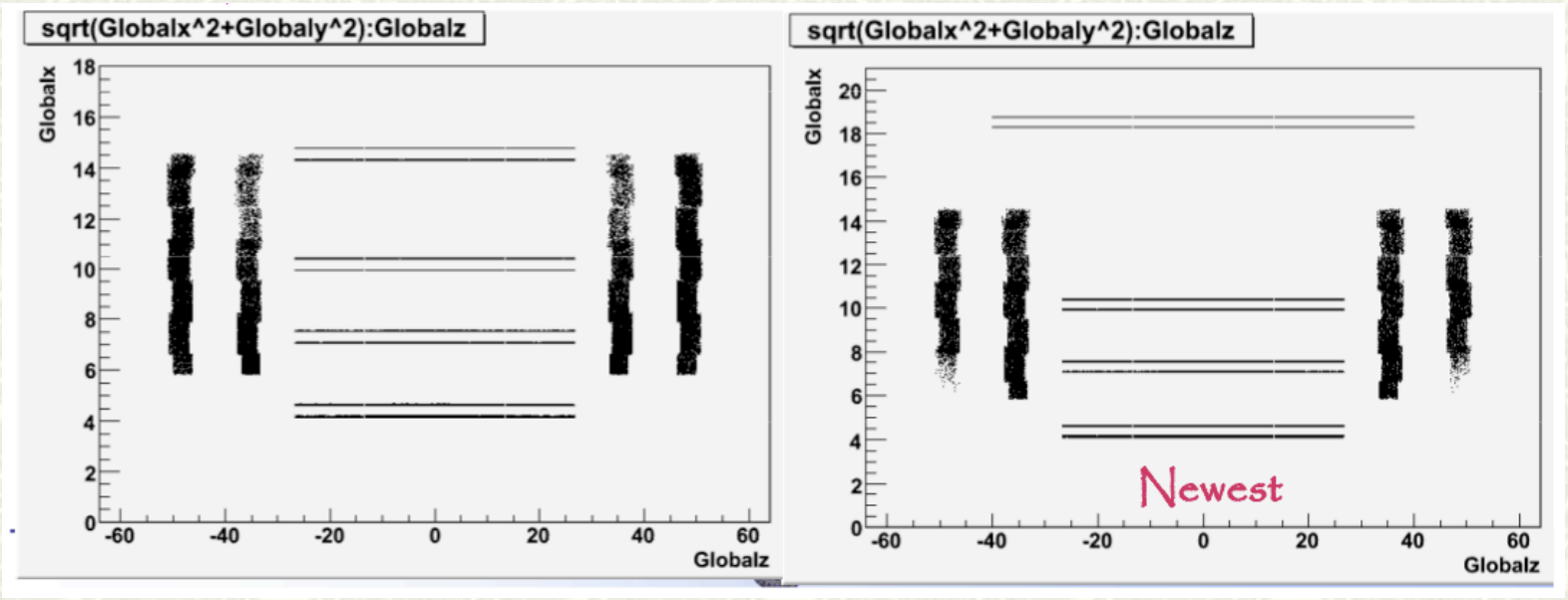
Group Priorities Continued

Simulation Software and Performance Benchmark Tools

- Create a set of performance benchmarks or plots for comparisons of tracking and trigger performance for studies of different tracking system geometries.
- Continue to develop code for the two strawman geometries and baseline tracking geometry.
- Create interface code for use by the trigger group to create L1 track trigger primitives.
- Work on making the pileup simulation for the FastSimulation more realistic (e.g. include out-of-time pileup as needed) to address the differences between the FastSimulation and the Geant simulation, e.g. occupancies, fakes rates.
- Work on remaining parts that are needed to simulate in the FastSimulation all the L1 objects that are needed for studies, e.g. ECAL objects.

Strawman0 for Phase 1

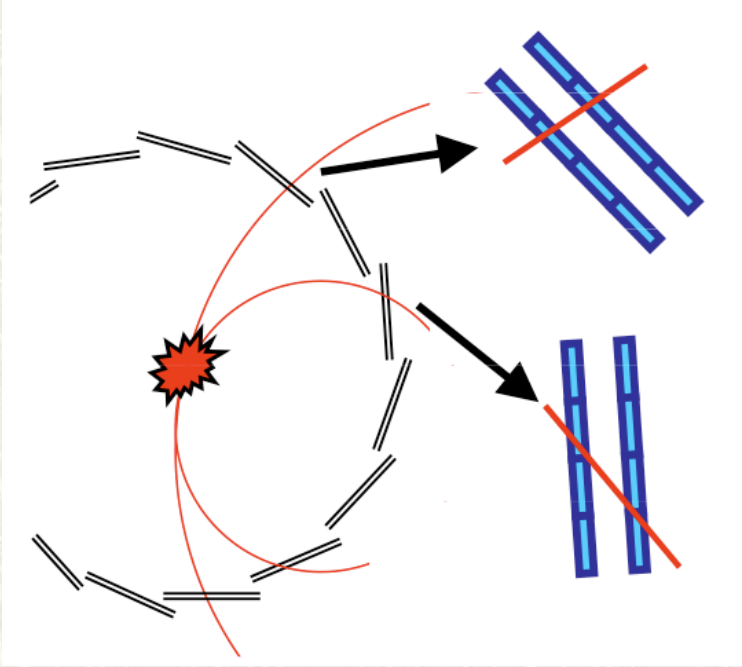
- Carlo Civinini (Firenze), Alessia Tricomi (Catania). Only change is to have 4 inner pixel layers
- No change in the forward pixel disks for the moment
- Original Layer 4 placed at R = 14.5, now moved to 18.5 cm
- Can now run in 2_2_3 with single muon gun over full simulation



Pt Layer for Triggering

- Proposal to allow trigger from Tracker
  - Currently studying for realistic simulations and detectors
- Use geometry of stack layer hits to cut out low Pt tracks

•Current Strawmen use layer separation of 1-5 mm
•Matching code needs to correct for position of the track in the sensor and tilt of sensor to get matching correct



Interface to Trigger

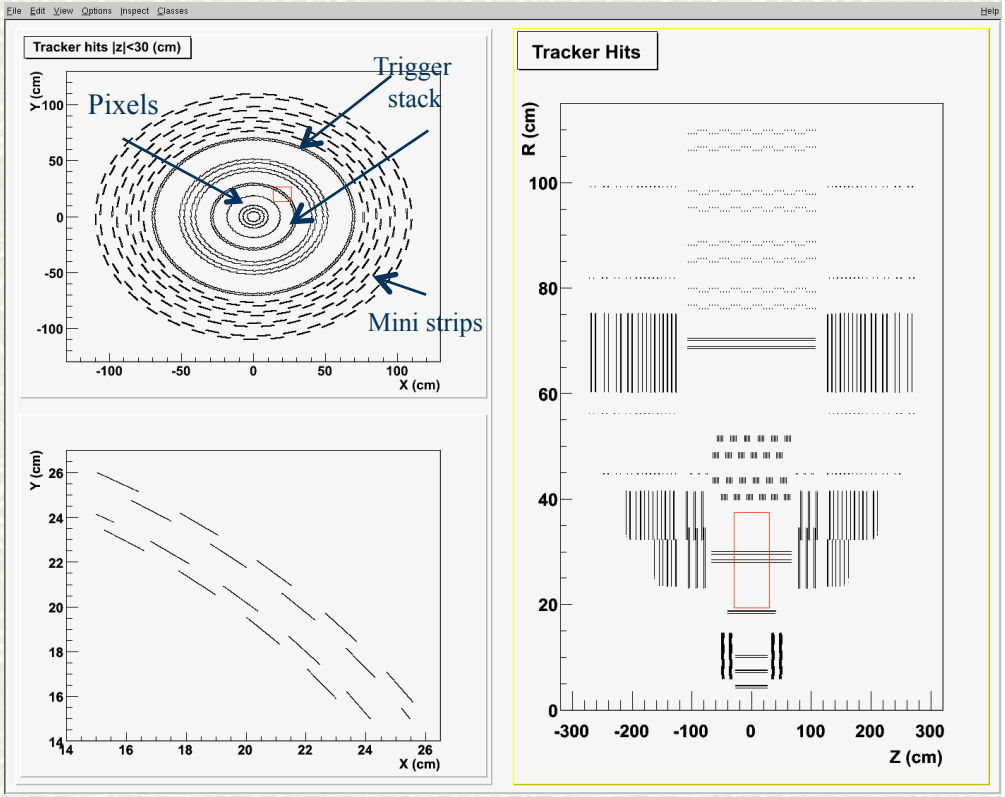
- Working with trigger upgrade group
- Will provide the tracker TPGs to allow testing of SLHC trigger in simulation
- New data formats are in place
  - Trigger hit similar to digi
    - Created separately to allow for changes in algorithm
  - Trigger stub
    - Vector of hits in stack

Strawman Proposals for Phase 2

- Set up Strawman Geometry as starting point for studies
- Not intended to be a final proposal, but a framework to allow modifications
- Are ready to be used in Full or Fast Simulation in CMSSW_1_8_4
- Very configurable
  - Size of pixels and strixels
  - Position and number of layers
  - Ladder length, pitch…
- Instructions on Webpage on how to
  - remove layers
  - add layers
  - add long layers
  - add strip layers with short strip length
- We are encouraging people to use the strawman geometries already set up and the configurability to setup what they want

Strawman A

- Modification of standard geometry
  - 4 inner pixels
  - 2 TIB strixels
  - 2 TIB short strips
  - 2 TOB strixels
  - 4 TOB short strips
- Very configurable
  - Currently being modified to allow for a more reasonable number of channels
- Instructions for CMSSW_1_8_4:
  - https://twiki.cern.ch/twiki/bin/view/CMS/ExampleStrawmanA
- Not realistic due to number of channels
  - Modifications are coming



Use strixels at trigger layer

Number of Strawman A Channels

- Need to reduce number of channels to more realistic amount
  - Reduce trigger stacks radii
  - Reduce mini-strip layers
  - Remove outer trigger stack
  - Add in standard TOB Stereo layers
  - Third forward disk added
  - Stereo ministrips in TOB 1 & 2

Original Geometry	Active Surface [cm2]	# ROCs	# channels	# modules
Barrel - Pixels (PXB)	7558.26	11520	47923200	768
Endcap - Pixels (PXF)	2834.36	4320	17971200	672
Barrel - Strips (TIB + TOB)	1103896.7	38160	4884480	7932
Endcap - Strips (TID + TEC)	902046.7	34624	4431872	7216

Strawman A	Active Surface [cm2]	ROCs	# channels	modules
Barrel - Pixels (PXB)	251522.3	79552	330936320	24240
Endcap - Pixels (PXF)	2834.4	4320	17971200	672
Barrel - Strips (TIB + TOB)	616886.2	85968	11003904	18132
Endcap - Strips (TID + TEC)	902046.7	34624	4431872	7216

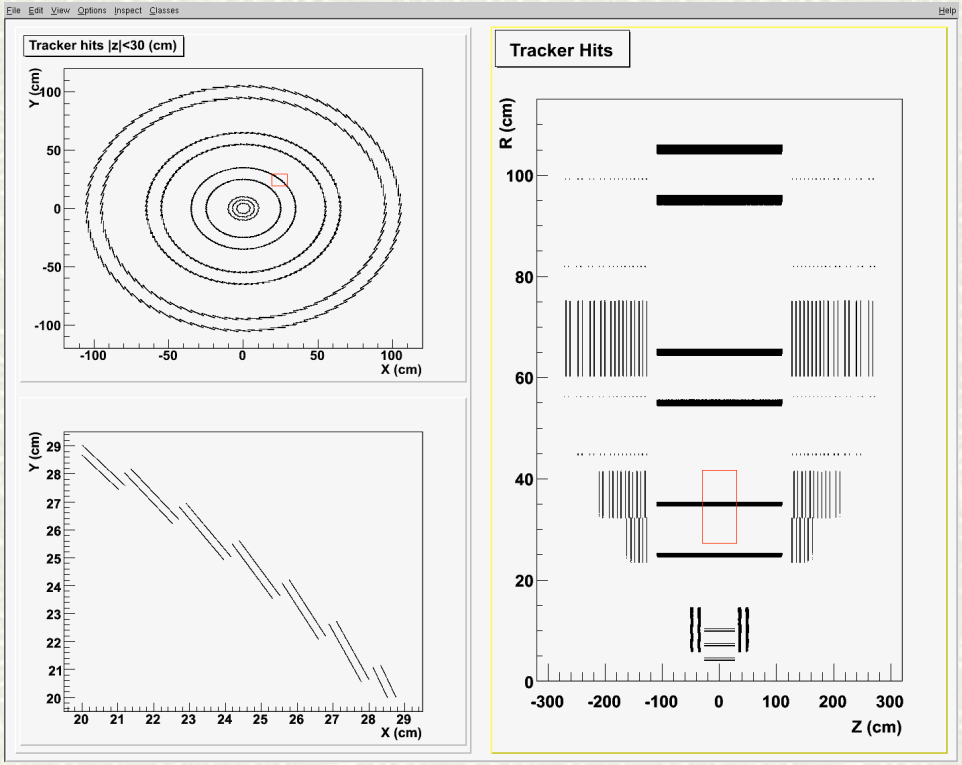
Realistic Strawman A	Active Surface [cm2]	# ROCs	# channels	# modules
Barrel - Pixels (PXB)	58030.73	41408	172257280	5680
Endcap - Pixels (PXF)	2834.36	4320	17971200	672
Barrel - Strips (TIB + TOB)	829242.6	72288	9252864	14712
Endcap - Strips (TID + TEC)	902046.7	34624	4431872	7216

Strawman A Status

- The modified algorithm which are necessary to sim-digi-reco the strawA have been ported into 2_2_3 and checked with the standard geometry
- The xml files have been moved to 2_2_3 (without modifications)
- The pixel part of the geometry is working for the full chain
  - (gen-full sim-digi-reco-valid)
- Working is ongoing for strips
- When full sim is completed the fast sim part will be implemented

Strawman B

- TIB and TOB replaced with 3 stacked doublets
- Each doublet consists of two stack layers
- Can use correlations within stacks to make further trigger selections
- https://twiki.cern.ch/twiki/bin/view/CMS/ExampleStrawmanB



Number of Strawman B Channels

Layer name	Mean Radius (barrel) [cm]	Min. Radius (endcap) [cm]	Max Radius (endcap) [cm]	Layer half-length (barrel) [cm]	Mean z position (endcap) [cm]	Sensitive surface [cm2]	# ROCs	# channels
PXB1	4		0	27		1,512	2,304	9,584,640
PXB2	7		0	27		2,519	3,840	15,974,400
PXB3	10		0	110		75,227	81,920	26,214,400
PXB5	35		0	110		105,318	114,688	36,700,160
PXB6	55		0	110		174,288	90,112	28,835,840
PXB7	65		0	110		205,976	106,496	34,078,720
PXB8	95		0	110		308,632	77,824	24,903,680
PXB9	105		0	110		448,457	86,016	27,525,120
Tot Layer 1-9						1,321,929	563,200	203,816,960
Tot Layer 4-9						1,317,898	557,056	178,257,920

Strawman A	Active Surface [cm2]	ROCs	# channels	modules
Barrel - Pixels (PXB)	251522.3	79552	330936320	24240
Endcap - Pixels (PXF)	2834.4	4320	17971200	672
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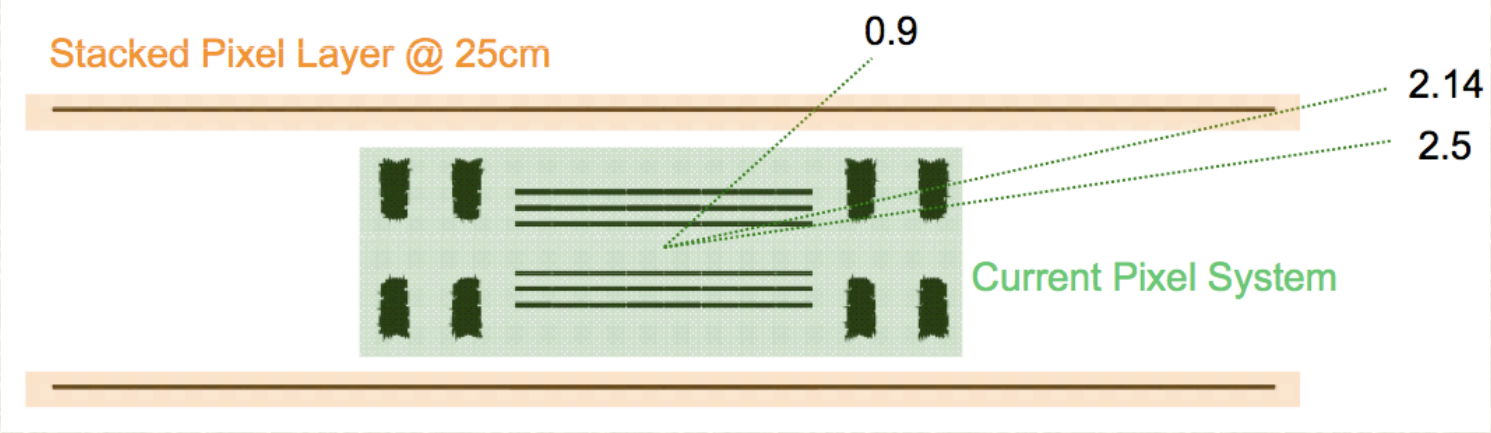
StrawB in single stack studies

Mark Pesaresi (Imperial College)

- Use StrawB geometry as a starting point to study single stack layer for trigger
- Single layer at r=25cm, length=221cm
- Ignore outer geometry for now



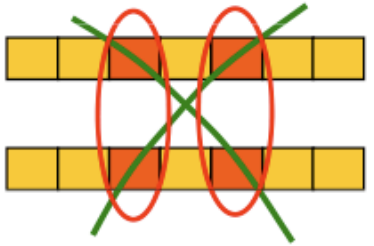
Algo Performance

Separation [mm]	Max Efficiency [%]	Fake [%]	Reduction Factor
1.0	99.35	4.14	22.26
2.0	97.745	17.83	95.99
3.0	96.00	39.08	210.28
4.0	92.95	47.27	254.35

Performance of a detector stack at r=25cm for sensors with pitch 100µmx2.37mm.
Correlation cuts optimised for high efficiency

Max Efficiency: Average maximum efficiency for a high p_t track to form a stub. Inefficiencies due to sensor doublet acceptances and algorithmic efficiency (window cuts)

Fake: Average fraction of stubs per event generated by correlating hits from different tracks



Reduction Factor: Average data rate reduction factor per event (N_{Stubs} / N_{Digis}) where N_{Digis} is number of hits with charge >adc_{digi} for the whole stacked layer

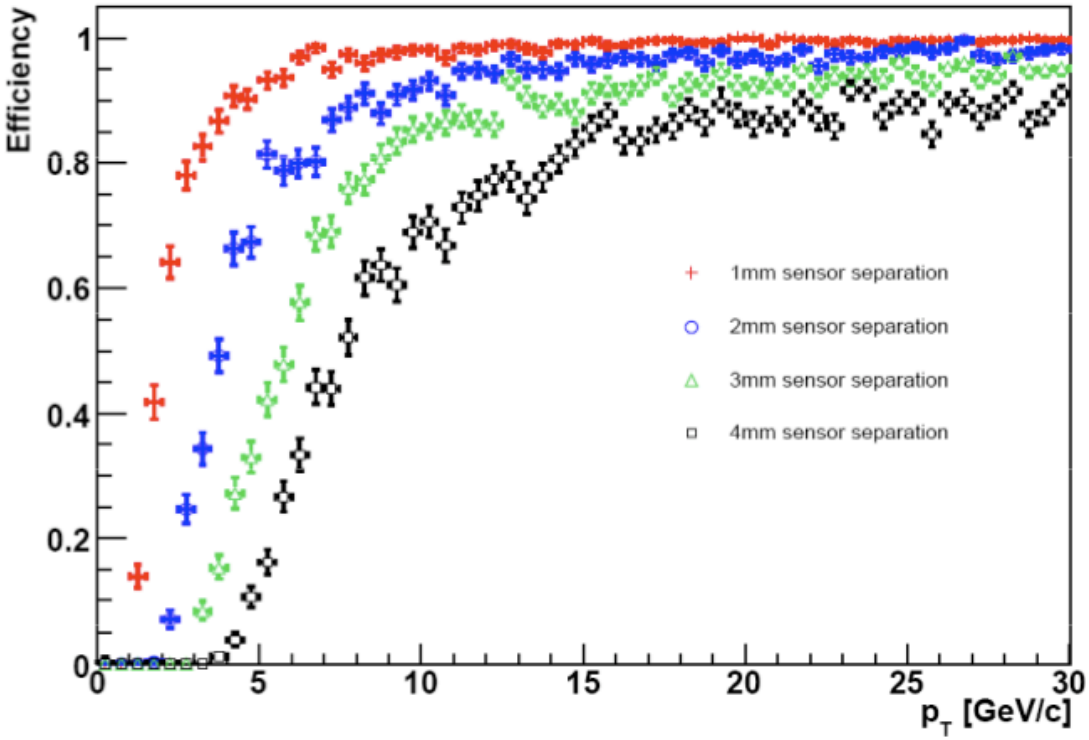
Separation Efficiency

Sensor separation is again an effective cut on p_t – as with the stacked strips

Again, the width of the transition region increases with separation. Due to:

- pixel pitch
- sensor thickness
- charge sharing
- track impact point

Efficiencies decrease with sensor separation due to the larger column window cuts – sensor acceptances and fake containment are issues



p_T discriminating performance of a stacked layer at r=25cm for various sensor separations using 10,000 di-muon events with smearing

Cuts optimised for high efficiency:

Row window = 2 pixels
Column window = 3 pixels @ 1mm, 2mm; 4 pixels @ 3mm; 6 pixels @ 4mm

Pileup Results

Choosing a sensor separation of 2mm, the effect of the window cuts has been determined

Column Width \ Row Width	1	2	3
1	19.05	41.96	42.085
2	44.075	95.585	95.89
3	45.155	97.745	98.07

Efficiency of a 50 GeV muon/antimuon generating a stub in the stacked layer [%]

20,000 single 50GeV Muon/Antimuon events with smearing

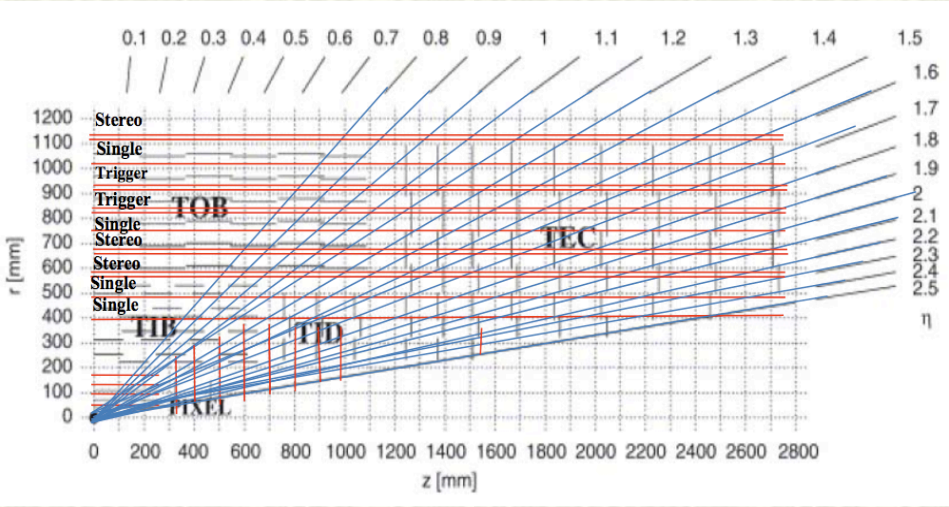
Data rate reduction factor achieved on MinBias events at SLHC pileup

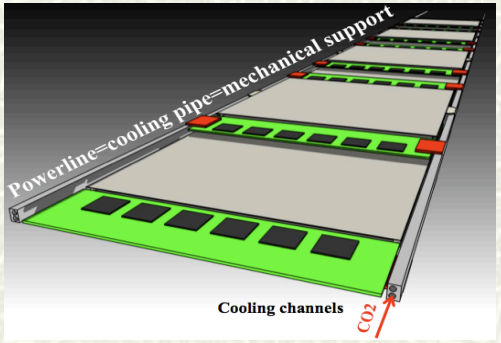
100 MinBias events with an average of 400 interactions per bunch crossing with smearing

Column Width \ Row Width	2	3
2	104.6	94.4
3	96.4	86.0

Long Barrel Strawman

- Another possibility is a long barrel proposal from Karlsruhe
- Use CO_2 cooling, allowing for replacement of TEC with barrel
  - Physical long ladder already built and functioning
- Eliminates material as no longer have endcap support

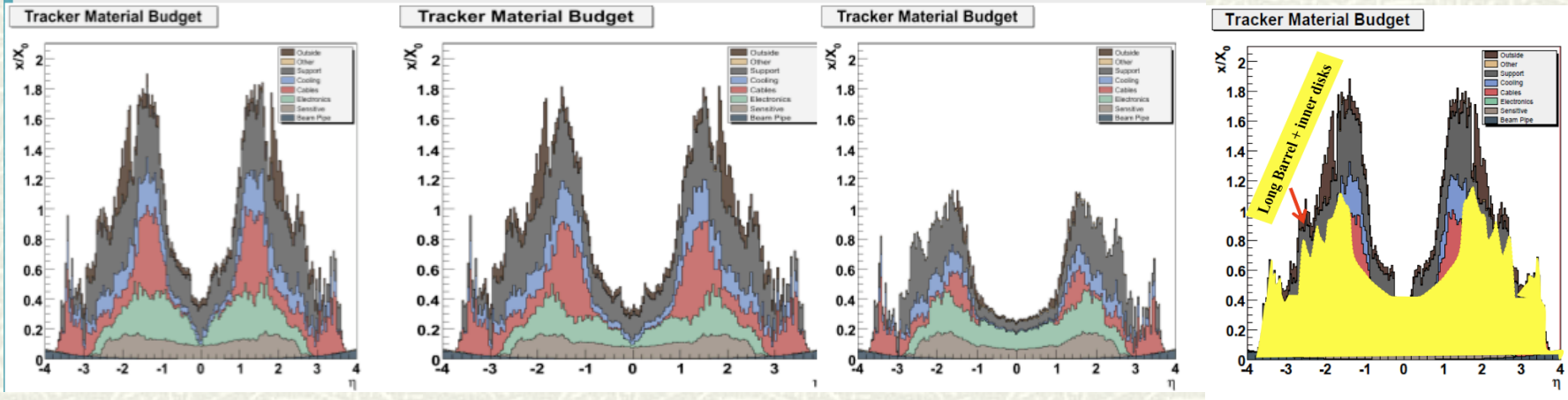




Material Budget [Kevin Givens]

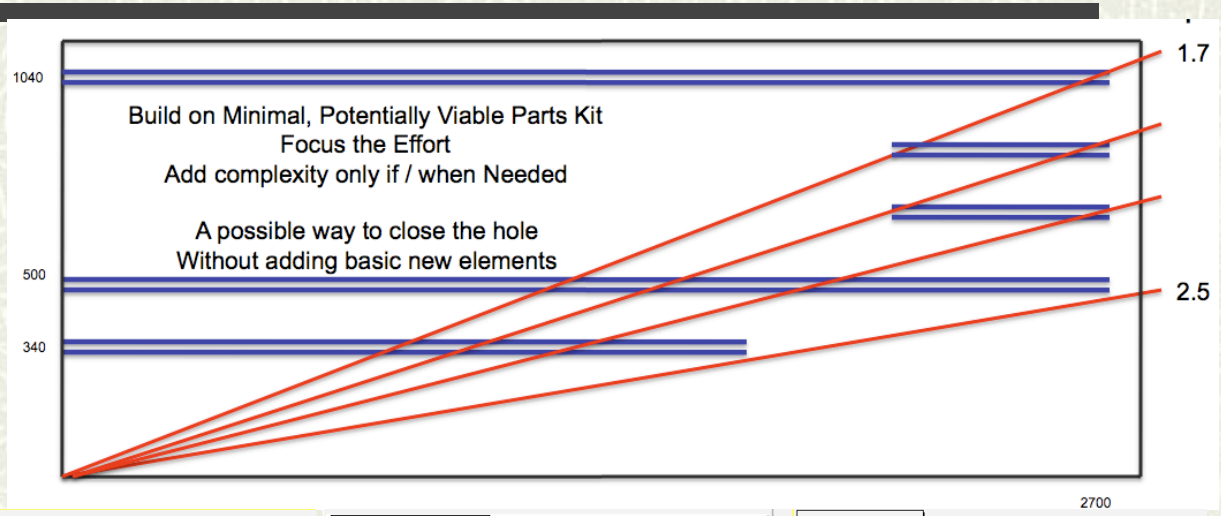
- Comparisons of regular, StrawA and StrawB geometries
- Most of the reduction if the elimination of barrel endcaps

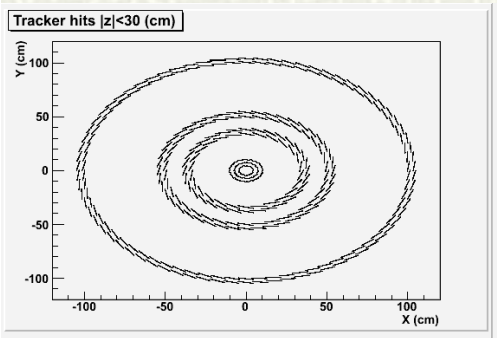
Standard Geo | Strawman A | Strawman B | LongBarrel

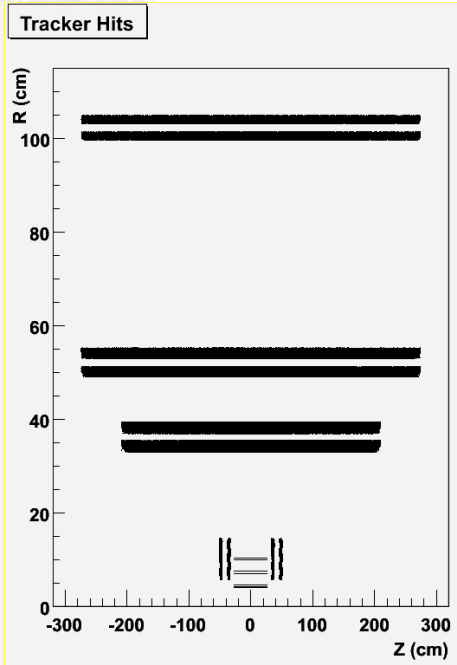


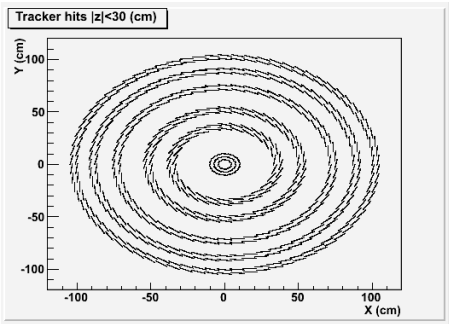
Baseline Geometry from Track Trigger Group

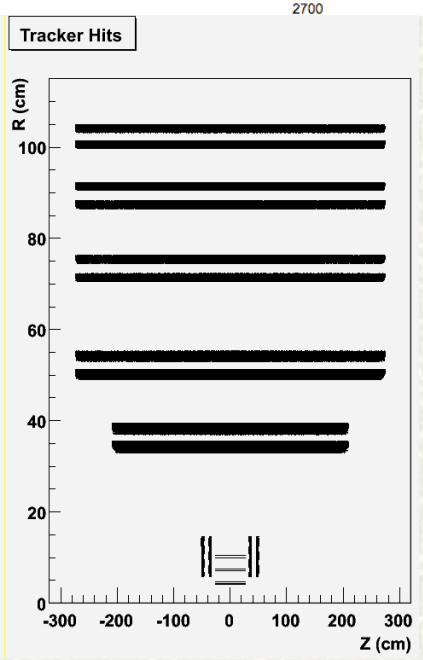
Start with StrawB
Remove TEC
Add in extra layers
Extend Barrel Length



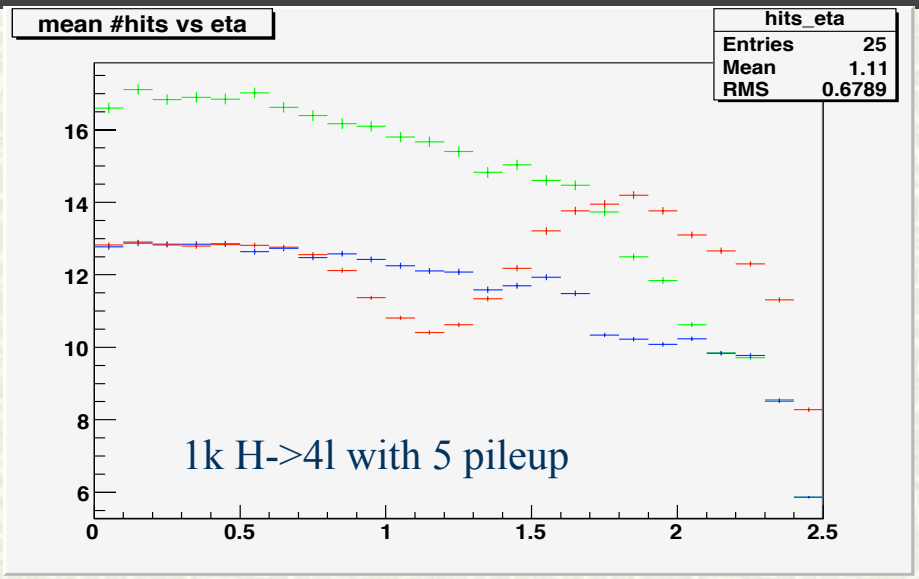


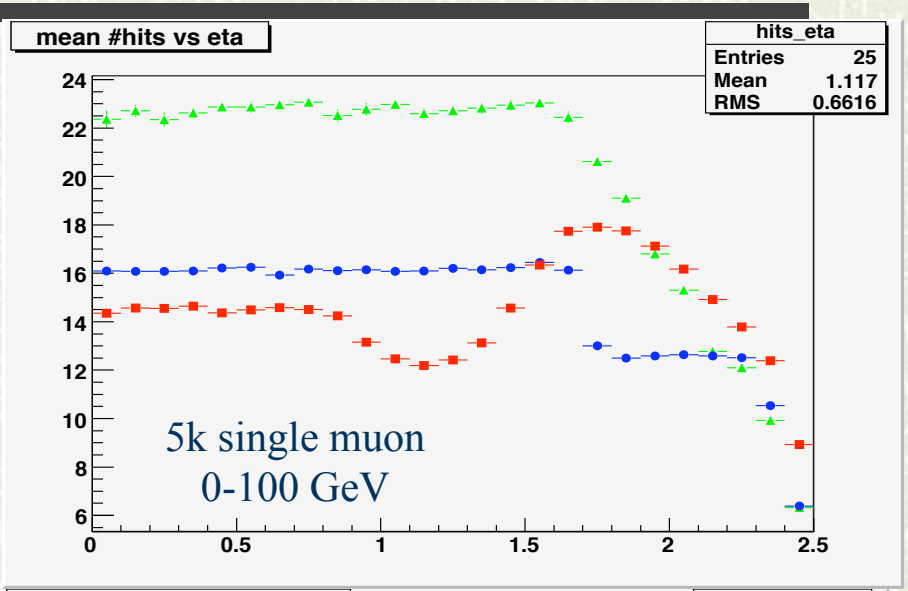


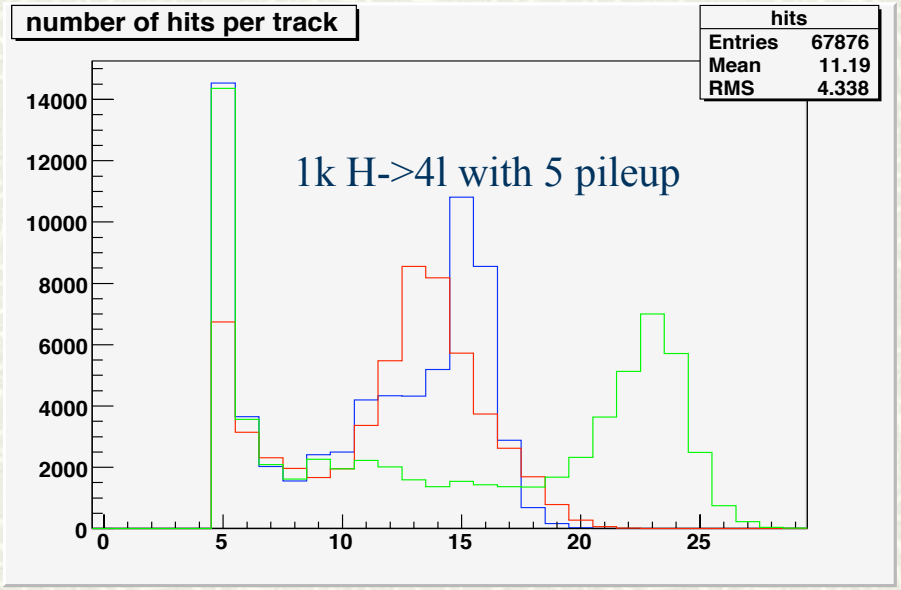


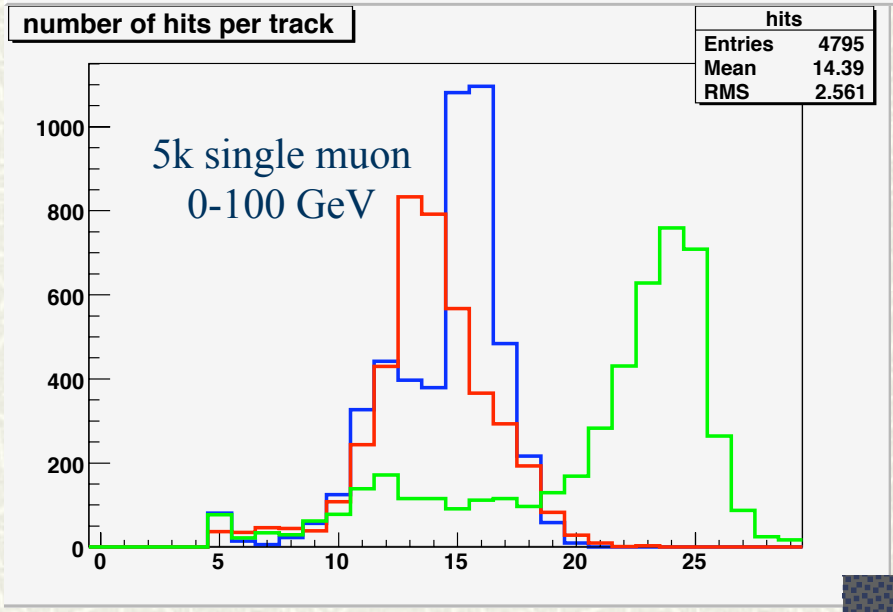


Comparisons of Regular Geometry versus the Two Long Barrel Designs



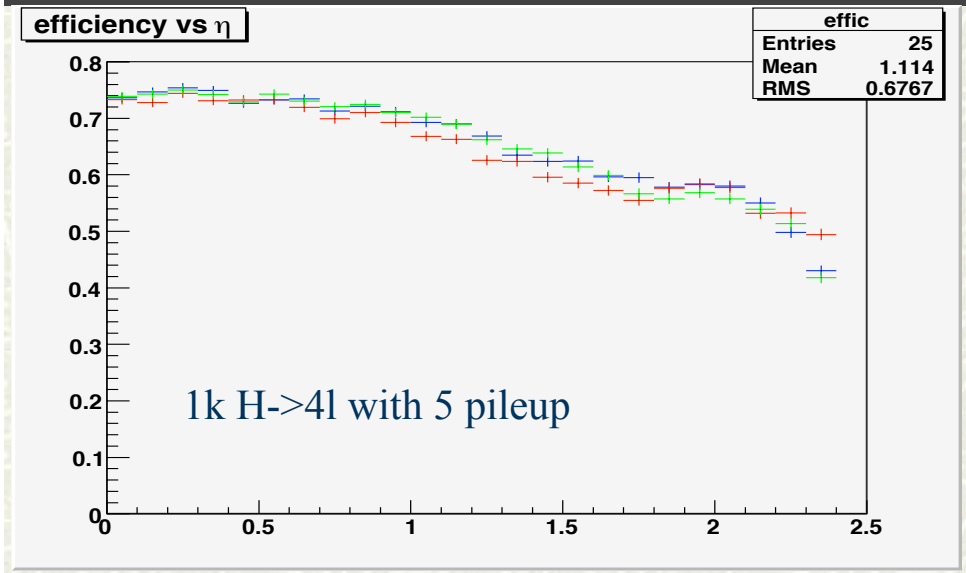


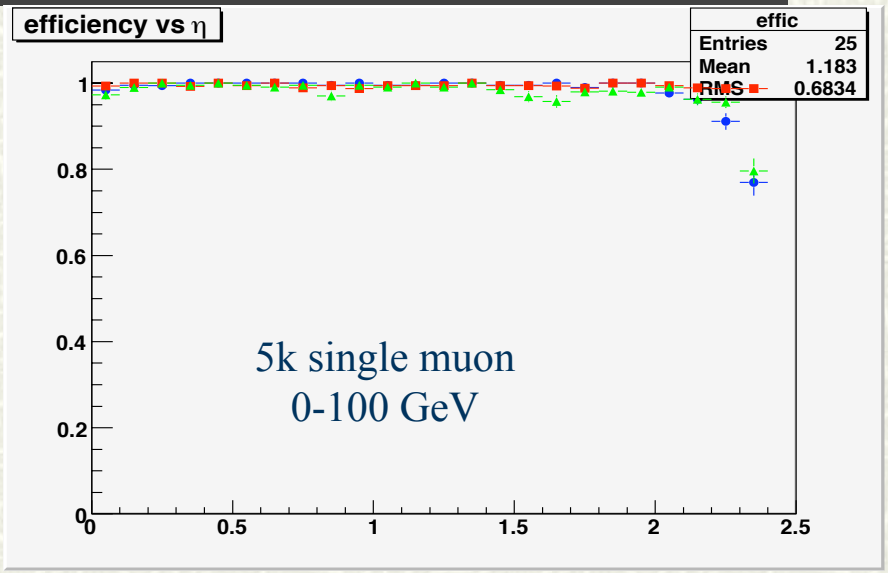


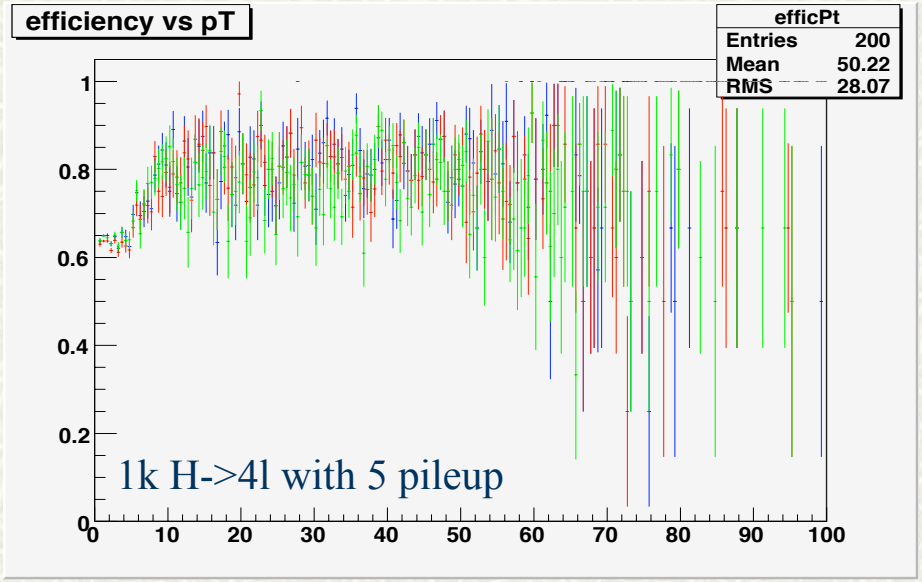


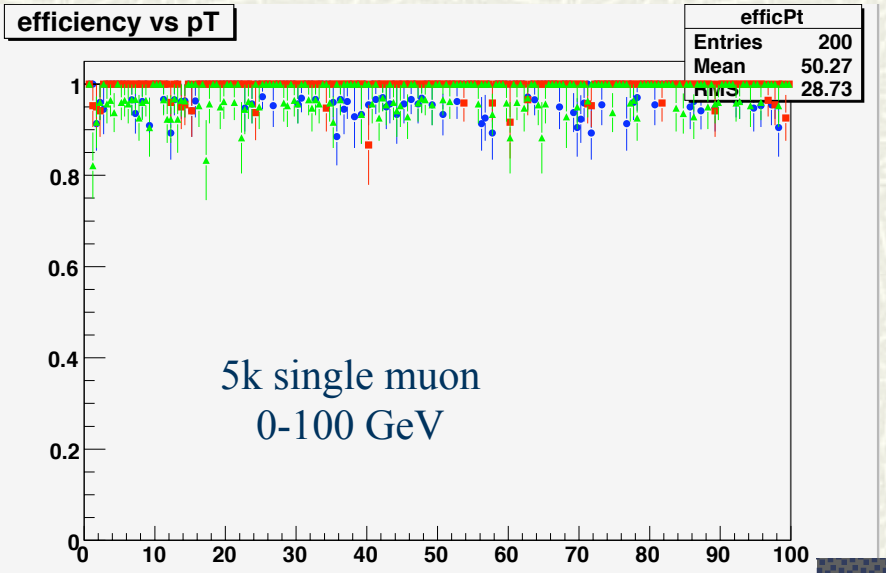
Red = Reg Geom, Blue = Long w/no middle, Green = Long with middle

Comparisons of Efficiencies



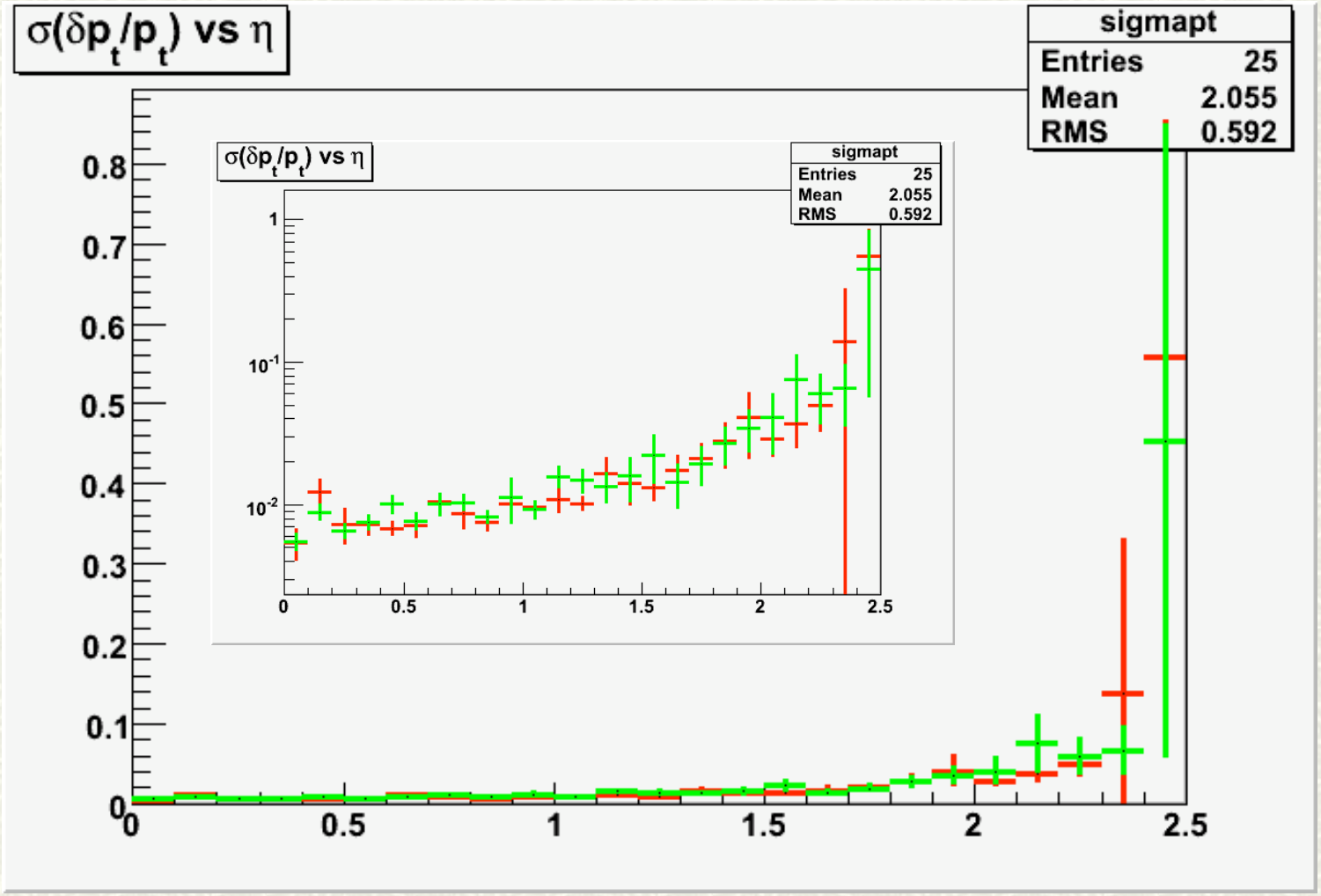






Red = Reg Geom, Blue = Long w/no middle, Green = Long with middle

Pt Resolution: 50[red] and 75[green] GeV Muons vs eta

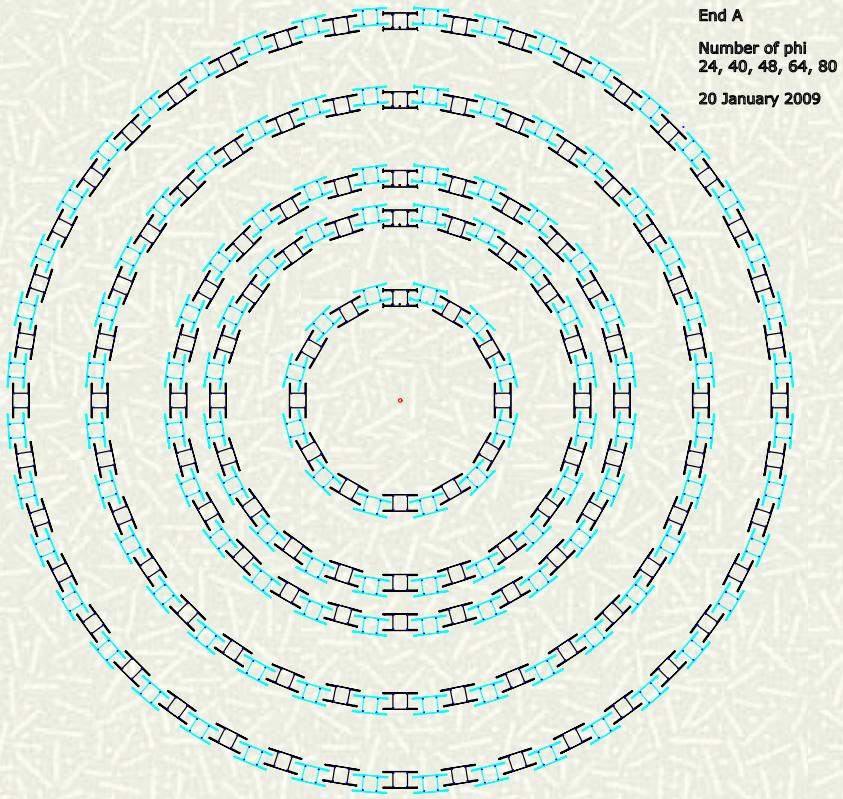


Status of Move to 2_2_3

- Started move to 2_2_0, but that had too many issues, so switched to 2_2_3
- Basic version of StrawB is now working in 2_2_3
- The two versions of Long Barrel Strawman also in 2_2_3
- Testing digis [needed for trigger]
  - Working with Trigger group
    - They see digis, but not all trigger elements are created

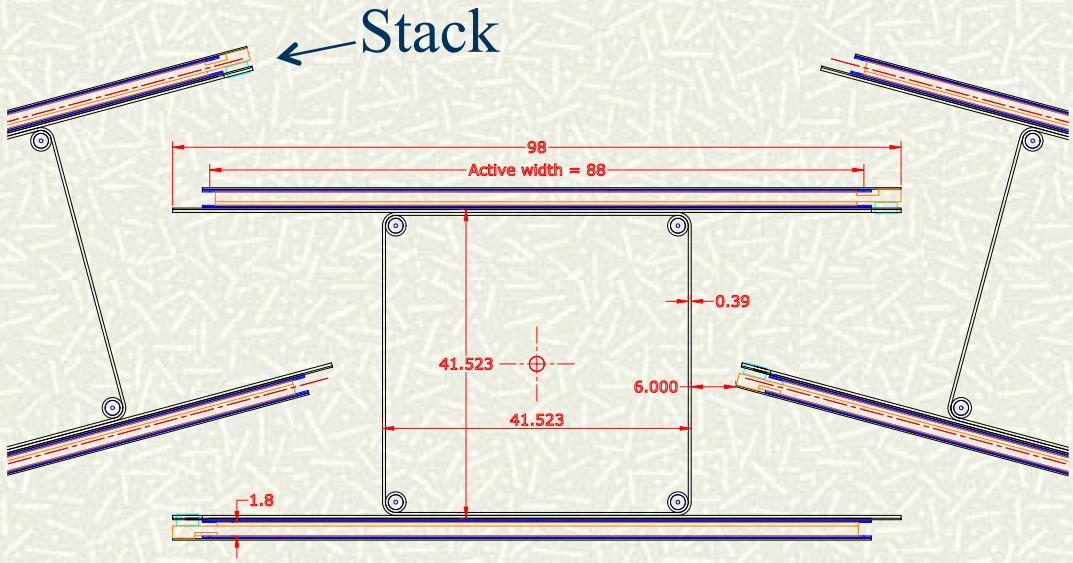
Toward a more realistic design

- Have been working with detector group at Fermilab to make sure simulation matches the physical design
- Switch from pinwheel to alternating ladders
  - Being studied as to how this will affect triggering
- Overlap at Z=0



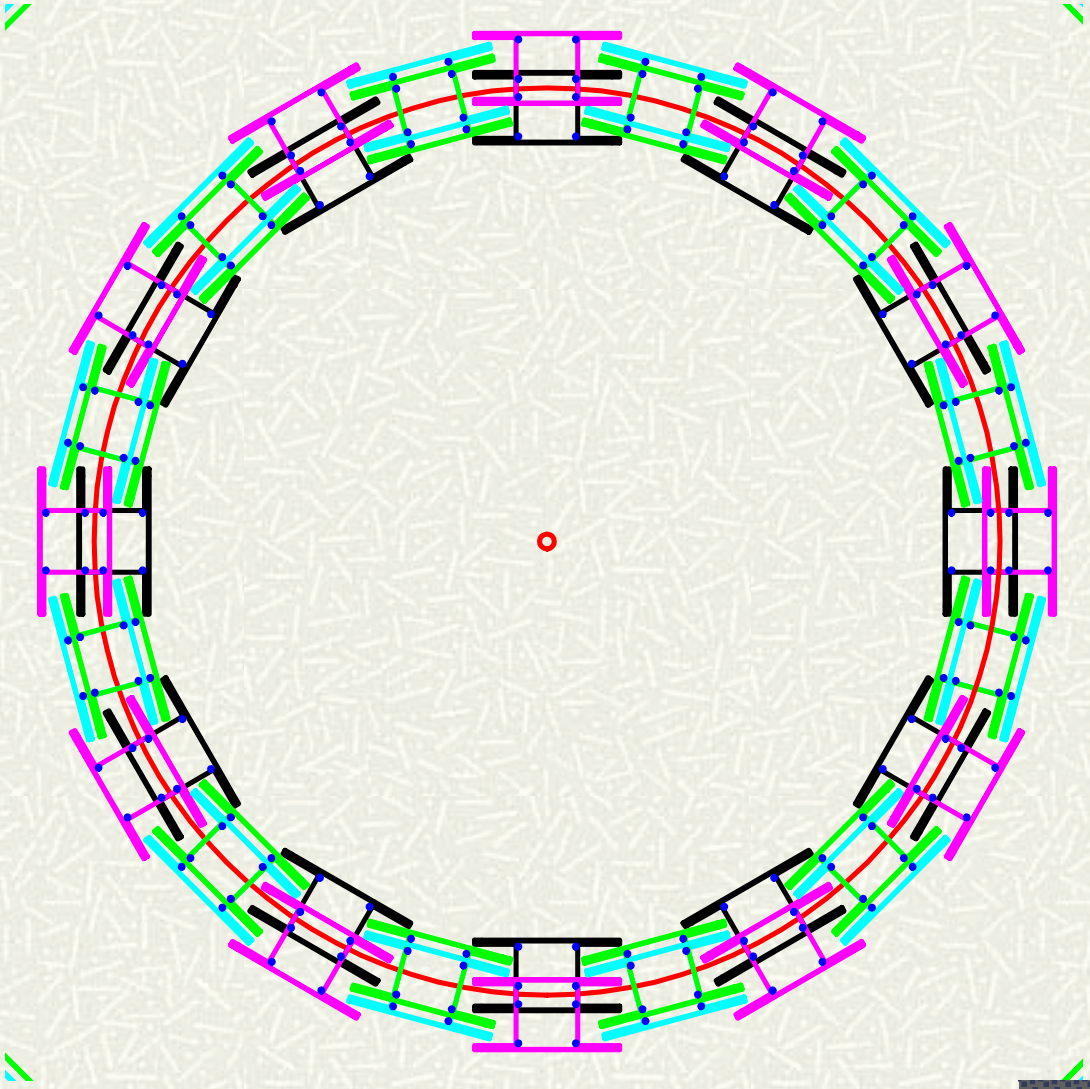
Pinwheel vs alternating

- Strawman B uses pinwheel geometry. This keeps a constant radius for the stub finding.
- Much more difficult to make the overlap at Z=0 work
- Current version has the alternating layout, which will be studied to make sure it can work for the trigger group also



Overlap at Z = 0

- This shows the overlap in the two sides at Z=0
- Blue and Black is one side of Z
- Red and Green is the other side



Status and Plans

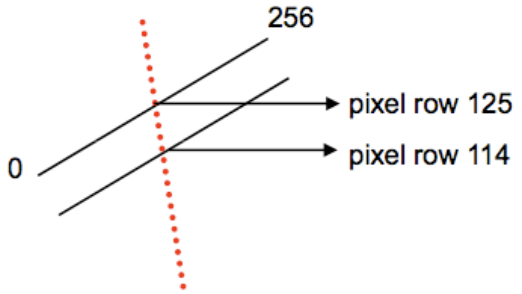
- In progress with the port to 2_2_3
- Next step is to add the short middle layers
- Then adjust simulation to accurately reflect the physical design
- Perform studies of new geometry for tracking and triggering

Backup

Correlation Calculation

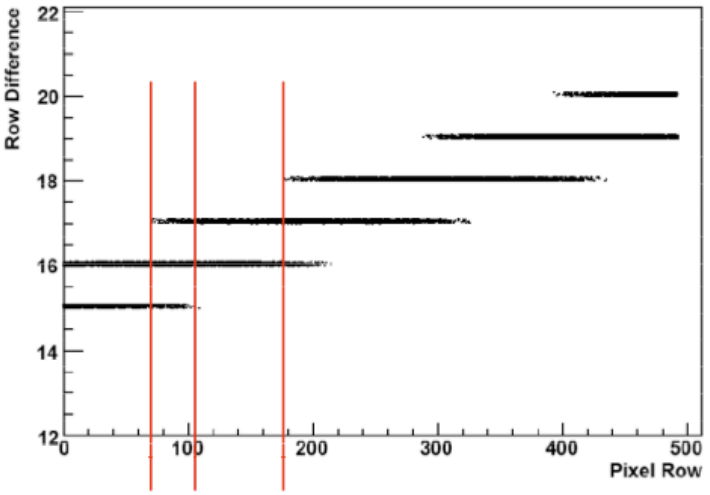
Row difference calculation

Since the sensors are tilted, there is a difference between the position of the higher and lower sensor hits for a high p_t track which is also dependent on the position of the incident track on the sensor



The fixed offset as a function of the row number can be applied to calculate the true row difference

Equivalent to an on detector map between the hit position on the higher sensor to a set of positions on the lower sensor

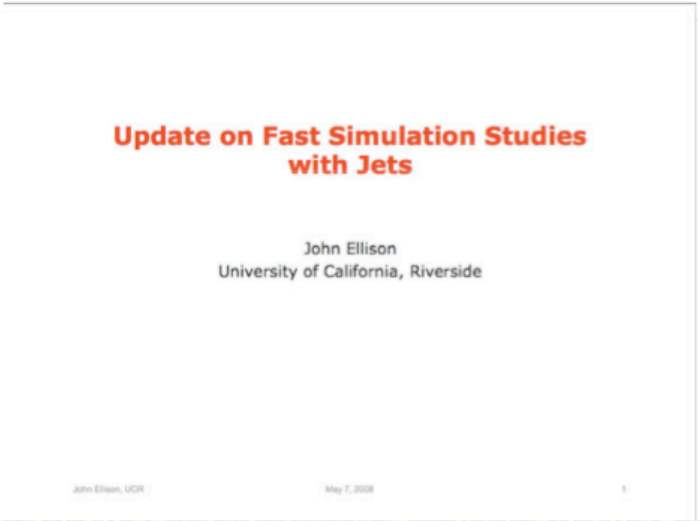


Column difference calculation

Column difference is not symmetrical – dependence on whether hit is in detector +/-z. Can be exploited to maximise rate reduction.

Bug Caught by Simulation group in FastSim

- Uncovered bug in TrackingParticle collection in FastSim
  - John Ellison and Avdhesh Chandra interested in tracking efficiency in jets for upgrade, looked at FastSimulation and found a difference compared to Full simulation, presented to a FastSimulation meeting in Mar. 2008 http://indico.cern.ch/conferenceDisplay.py?confId=28534
  - Problem turned out to unstable particles (e.g. Δ^-, $K^*(892)^+$, $\rho(770)^+$, Δ^{++}, Σ^-) were included in the TrackingParticle collection for FastSim affecting the MultiTrackValidator for FastSim. Update presented by John at the May 7th tracker upgrade simulation meeting http://indico.cern.ch/conferenceDisplay.py?confId=33117



Fixed in subsequent releases