Forward pixels – on tracking at higher η in CMS

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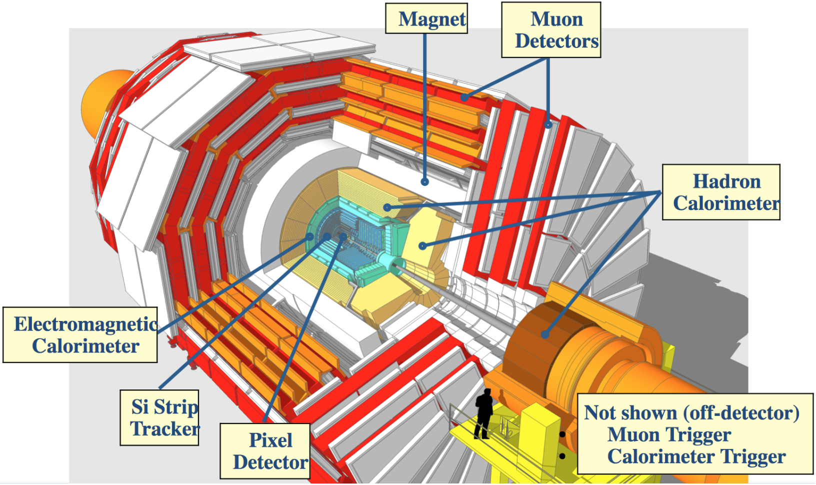
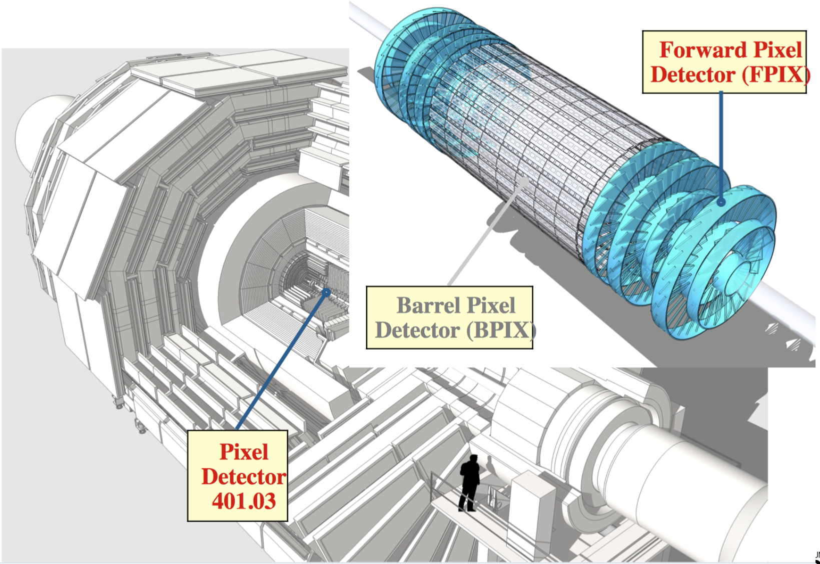
Introduction

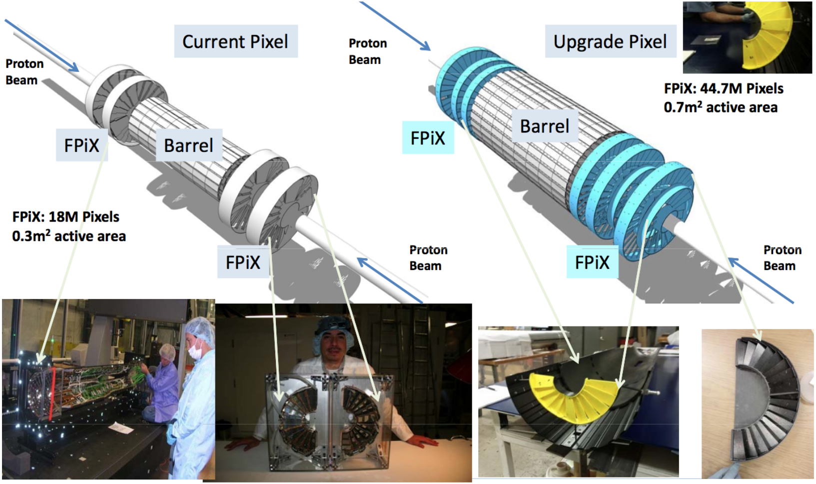


Introduction

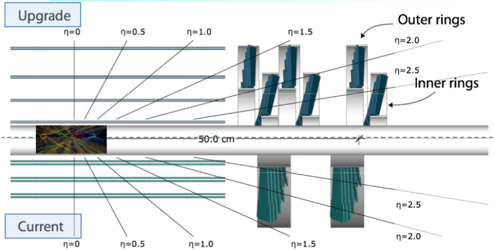


Overview

Phase-I forward pixels



Phase-I forward pixels



The **upgrade** is foressen to be installed at YETS2016

- Baseline: $L = 2 \cdot 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ @ 25 ns $\rightarrow$ 50 PU with negligible efficiency loss
- Tolerate: $L = 2 \cdot 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ @ 50 ns $\rightarrow$ 100 PU with reduced performance
- Survive integrated luminosity of $500\,\mathrm{fb}^{-1}$
- Evolutionary upgrade
- Robustify tracking: 4 instead of 3 hits; from 2 to 3 disks (*can* compensate point losses in strips)

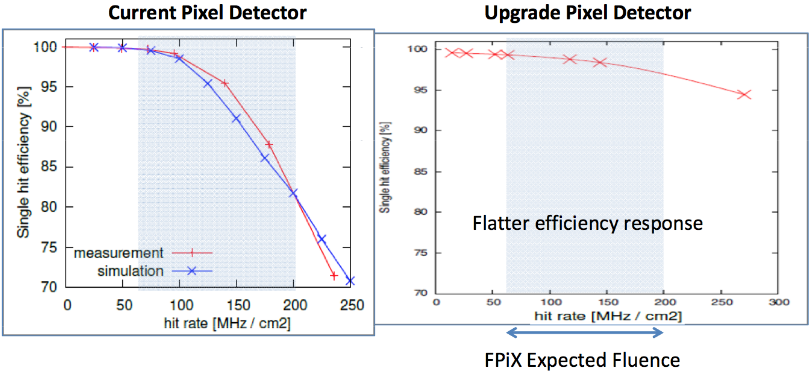
Phase-I: Motivation

Requirements (TDR)

- Running at 50 or more pile-up, same or better than current detector in low pile-up (PU)
  - Maintain or improve the high efficiencies and low fake rates
  - Maintain or improve the track impact resolutions and vertex resolutions
- Maximize 4-pixel-hit coverage over an η range of ± 2.5
- No increase of material in the tracking volume; Minimize degradation due to radiation damage
- Reuse patch panel and off-detector cables and fibers
- Have one FPix module type, simplifying production and maintenance
- Be compatible with the new smaller diameter beam pipe
- Switch to 2-phase CO_2 cooling, target -25°C
- Install during a slightly extended year-end technical stop

Phase-I forward pixels

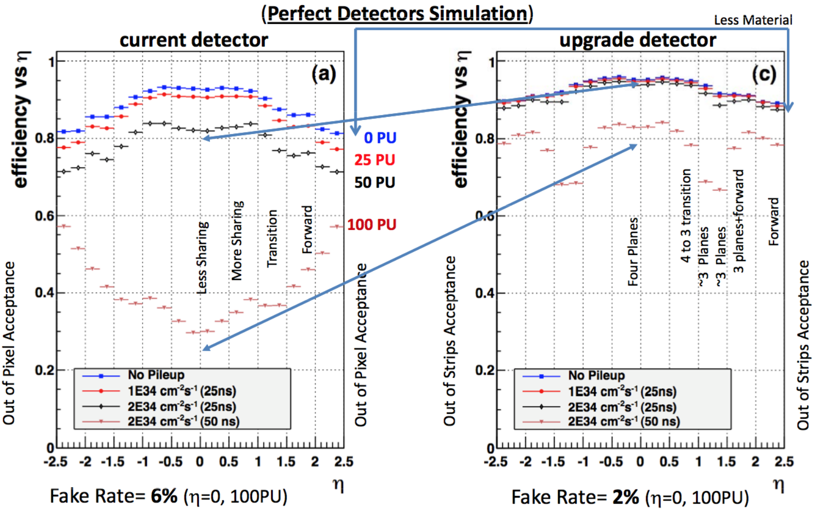
Plots show expected fluence in innermost disk:



Comparison based on x-rays.

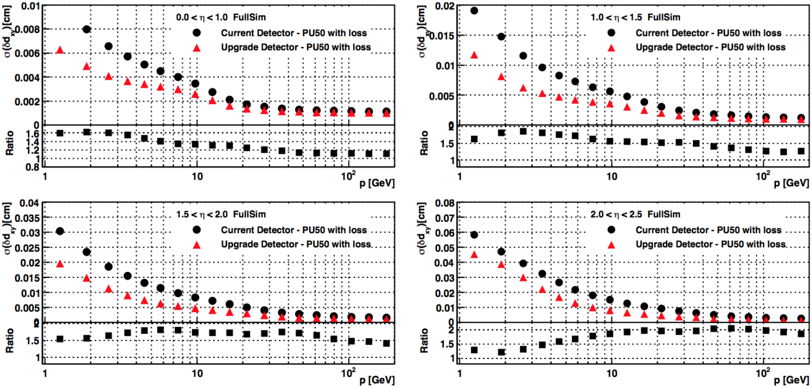
Phase-I forward pixels

Comparing old and new for efficiency:



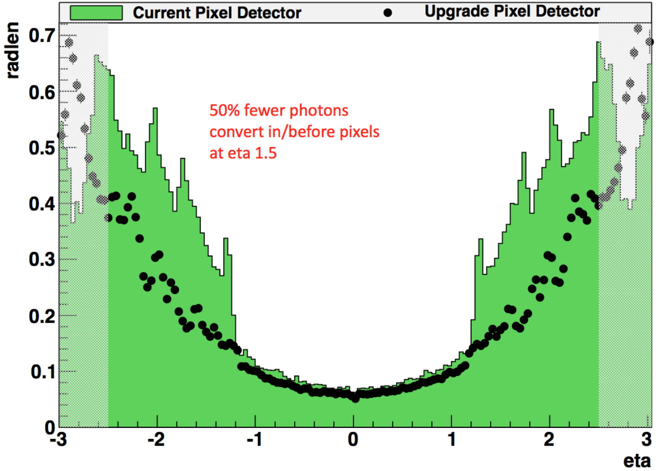
Phase-I forward pixels

Improvements in impact parameter resolution:



Phase-I forward pixels

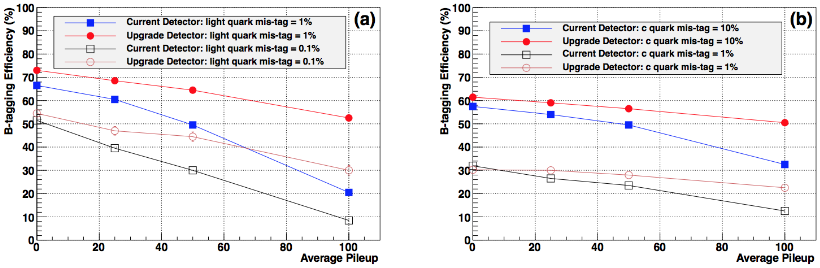
New design reduced mass



Biggest impact: optimized cabling, end-flange of barrel, cooling

Phase-I forward pixels

B-tagging efficiency



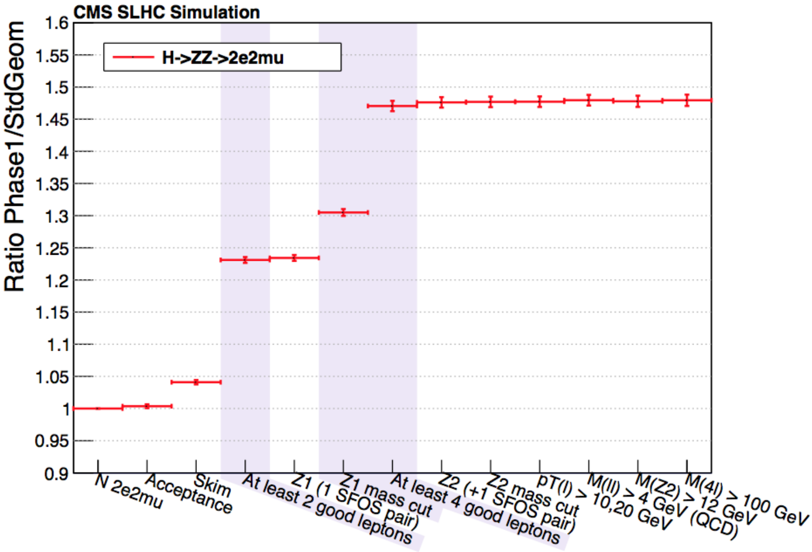
Phase-I forward pixels

One physics example: $H \to ZZ \to 4\ell$
Analysis does:

1. trigger on di-lepton
2. kinematic reconstruction of 2 Zs from isolated di-leptons
3. reconstruct invariant mass of H

Plot on next slide shows a *cut flow-chart* to emphasize on cuts that make the biggest improvement

Phase-I forward pixels



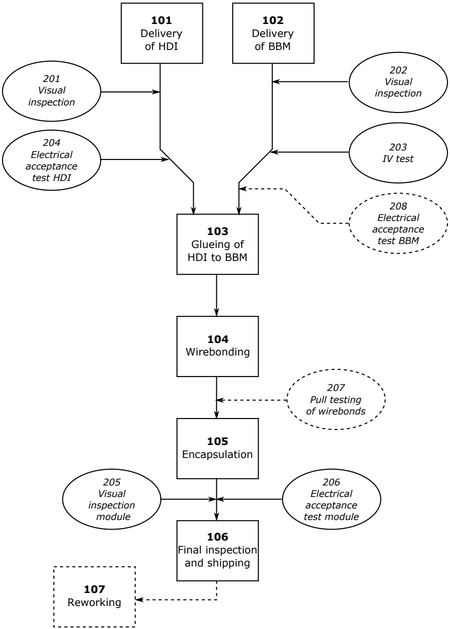
Phase-I forward pixels

Where are we?

- FPix passed CD reviews (critical decision), production can start
- Final pre-production of modules end of February
- Module production seems to work
- Mechanics starts now as well

Want to emphasize on some module manufacturing issues

Phase-I forward pixels

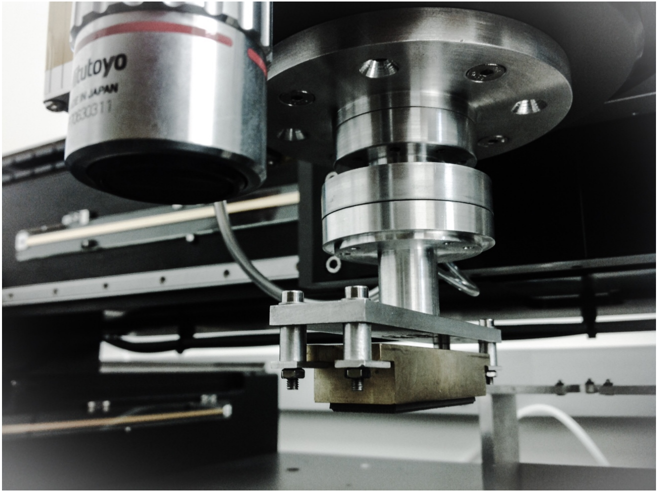


This is the workflow at UNL. The second production center, Purdue, differs slightly

We use a semi-automated manufacturing process using a robotic gantry, a Delvotec wirebonder and some test equipment

Bare modules (sensor + ROC) are made at a commercial vendor (RTI), as well as the HDI (Compunetics)

Phase-I: Motivation

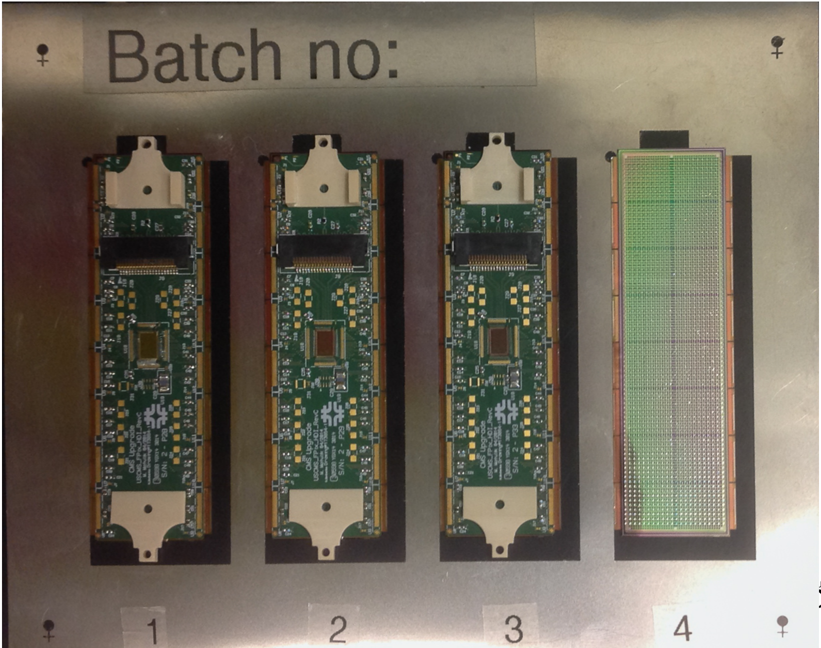


Phase-I forward pixels

https://www.youtube.com/watch?v=ofdntTIwKY4

Beware: it is not an action movie. . .

Phase-I forward pixels



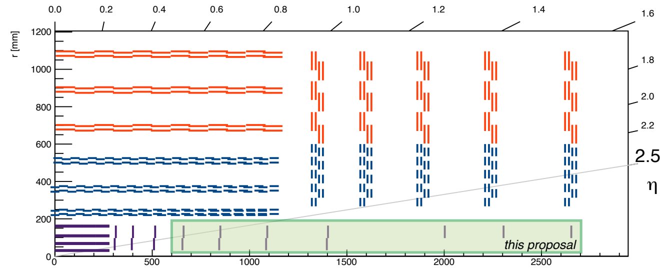
Phase-II forward pixels

- Phase-II is beyond about 2023
- 10$\times$ more instantaneous luminosity, even more PU
- Major challenge
- Simply said: what layer 1 of the barrel is in Phase-I would become the outer layers and new technology will be needed for innermost layer(s)

I will focus on some very forward studies and will briefly come back to this at the end

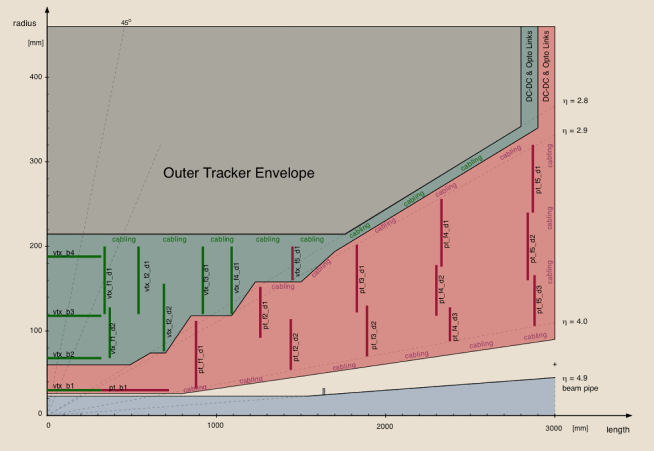
Very forward pixels

- VFPix effort studies optins in high pseudorapidity tracking using optimised pixels ($2.5 < |\eta| < 4.0$)
- Worked on three areas:
  - **Simulation:** Explore physics potential and resolution impact by studying different strawmans and pixel cell geometries
  - **Sensor R&D:** Explore potential of other pixel sizes than currently in use
  - **Hardware:** Finish up the construction of a precision telescope (from a PIRE project)
- Will flash status on all three areas.
- Baseline layout from TP:



Very forward pixels

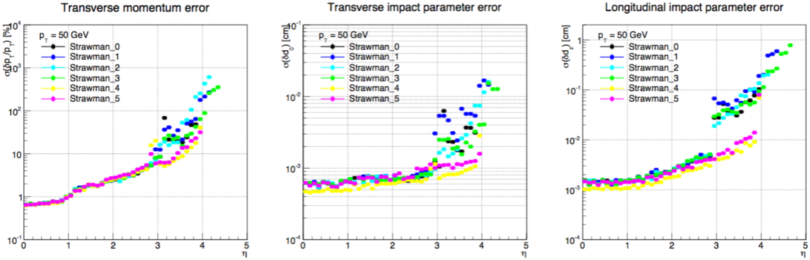
Latest proposal (strawman 5):



Observe: Extended inner layer, two types of modules. Has insertion already in mind.

Simulations

Results from `TkLayout` studies:



Strawman 0: TP; Strawman 5: Previous slide.
Pixel size is $75 \times 100\,\mu m^2$. Estimated resolutions were (assuming digitized analog pulse-height and charge sharing based on mounting angle/B-field):

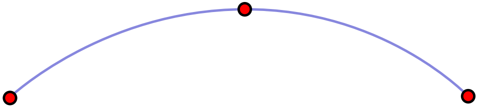
FPix/VFPix: $6.8 \times 28\,\mu m^2$
BPix: $6.8 \times 14.8\,\mu m^2$

Details: `https://twiki.cern.ch/twiki/bin/view/CMS/VFPi`

Simulations

This already allows to justify the importance of a well-chosen envelope.

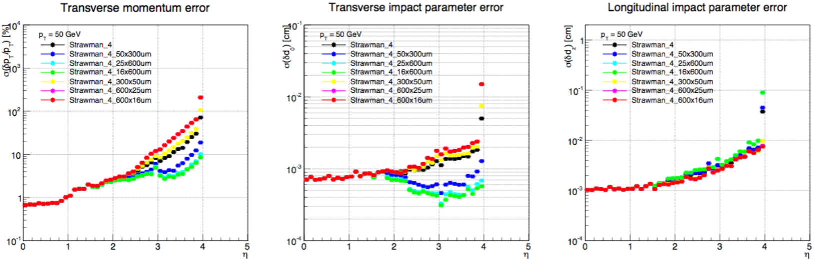
- Conical geometry performs better than cylindrical
- Keep in mind: there is a strip tracker around this volume
- For a good p_T measurement, three points need to be measured to good precision:



- Why do we need good p_T? Think of calorimetry and *particle flow*

Simulations

Results from `TkLayout` studies:



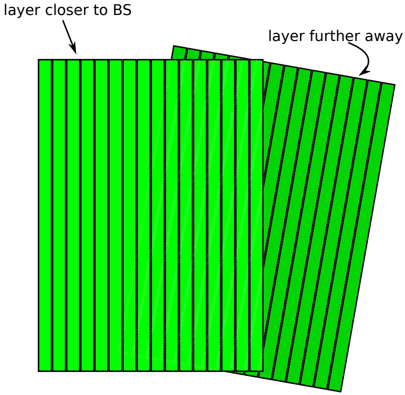
Strawman 4, similar to 5

Observe: To establish charge of a track, a good p_T resolution matters, even one is tempted to optimize on z resolution

NB: p_T resolution comes from lever arm and hit resolution, z resolution dominated by distance to first hit

Simulations

How to recover z resolution?



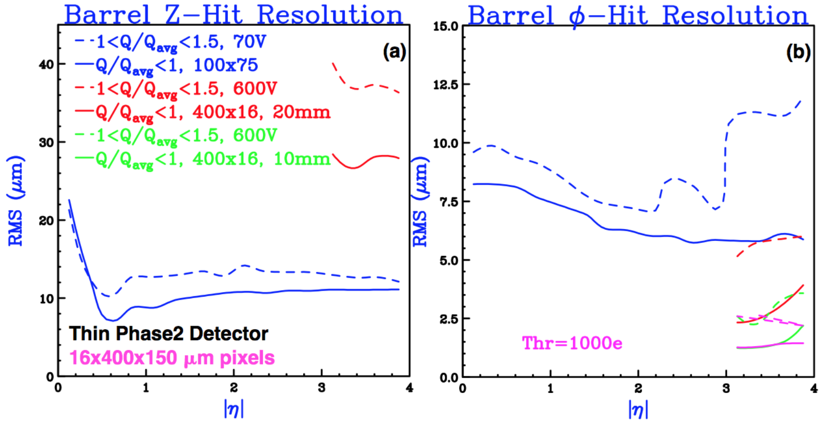
Overlap helps. Some we get in the disks "for free", some downstream.

The resolution studies already have some assumptions on z resolution beyond just the local pixel resolution.

Simulations

Hot off the press: Resolution studies using PixelAV (courtesy Morris Swartz)

First look at unirradiated barrel 100x75x150μm and high η barrel with 400x16x150um sensors. First look at high η [solid/dashed red] was surprisingly poor: 2-4 and 5-6 μm!!



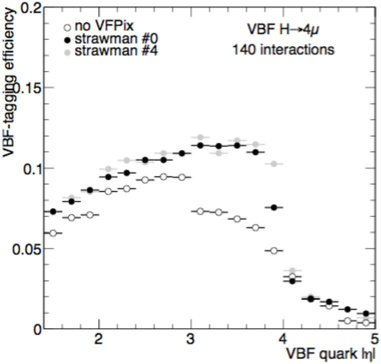
Simulations

Next steps here:

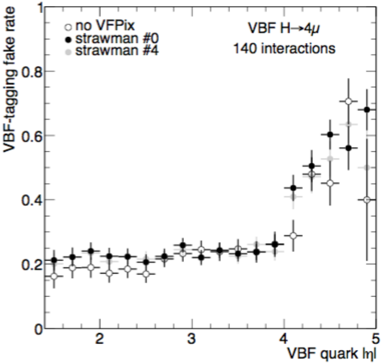
- Use this information in TkLayout simulation
- Have to deal with clusters of size 30. . . – but we already have some ideas how to handle this
- ROC: psi46 architecture can be translated into more advanced technologies. I.e. 110 nm offers reduction of pixel cell by factor 5, good for pixels of size $60 \times 90\,\mu\mathrm{m}^2$. Would allow for evolutionary design.

Simulations

Results from `Delphes` using resolution data from `TkLayout`:



efficiency

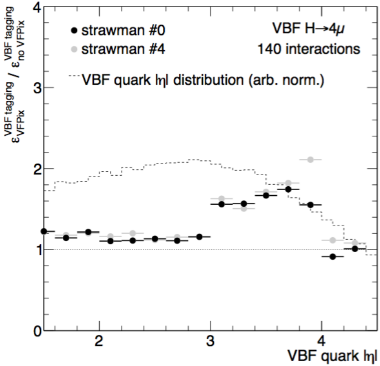


fake rate

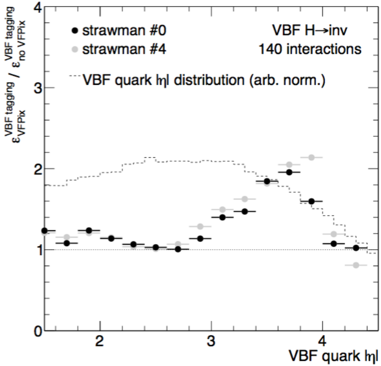
Details: See TWiki, table of presentations.

Simulations

Results from Delphes using resolution data from TkLayout:



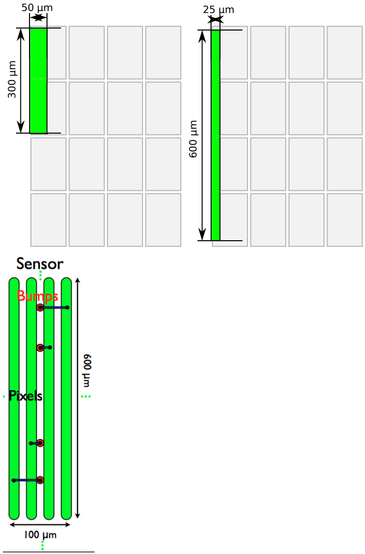
VBF H→4μ



VBF H→inv

Details: See TWiki, table of presentations.

Sensor R&D:



- All our pixel geometries used same area
- Want to study resolution using some clever metal layer routing
- Made a sensor design good for current Psi46 pixel, available spring 2015
  Disadvantage: increased capacitance, of course
- Will have 300 $\times$ 50 μm^2 and 600 $\times$ 25 μm^2 geometries

Hardware

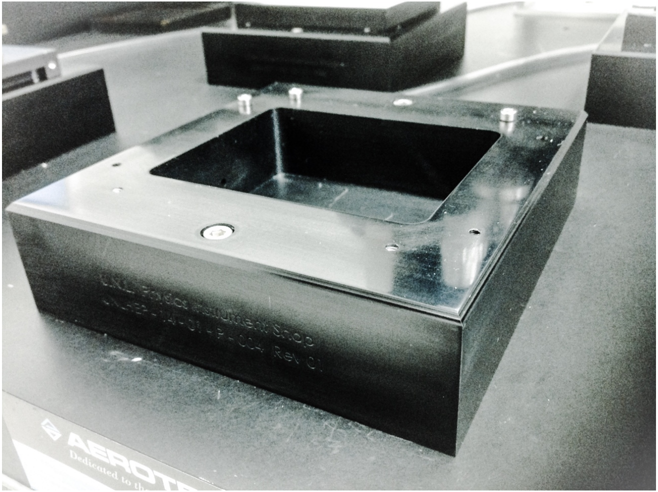
- We work on external triggering and soft TBM for the DTB
- Build a telescope based on PIRE project
- Uses thinned-down strip sensors with 25 μm pitch
- APC128 chip with analog readout
- Telescope had some issues with signal quality. Improving that to get decent S/N
- Should be ready in spring 2015
- Target resolution: $\approx 1\,\mu m$

Conclusions

- Established simulation chain
- Resolution studies show very nice results
- One physics case studies with clear benefit from VFPix
- More physics channels in the come
- Hardware studies will soon start as well
- Telescope should be available for beam tests
- Will keep you updated

Conclusions

- Phase-I forward pixel ongoing and on track
- For Phase-II, I've shown some studies we did for very forward tracking
- Efforts ongoing

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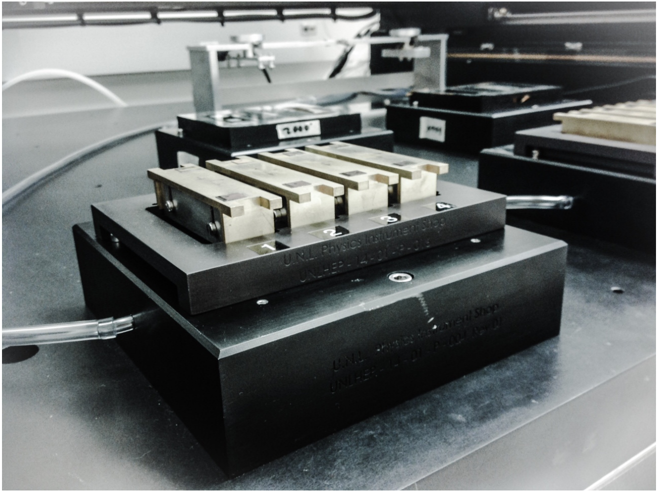
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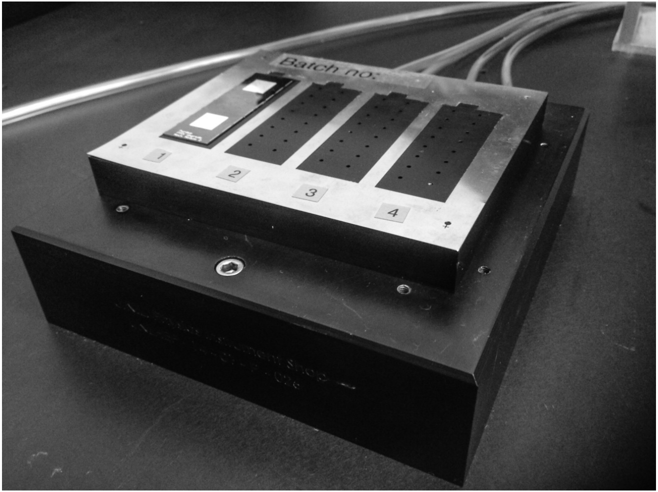
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