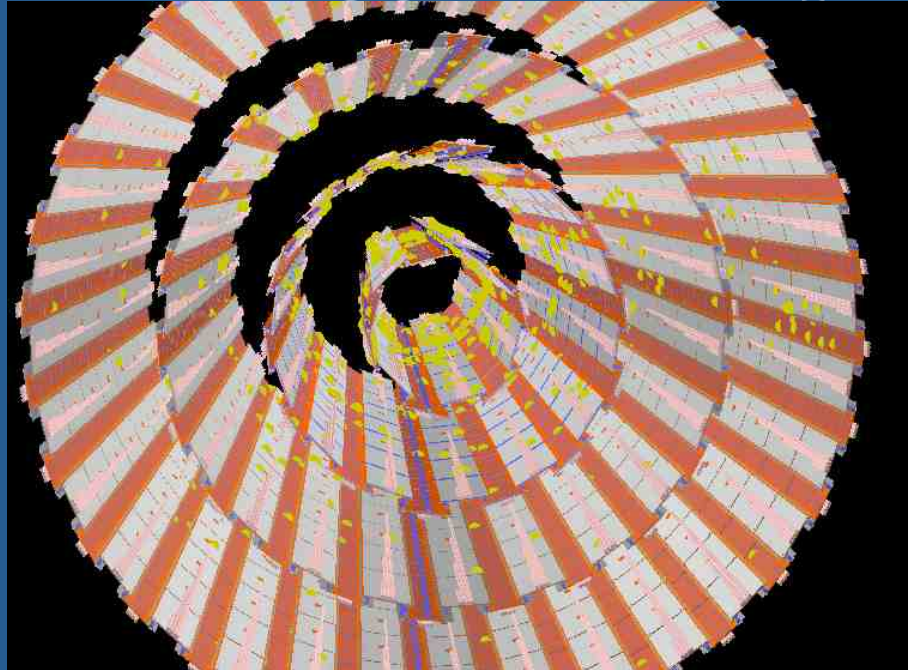


Towards a Pixel-based trigger:

status on e-trigger & L1 primitives



A. Savoy-Navarro, Paris-Diderot U./CNRS & INFN-Sezione di Pisa

Ongoing collaborative work with:

*D. Christian, S. Kwan, M. Wang, C. Maciel, T. Santini, J. Cupertino, S. Novaes,
T. Tomei, C.S. Moon & A. S-N.*

TRACK TRIGGER Integration Meeting, DESY, June 6, 2013

Outline

- Goals, strategy, milestones: reminder
- Performed comparison MC/data of the pixel detector performances
- Progress on PiXTRK feasibility studies
- Progress on benchmarking tests developments

1) Goals & strategy

Main goals for a L1 pixel-based trigger:

- Improving the Electron ID in L1 e/gamma => electron trigger, with direct feedbacks on muon and tau ID (“by-products”)
- Exploring the possibility of a standalone L1-pixel based trigger, with, as a first step sending pixel track segments as primitives to the HLT.
- Longer term: include this “track segment” in the overall L1 track trigger strategy as an additional track segment to the ones provided by the new outer tracking.

With as strategy-leitmotiv:

Our roadmap to Phase 2 upgrade is based on a continuously ramping up upgrade and non-disruptive strategy

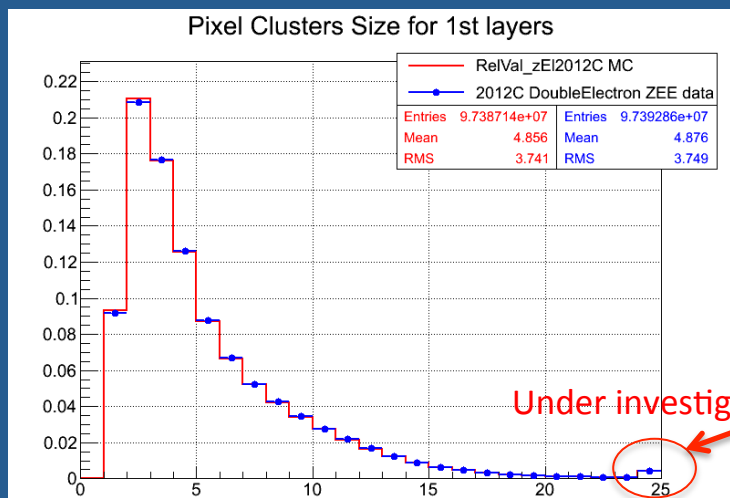
- => Implementing a preliminary demo while data-taking (a-la-CDF)
- ⇒ starting with the current system and thus learning at the same time how we might gradually upgrade/improve it.
- ⇒ getting in-situ expertise with real data and real system
- ⇒ in parallel and complementary to the simulation studies.

2) Comparison MC/data of the pixel detector performances

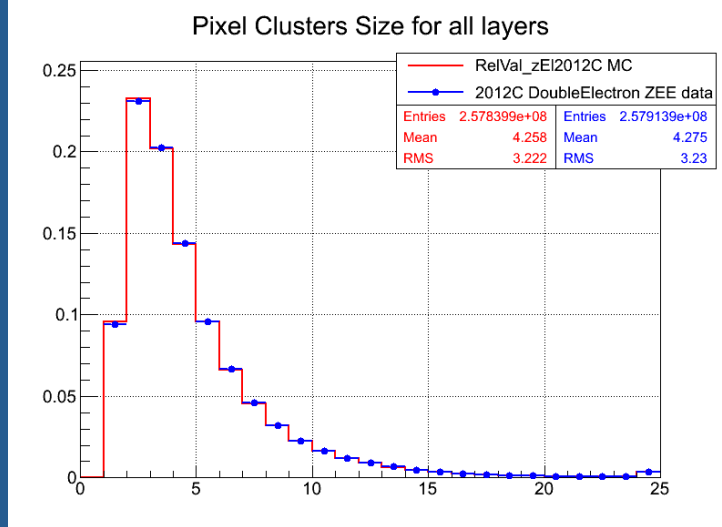
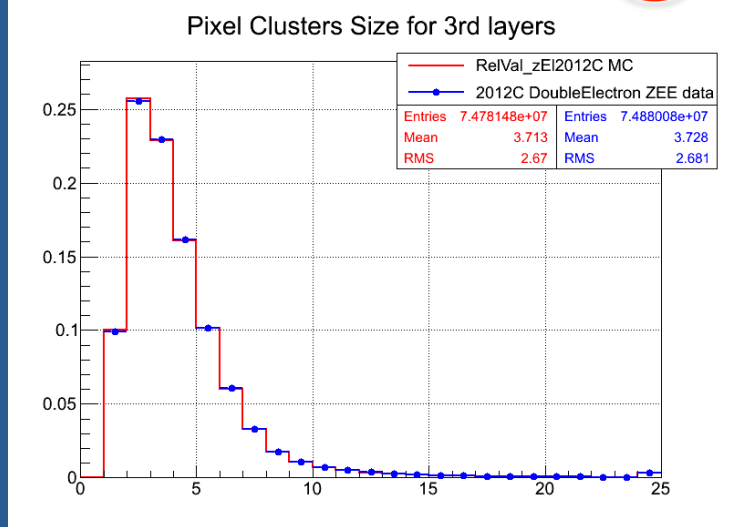
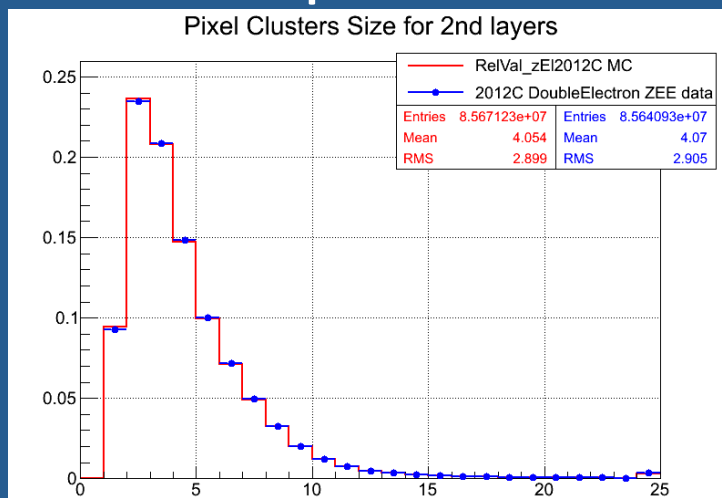
- ✓ Performed comparison between MC and real data of the pixel detector performances (see details by C.S. Moon in the simulation session)
- ✓ Performed same studies with Phase 1 pixel detector in order to study the evolution of these detector characteristics & performances with higher energy & P.U. (see details by C.S. Moon in the simulation session)
- ✓ Allow getting a good handle on pixel cluster modelling and on pixel detector performances in terms of occupancy and interesting feedbacks for the electronics.

Next slides some updates wrt Chang-Seong' slides

Pixel Cluster Size – Barrel pixel

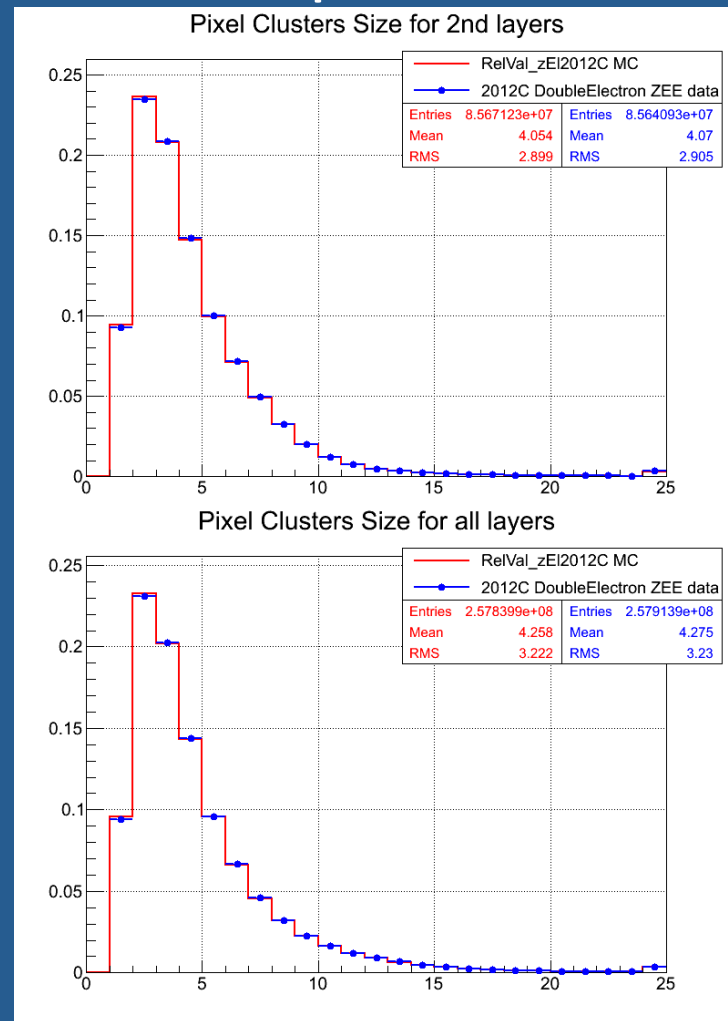
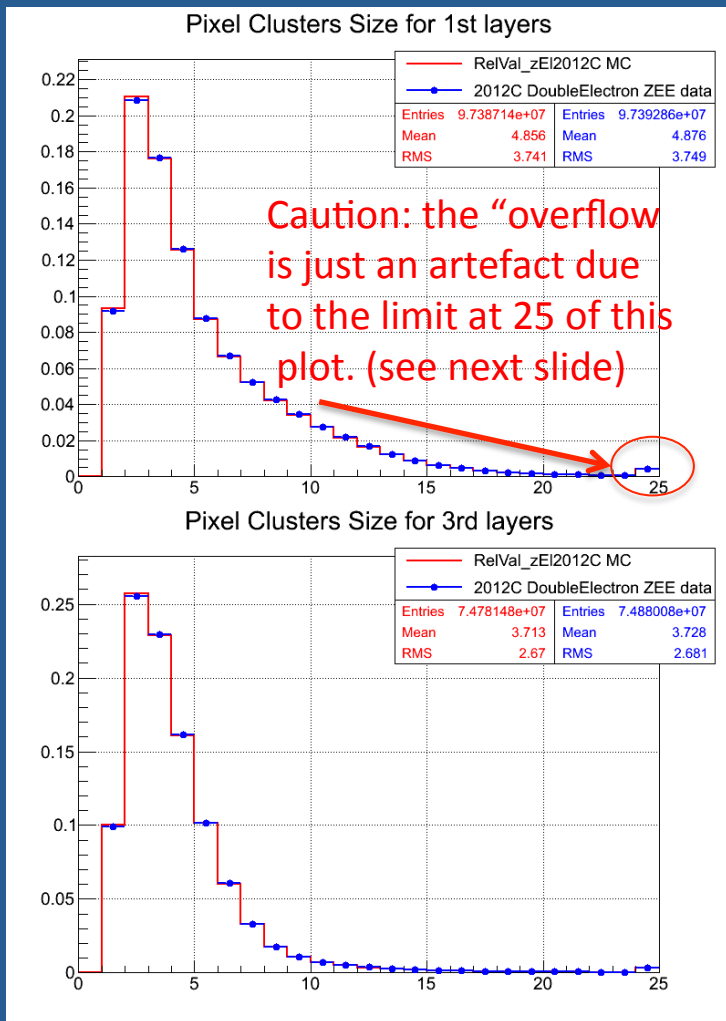


Under investigation



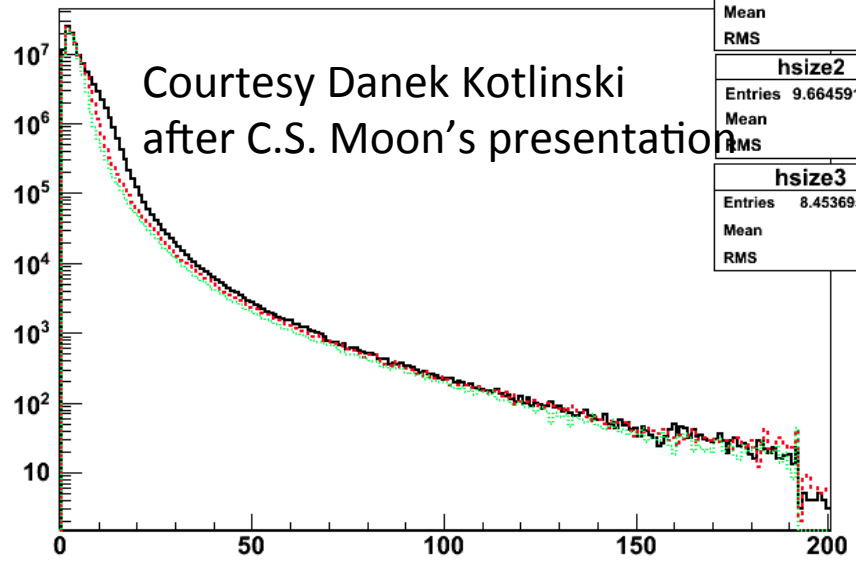
- Excellent agreement data/MC
- The cluster size slightly decrease from innermost to outermost layer: average values are 4.8, 4.0, 3.7 respectively.
- There are few clusters with more than 25 pixels and some are XXXXXL => see next...

Pixel Cluster Size – Barrel pixel



- Excellent agreement data/MC
- The cluster size slightly decrease from innermost to outermost layer: average values are 4.8, 4.0, 3.7 respectively.
- There are few clusters with more than 25 pixels and some are XXXXXL => see next

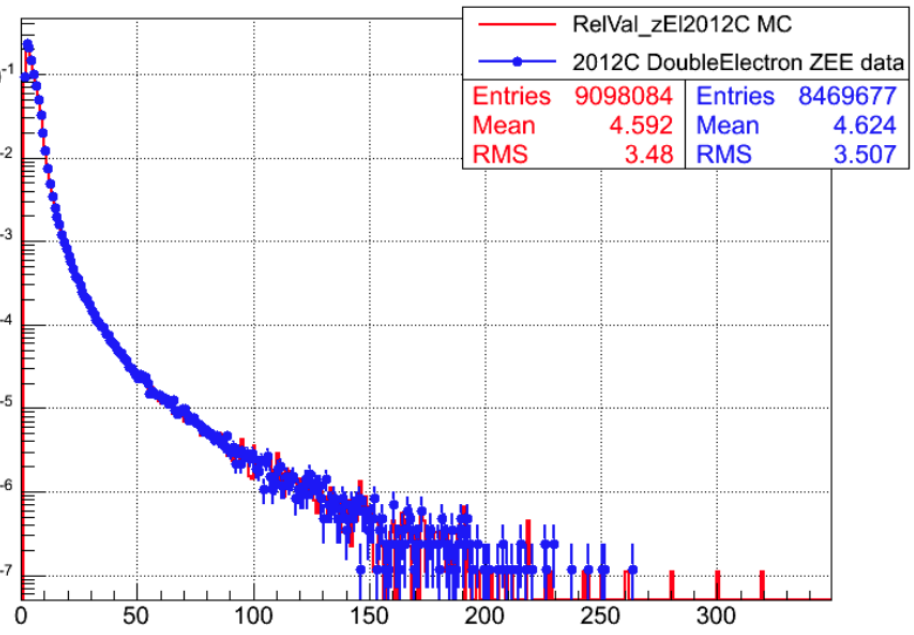
layer 1 clu size



| hsize1 | |
|---------|--------------|
| Entries | 1.095617e+08 |
| Mean | 4.734 |
| RMS | 4.092 |
| hsize2 | |
| Entries | 9.664591e+07 |
| Mean | 4.061 |
| RMS | 3.454 |
| hsize3 | |
| Entries | 8.453695e+07 |
| Mean | 3.721 |
| RMS | 3.248 |

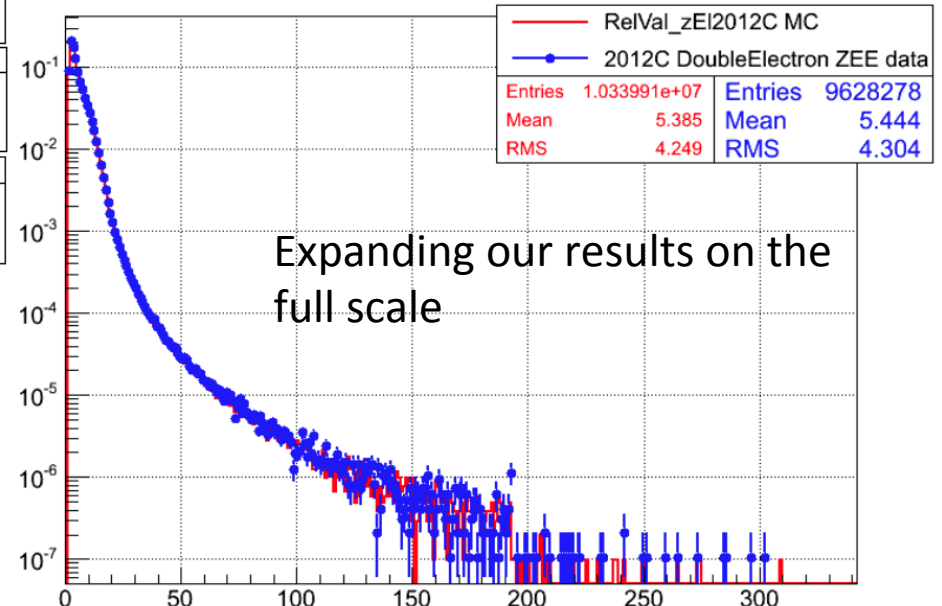
Courtesy Danek Kotlinski
after C.S. Moon's presentation

Pixel Cluster Size for 2nd Barrel layer



| RelVal_zEI2012C MC | | 2012C DoubleElectron ZEE data | |
|--------------------|---------|-------------------------------|---------|
| Entries | 9098084 | Entries | 8469677 |
| Mean | 4.592 | Mean | 4.624 |
| RMS | 3.48 | RMS | 3.507 |

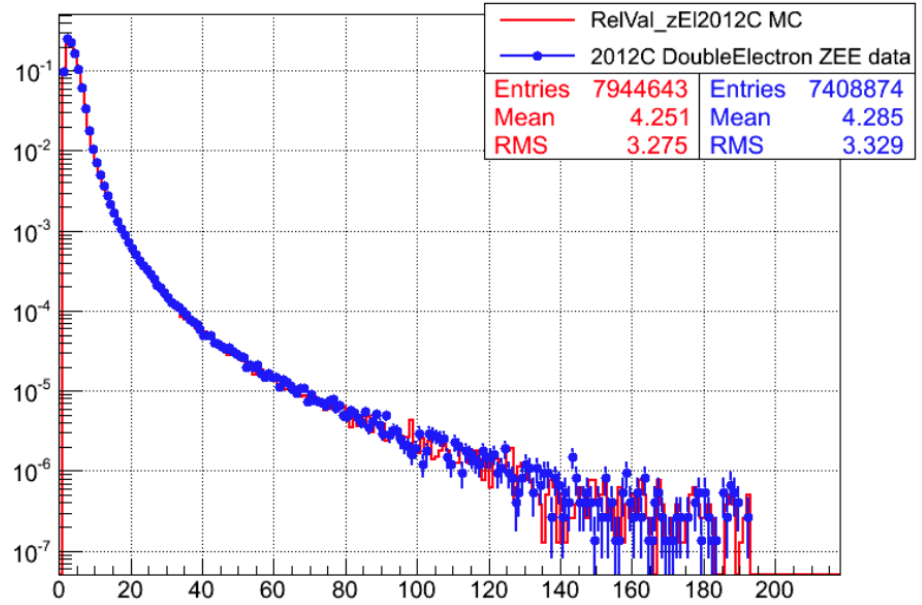
Pixel Cluster Size for 1st Barrel layer



| RelVal_zEI2012C MC | | 2012C DoubleElectron ZEE data | |
|--------------------|--------------|-------------------------------|---------|
| Entries | 1.033991e+07 | Entries | 9628278 |
| Mean | 5.385 | Mean | 5.444 |
| RMS | 4.249 | RMS | 4.304 |

Expanding our results on the
full scale

Pixel Cluster Size for 3rd Barrel layer



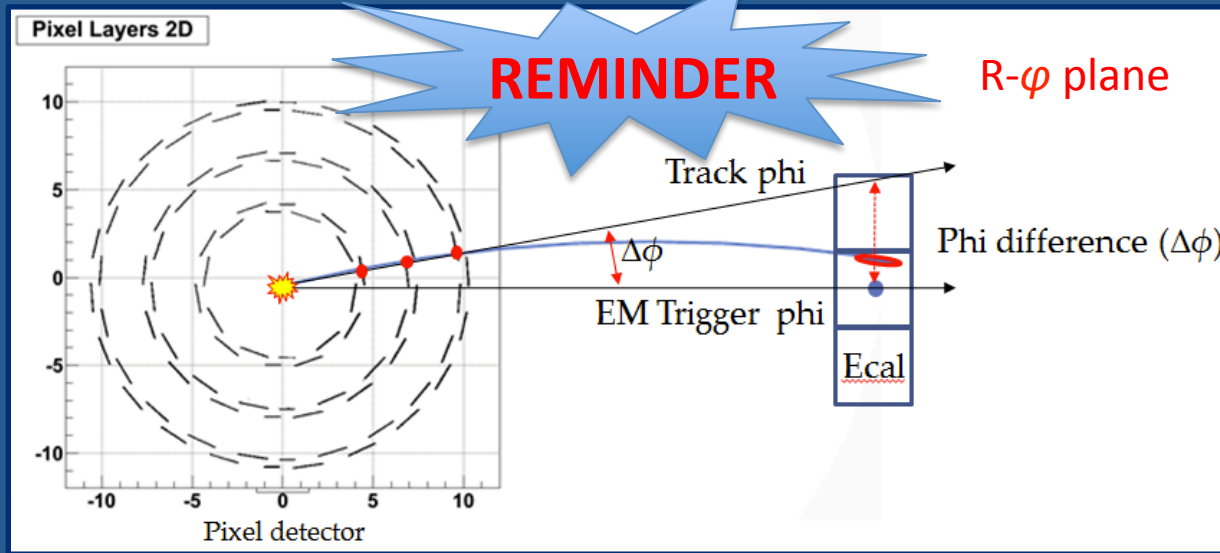
| RelVal_zEI2012C MC | | 2012C DoubleElectron ZEE data | |
|--------------------|---------|-------------------------------|---------|
| Entries | 7944643 | Entries | 7408874 |
| Mean | 4.251 | Mean | 4.285 |
| RMS | 3.275 | RMS | 3.329 |

| PIXEL NOW Pixel Layer (R in cm) | Area(cm ²) | Total # of pixel cluster/layer/Bx | | Number of cluster /layer/ cm ² /Bx | |
|---------------------------------------|------------------------|-----------------------------------|------------|---|------------|
| | | MC | 2012c data | MC | 2012c data |
| BPixel L1 (4.4) | 1800 | 974 | 974 | 0.54 | 0.54 |
| BPixel L2 (7.3) | 3000 | 857 | 856 | 0.29 | 0.29 |
| BPixel L3 (10.2) | 4200 | 748 | 749 | 0.18 | 0.18 |
| FPixel D1 (6-15) | 1400 | 431 | 437 | 0.32 | 0.31 |
| FPixel D2 (6-15) | 1400 | 422 | 422 | 0.30 | 0.30 |

| PHASE1 Pixel Layer | Area(cm ²) | Total # of pixel cluster/ layer/Bx | | Nb cluster /layer/cm ² / Bx | |
|-------------------------|------------------------|------------------------------------|-------|--|-------|
| | | No PU | 50 PU | No PU | 50 PU |
| BPixel L1 (R = 2.9cm) | 1100 | 156 | 3589 | 0.14 | 3.26 |
| BPixel L2 (R = 6.8 cm) | 2560 | 127 | 2989 | 0.05 | 1.17 |
| BPixel L3 (R = 10.9 cm) | 4110 | 103 | 2481 | 0.03 | 0.60 |
| BPixel L4 (R = 16 cm) | 6030 | 83 | 2007 | 0.01 | 0.33 |
| Fpixel D1 | 1680 | 100 | 2425 | 0.06 | 1.44 |
| FPixel D2 | 1680 | 103 | 2426 | 0.06 | 1.44 |
| FPixel D3 | 1680 | 98 | 2365 | 0.06 | 1.41 |

3) PROGRESS on PiXTRK FEASIBILITY STUDIES:

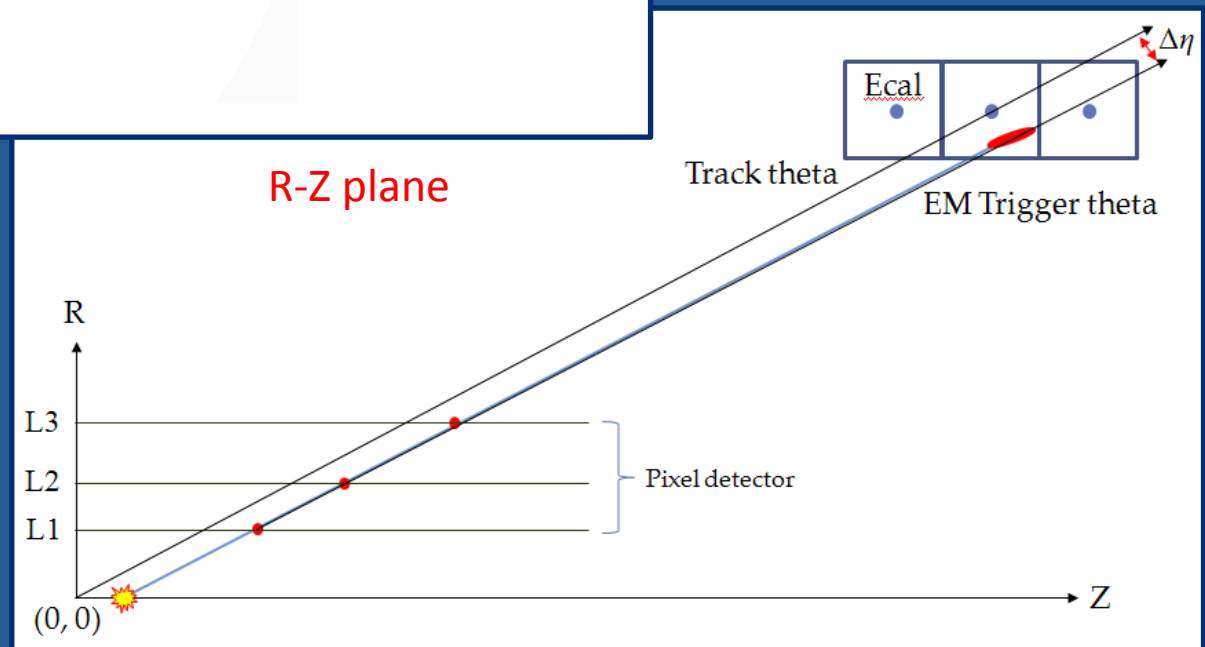
PiXTRK:Regional pixel track (“tracks” based on pixel clustering) originating and matching with e.m. calorimeter cluster



Improving background rejection by adding vertex detector-based information

e.m. cluster matching with regional pixel tracking using a ($\Delta\phi$ & $\Delta\eta$) signal window range.

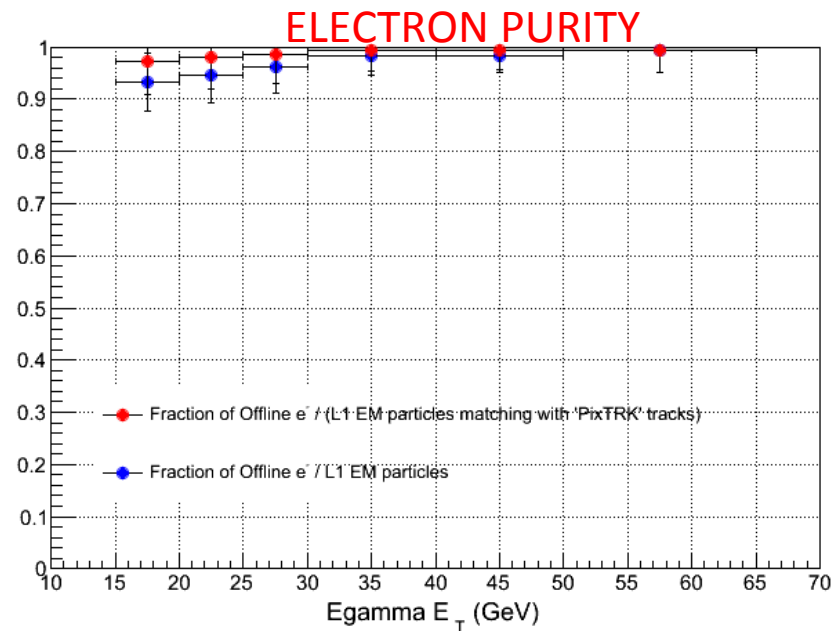
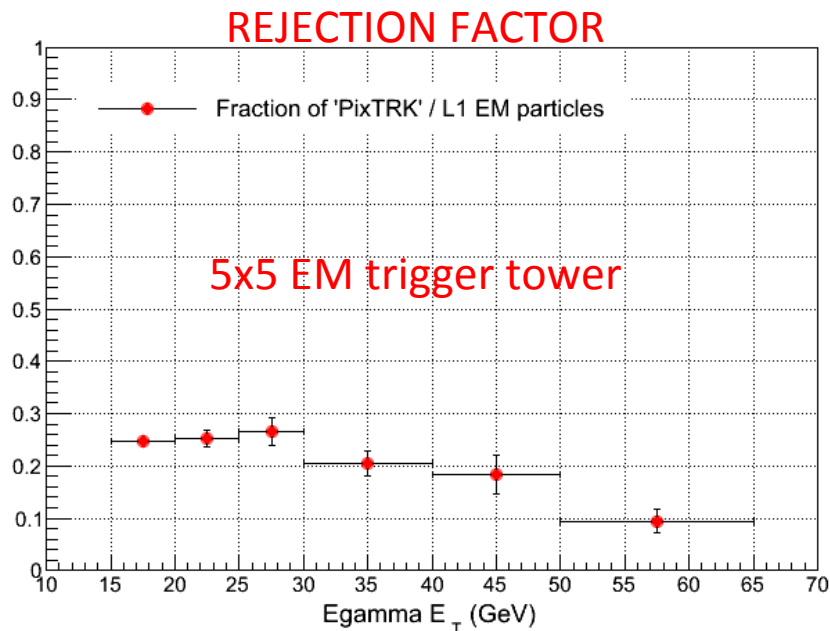
ANALYSIS PERFORMED WITH REAL DATA: 2011-2012 & present pixel tracker And with Phase 1 simulations



New results on PiXTRK feasibility studies

- Revisit electron purity performances using Phase 1 pixel tracker and Zee 14 TeV simulated events with 0 and 50 Pile up (see next slide)
- And rejection factor with minbias 14TeV with 0 and 50 PU (in progress)
- Investigating the possibility to include the Beam spot (X_{pos} , Y_{pos} and $Z=0$) constraint (in progress)

REMINDER: Rejection factor in ZeroBias dataset in 2011 & electron purity in the corresponding Zee MC data



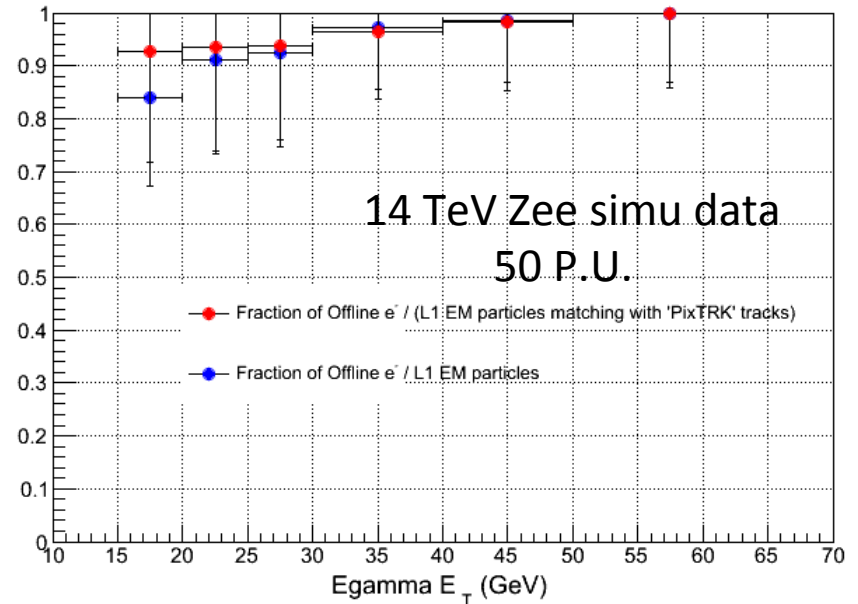
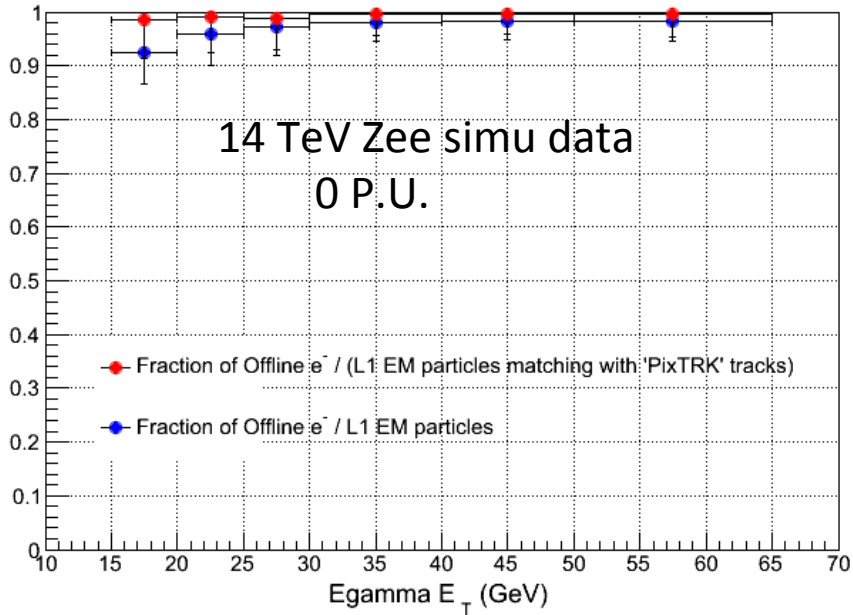
✓ **Red** : Fraction of 'PixTRK' tracks matching with L1 EM particles in the Zero Bias dataset

$(\# \text{ of L1 EM particles matching with 'PixTRK' tracks}) / (\text{Total } \# \text{ of L1 EM particles})$

Less than 25% of L1 EM particles match with a 'PixTRK' track.

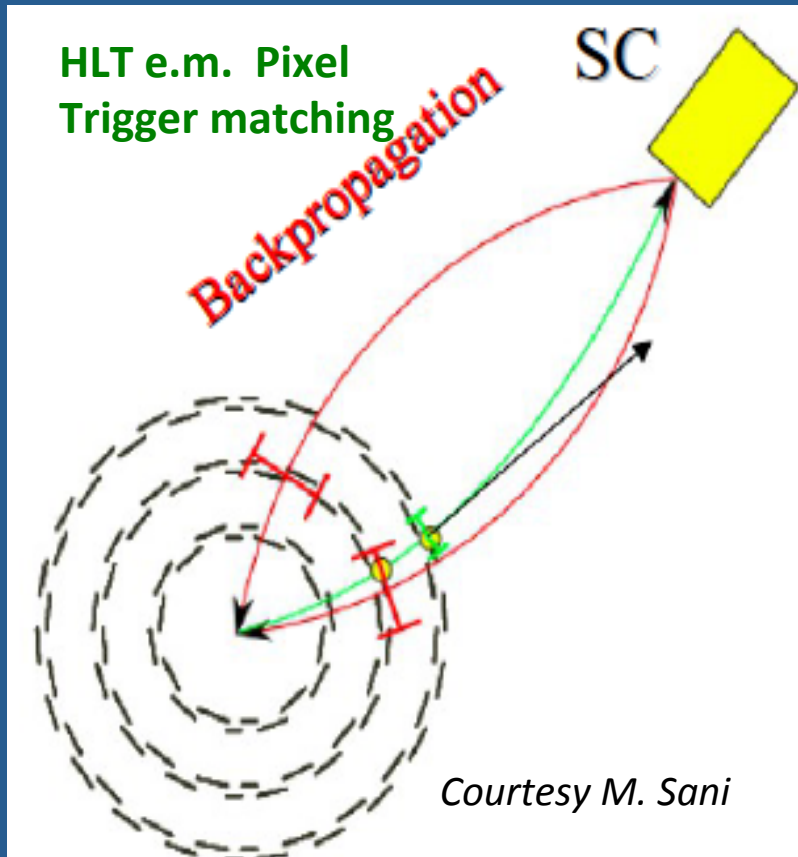
→ Background rejection factors IS ABOUT 4,5 for 5x5 em TOWER

New electron purity results (PHASE1)



PiXTRK-next-step = PiXTRK à-la-HLT

- Detailed study of HLT pixel matching in EG stream taught us how to improve L1 PiXTRK algorithm and what are the main issues:



Transfer to L1:

- **e.m. cluster** :
Present L1 trigger tower size => L1 cluster too rough, BUT:
Phase2 em calo upgrade on global trigger => improvement on PixTRK (already in our result as used em based on 5x5 cluster).
Also studied the benefits of SINGLE CRYSTAL
- **Beam spot**
- **Possibly e- isolation (?)**
- **Back propagation: helix**
Magnetic field map?

4) Benchmarking platforms:

Developing platforms used as demo-and learning frameworks with various Processing units in order to:

- ★ Develop a realistic **real-time L1 algorithm**
(data formatting, pattern recognition & track fitting)
- ★ Compare between Processing Units scenarios
- ★ Get a realistic idea of the needed latency & of
- ★ the integration issues in the overall trigger system

1) Test bench based on FPGA +VHDL

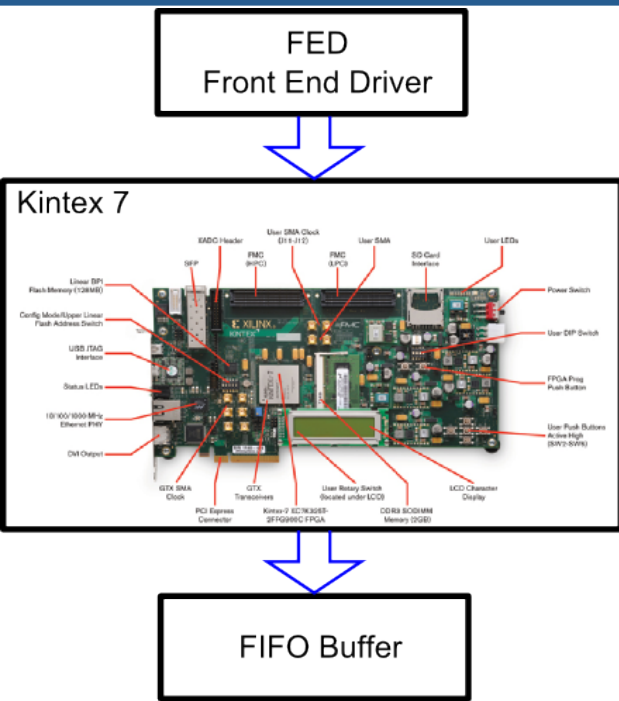
C. Maciel, T. Santini, C.S. Moon & ASN

FPGA: XILINX KINTEX 7 KC705

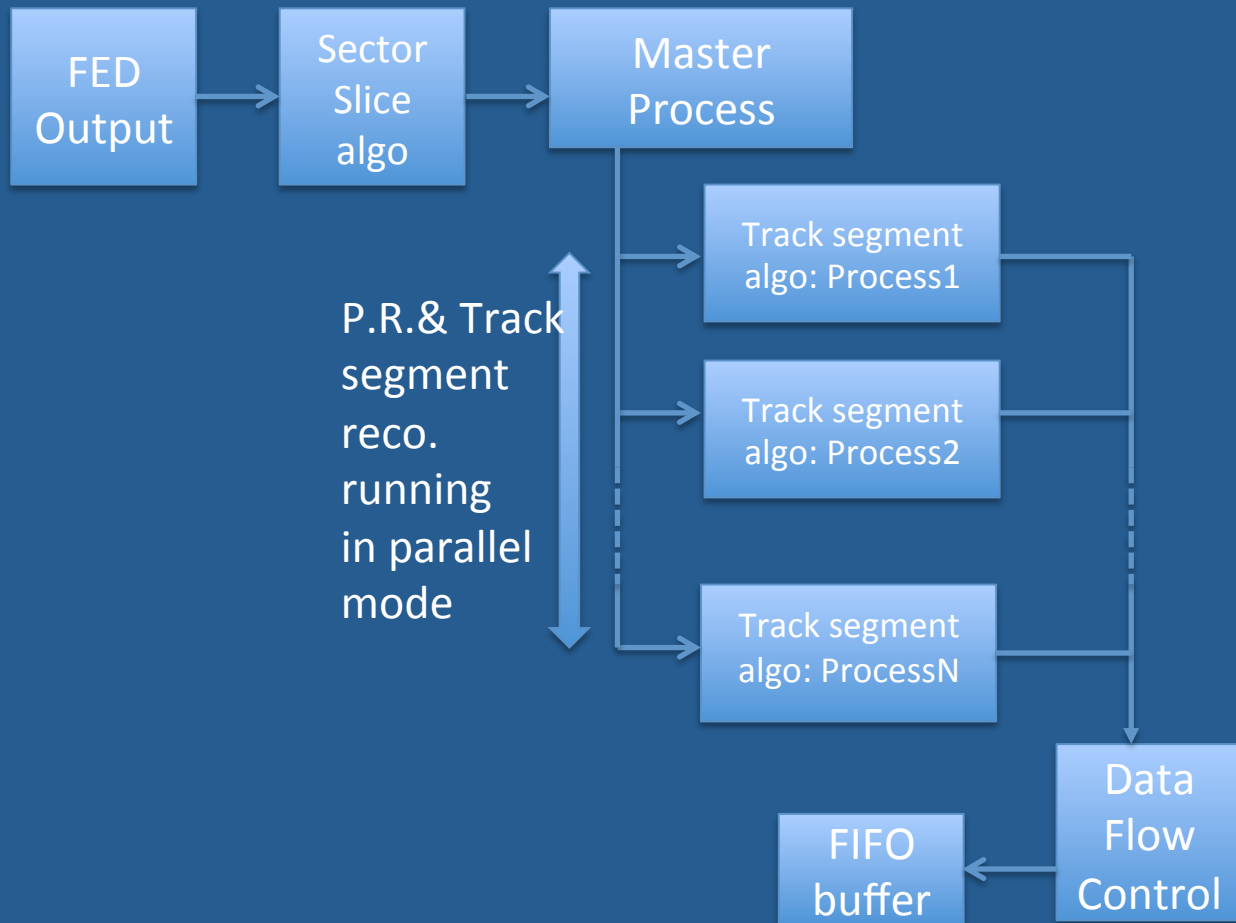
- **Data formatting**: based on the details of the FE-readout data processing is being studied;
To be implemented on the FPGA with VHDL code =>
evaluation of timing performances for this step
- **Pattern recognition & tracking fitting**:
“ Translation” of current PiXTRK L1 algorithm into VHDL
evaluation of timing performances for this step

Two steps being developed on in parallel: in progress

FPGA based basic design & Flow diagram



← Data formatting →



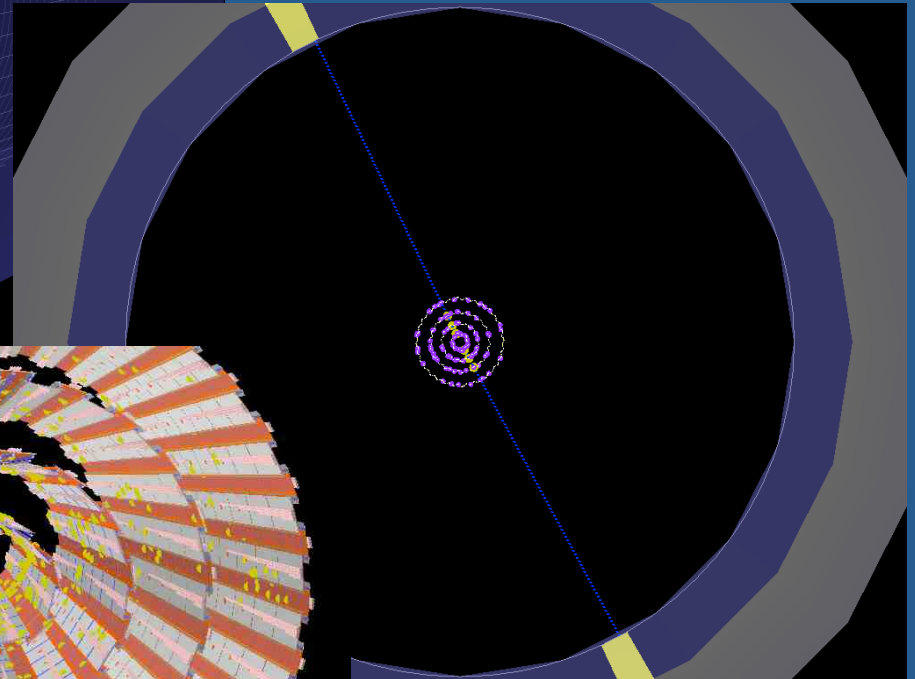
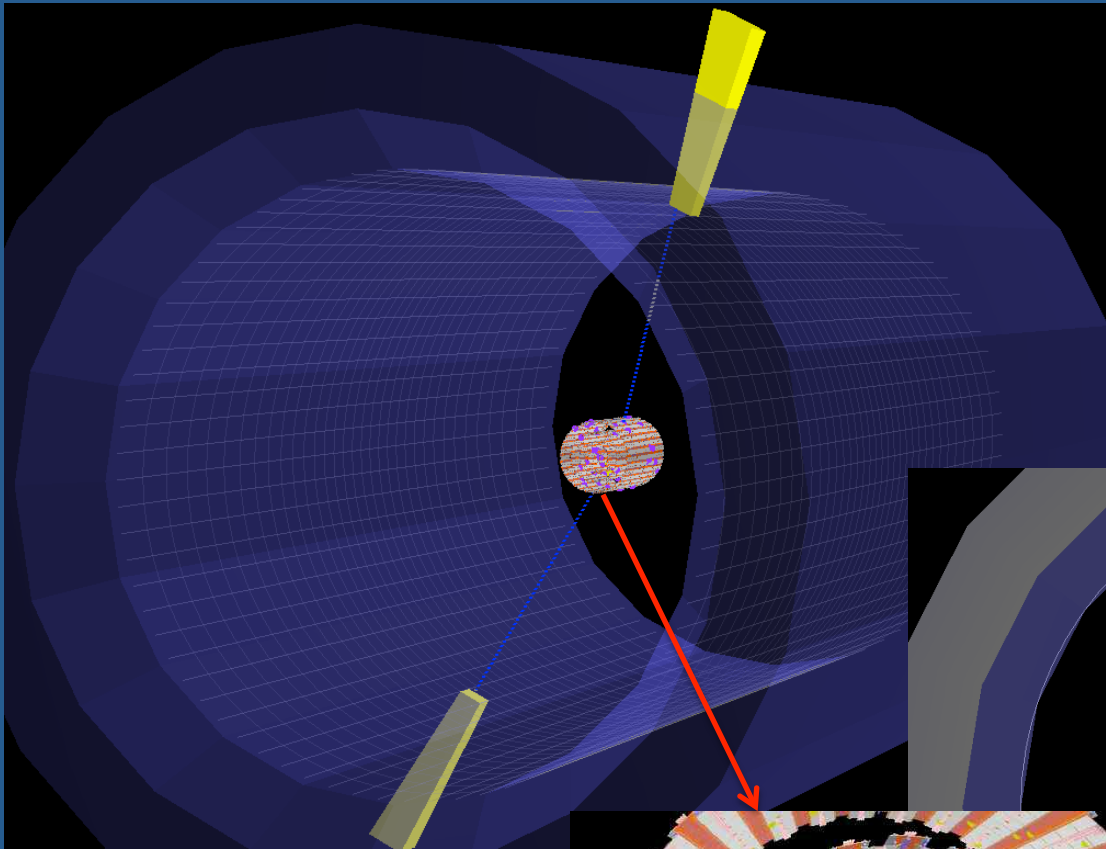
2) Benchmarking platforms (P.R. & track fitting) PU + C coding

M. Wang, S. Kwan, C.S. Moon, ASN

- Started setting things up, **for benchmarking algorithm on various commodity platforms** including new Intel Xeon-Phi many-core processor:
 - Cleaned up existing root macro implementation of the algorithm, removing all histogramming calls and retaining only code relevant to actual algorithm.
 - Translated root macro to c and replaced input root tree with simple ascii file to make code more portable for running on various platforms. Also included inline code for accessing real-time counters for measuring cpu cycles.

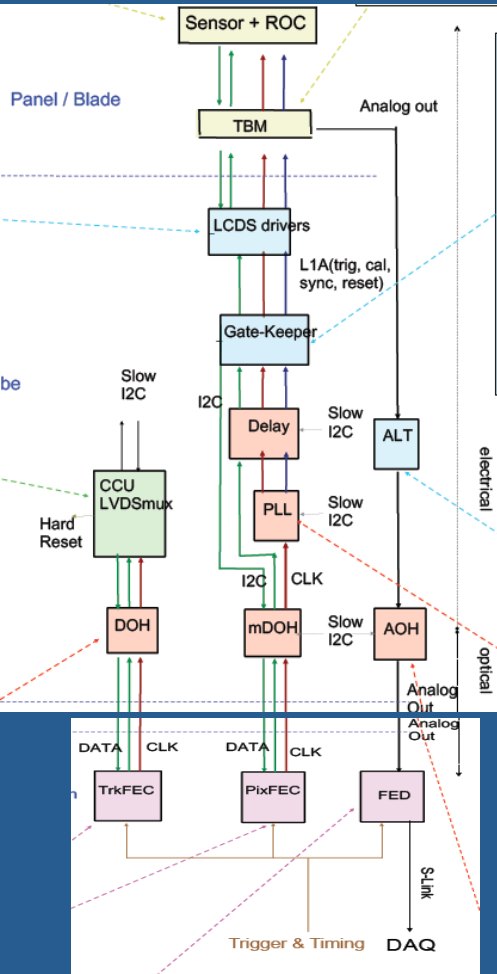
- Developed a root EVT-based 3D interactive event display for the purpose of debugging and developing new ideas to improve performance of current algorithm.
- Next steps: will begin systematic optimization of code (scalar/algorithmic, vectorization, parallelization) to minimize computation time. Once optimizations are in place, will benchmark the algorithm on candidate platforms.

Event display for pixtrk
algorithm development
(M. Wang)

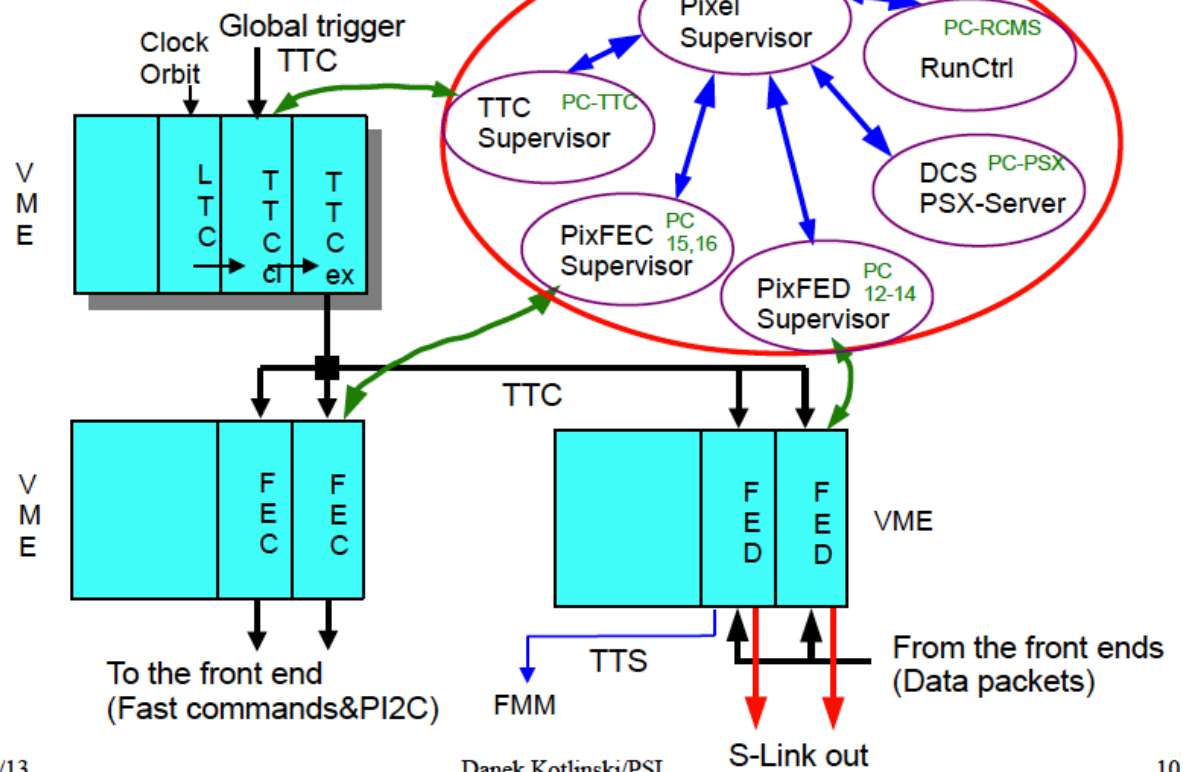


REMINDER: FEE & Readout system of current Pixel detector -> until Phase 1.

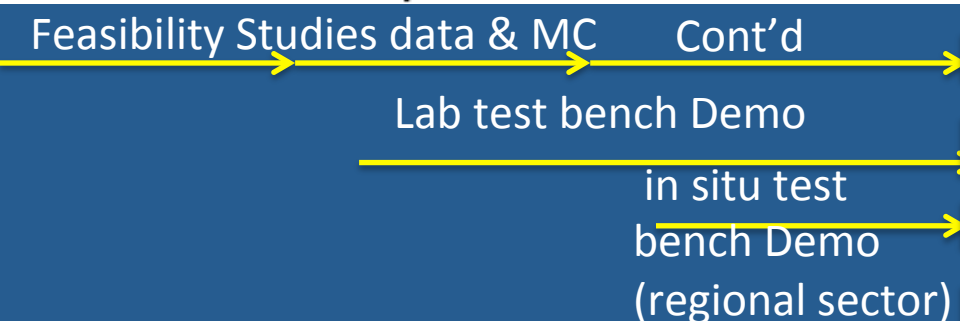
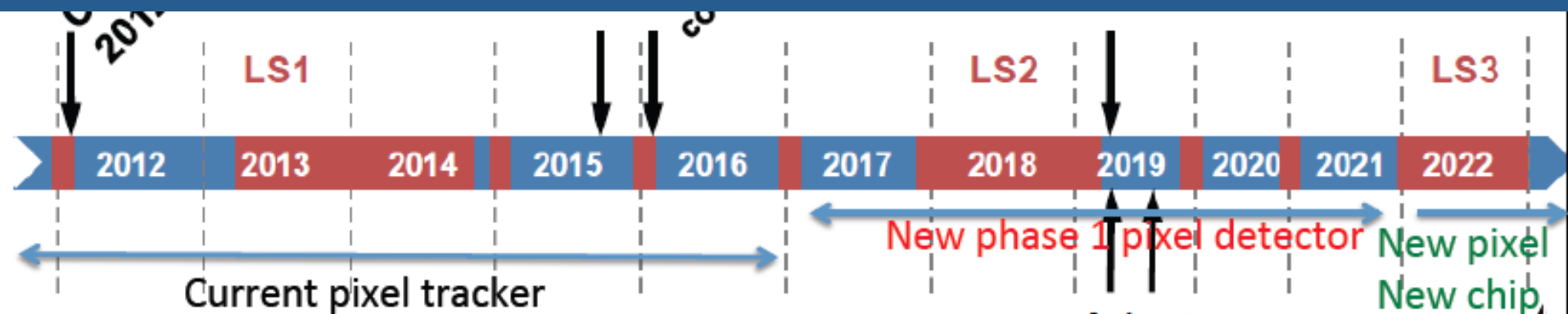
These last weeks:
 Instrumental contacts with PSI colleagues: H.C. Kaestli & Danek Kotlinski to understand the details of this system



Access to raw data: for training



Workplan & milestones & perspectives



These tools will be cont'd and kept evolving according results & decisions

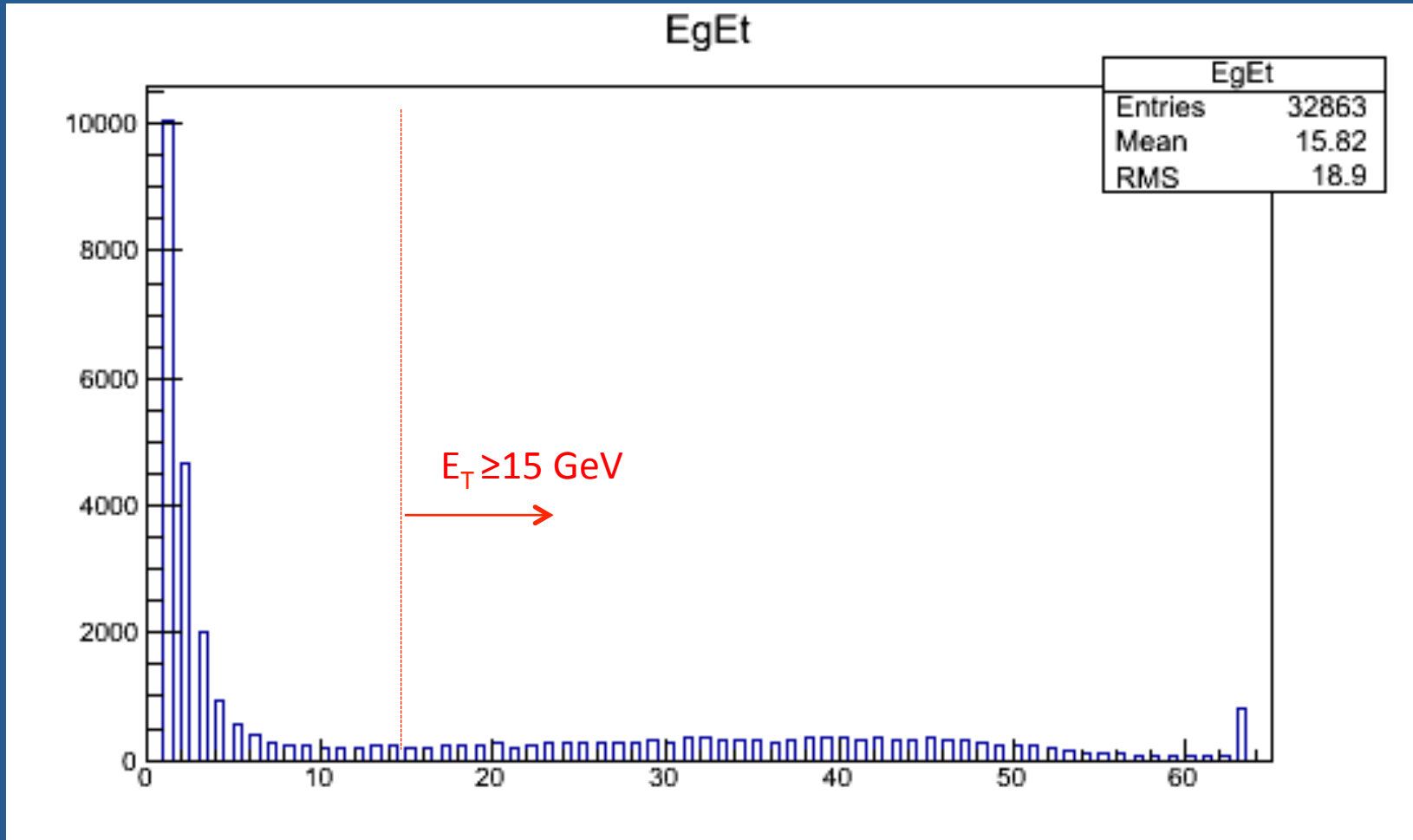
CRUCIAL "learning" /experiencing period

Different outcomes depending the results from the previous phase, with impact on:

- Need for extended L1-latency
- new FED and new chip designs
- Size of pixel size & +1 barrel (5th) layer?
- New pixel based primitives for HLT (?)

Backup slides

Et of L1 EM particles for ZEE Phase I MC (ZEE_14TeV_CMSSW_4_2_8_SLHCtk3_patch1)



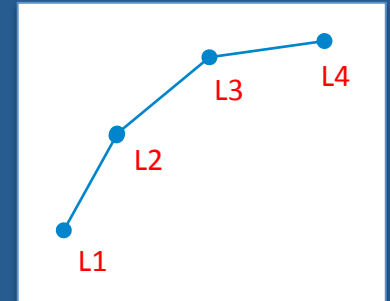
PiXTRK with Phase I Pixel track matching based on 5x5 EM cluster:

- Requirements on Pixel hits per layer to be aligned in phi with EM cluster
 - For each layer we request : | Z axis of Pixel Front-end Cluster | ≤ 30 cm. (Barrel region only)
 - Layer 1
 - Pixel Cluster radius ≤ 5 cm.
 - Dphi (Layer1 Pixel cluster phi, Ecal cluster phi) ≤ 0.2 // To find layer1 pixel clusters of phi regional interest.
 - Layer 2
 - Pixel Cluster radius > 5 cm & ≤ 8.5 cm.
 - Dphi (Layer2 Pixel cluster phi, Ecal cluster phi) ≤ 0.2 // To find layer2 pixel clusters of phi regional interest.
 - Layer 3
 - Pixel Cluster radius > 8.5 cm & ≤ 13 cm.
 - Dphi (Layer3 Pixel cluster phi, Ecal cluster phi) ≤ 0.3 /// To find layer3 pixel clusters of phi regional interest.
 - Layer 4
 - Pixel Cluster radius > 13 cm & ≤ 18 cm.
 - Dphi (Layer4 Pixel cluster phi, Ecal cluster phi) ≤ 0.3 // To find layer4 pixel clusters of phi regional interest.

PiXTRK with Phase I Pixel track matching based on 5x5 EM cluster:

- Requirements on Pixel track segments
 - Combination of aligned Pixel clusters in Layers 1 and 2 & aligned Pixel clusters in Layers 2 and 3 defined by:
 - $|D\theta(12_{23})| < 0.01$ and $|D\phi(12_{23})| < 0.02$, where:
 - $|D\theta(12_{23})| = \Delta(\theta_{L1L2}, \theta_{L2L3})$
 - $|D\phi(12_{23})| = \Delta(\phi_{L1L2}, \phi_{L2L3})$
 - Combination of aligned Pixel clusters in Layers 2 and 3 & aligned Pixel clusters in Layers 3 and 4 defined by:

- $|D\theta(23_{34})| < 0.01$ and $|D\phi(23_{34})| < 0.02$, where:
 - $|D\theta(23_{34})| = \Delta(\theta_{L2L3}, \theta_{L3L4})$
 - $|D\phi(23_{34})| = \Delta(\phi_{L2L3}, \phi_{L3L4})$



- Matching between regional Pixel track and corresponding EM cluster requirements:

- $|D\eta| < 0.085$ and $|D\phi| < 0.6$, where: // This is the Signal window for a 5x5 EM trigger tower.
 - $D\eta = \Delta(\eta_{L1L4}, \text{EM cluster } \eta)$
 - $D\phi = \Delta(\phi_{L1L4}, \text{EM cluster } \phi)$
 - As shown in the plot in the previous slide

