Technical Proposal for the Upgrade of CMS Pixel Detector

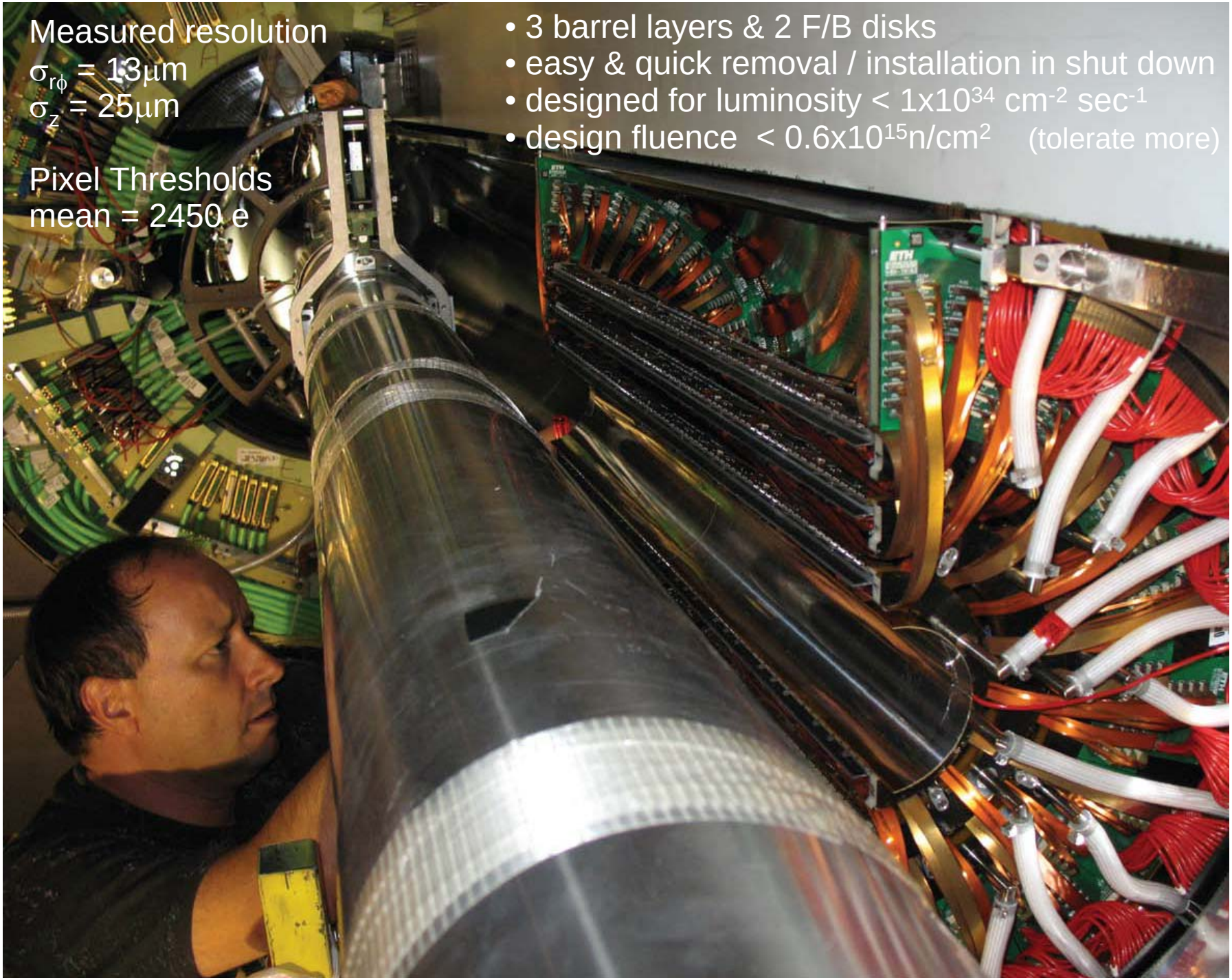
LHCC Meeting at CERN

16. November 2010

R. Horisberger, PSI

on behalf of the CMS Tracker Upgrade Group

Present Pixel Detector with 3 hit coverage works very well !

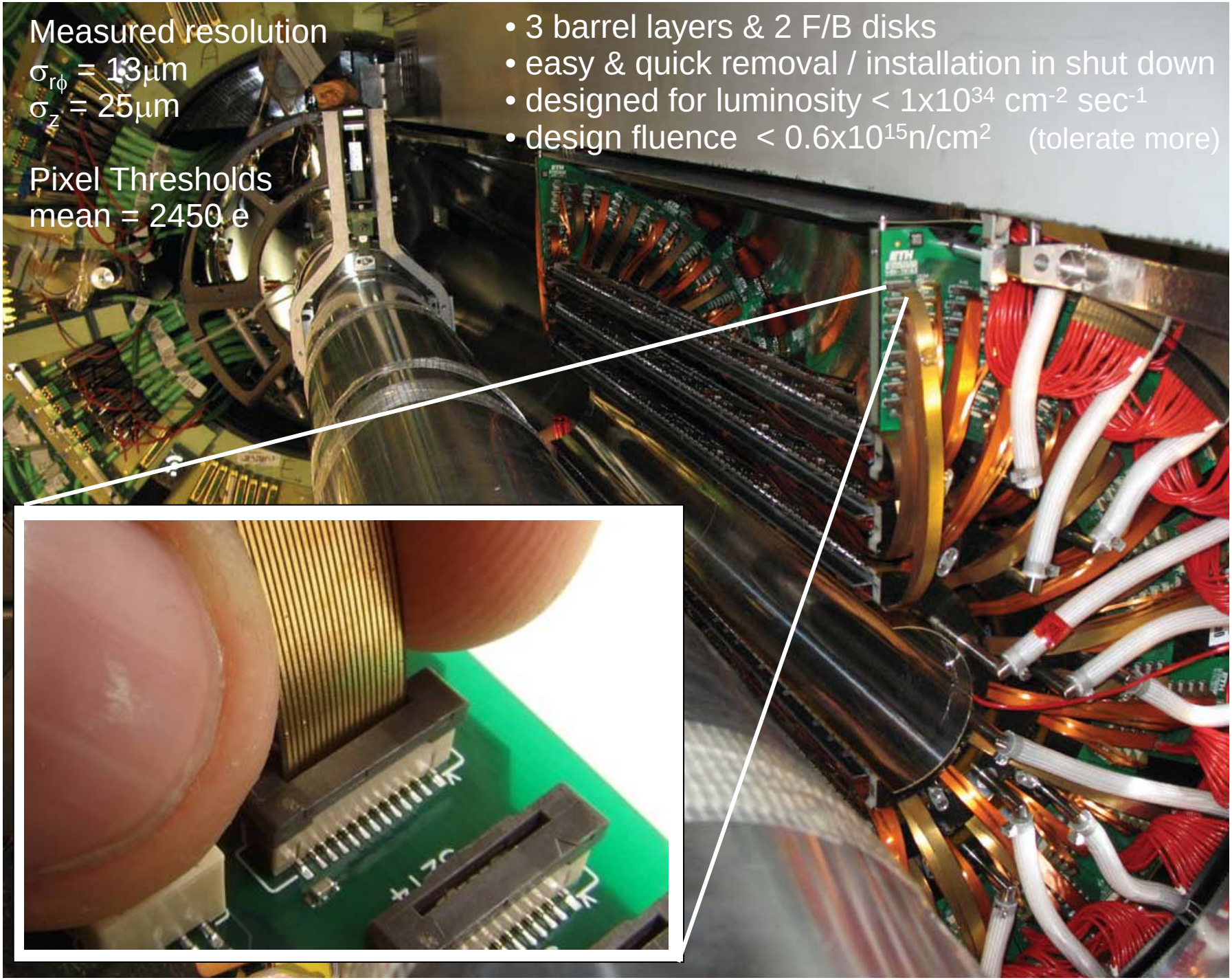


Present Pixel Detector with 3 hit coverage works very well !

Measured resolution
$\sigma_{r\phi}$ = 13μm
σ_z = 25μm

Pixel Thresholds
mean = 2450 e

- 3 barrel layers & 2 F/B disks
- easy & quick removal / installation in shut down
- designed for luminosity < $1x10^{34}$ cm^{-2} sec^{-1}
- design fluence < $0.6x10^{15}n/cm^2$ (tolerate more)



Proposed Pixel Upgrade

- BPIX 3 Layer → 4 Layers
- FPIX 2x2 Disk → 3x2 Disk

Increase number pixel tracking points 3 → 4

- CO_2 cooling based Ultra Light Mechanics
- Shift material budget out of tracking η–region

Significant X/X_0 reduction

- Minimize 1 Layer radius

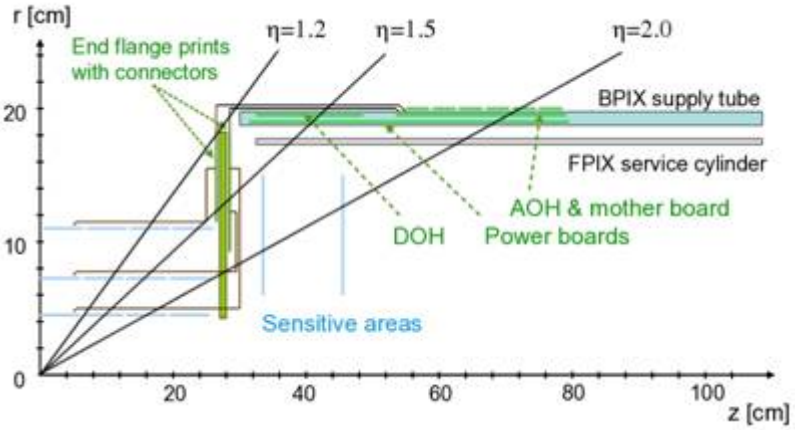
reduced impact δ_{xy} & δ_z error

- ROC modifications for operation up to L ~ $2x10^{34}$
- Use same cabling → DC/DC converters for power
  → 320MHz digital readout on fibres

→ pixel tracking & vertexing significant improved and robustified

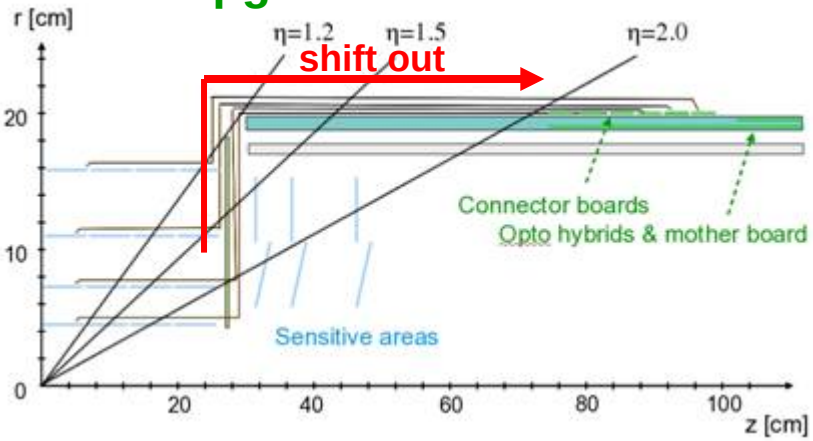
Shift material budget out of tracking region

Current BPIX Services

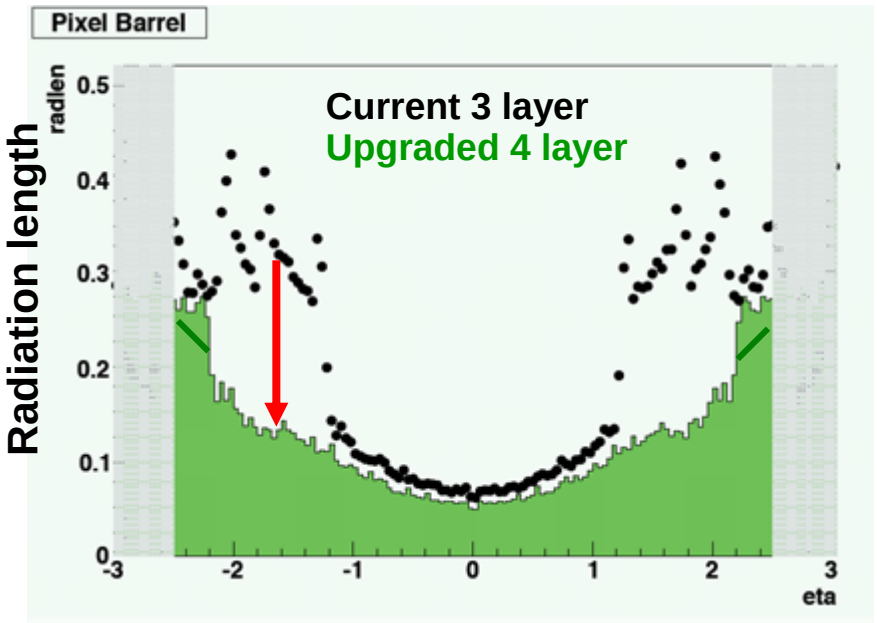


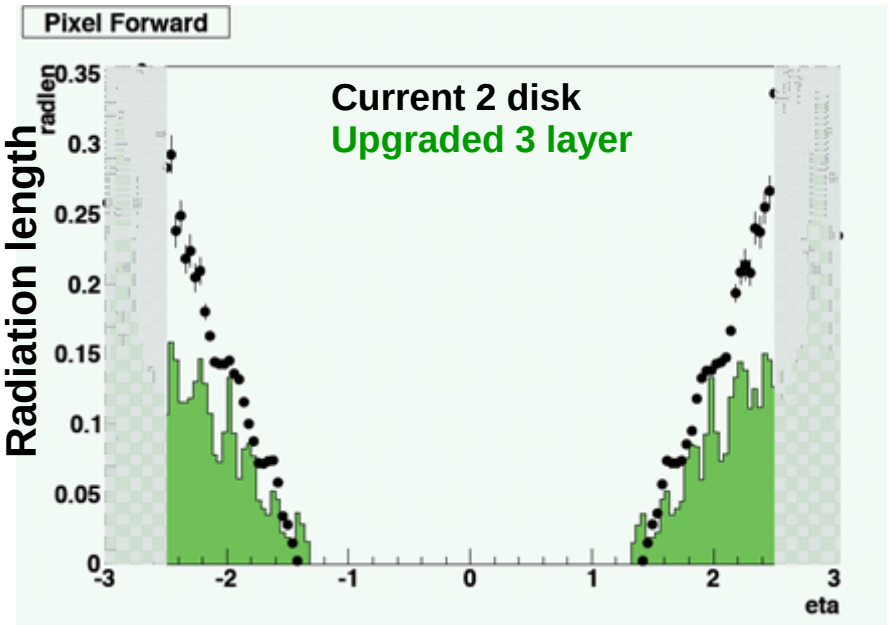
η<2.2 : weight = 16.9 Kg (3 layer)

Upgraded BPIX Services



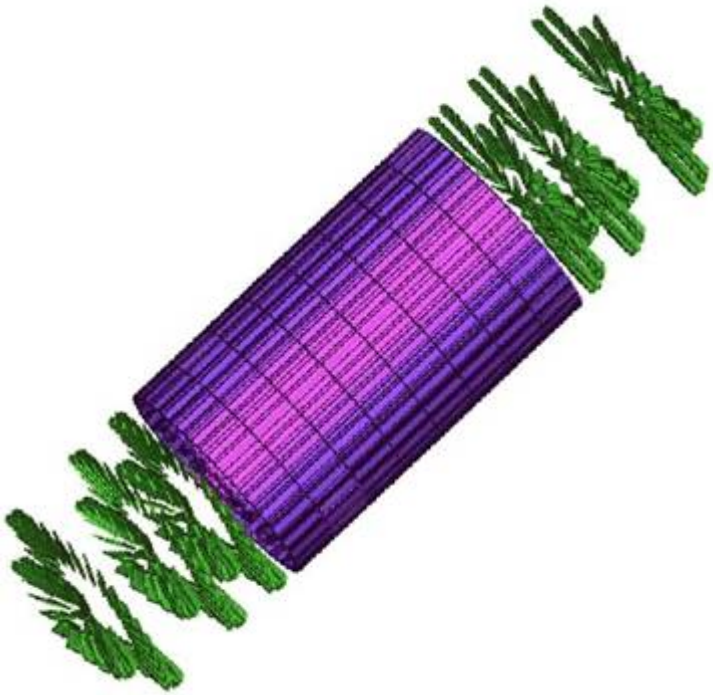
η<2.2 : weight = 6.5 Kg (4 layer)

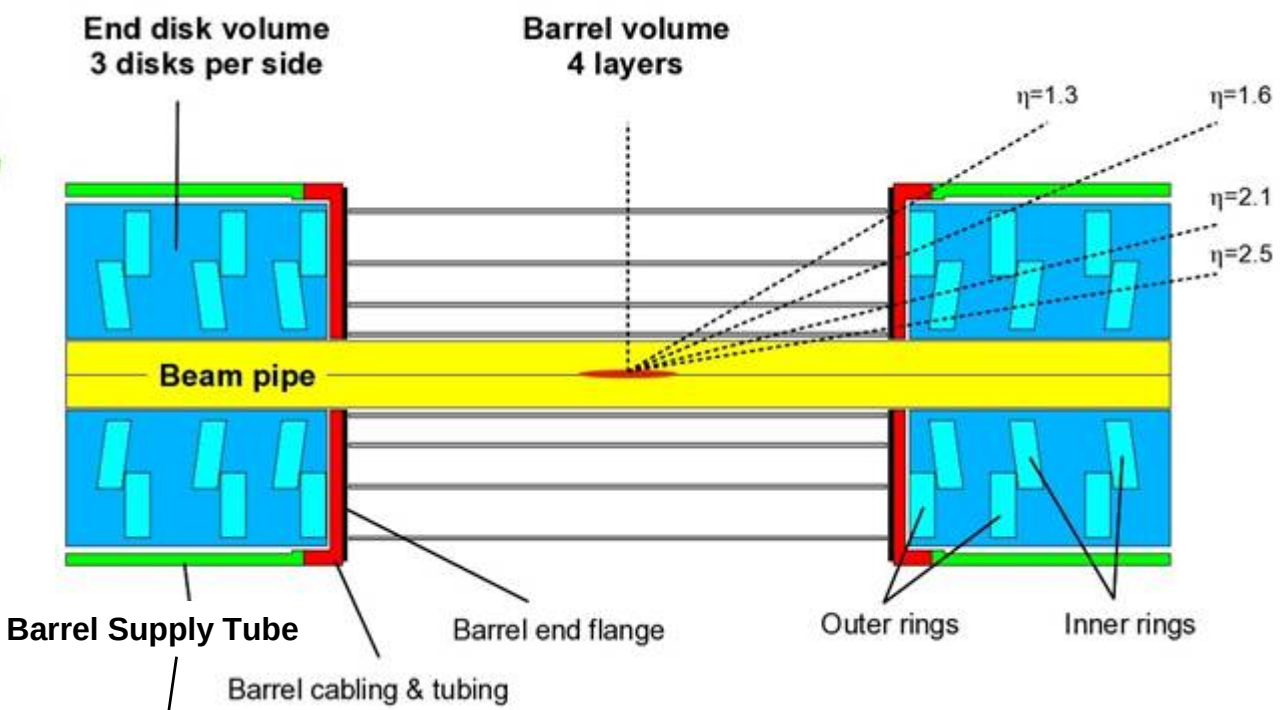




η ~1.5 : γ-conversion for H→ γγ from 22% to 11% for new 4 Layer Pixel System

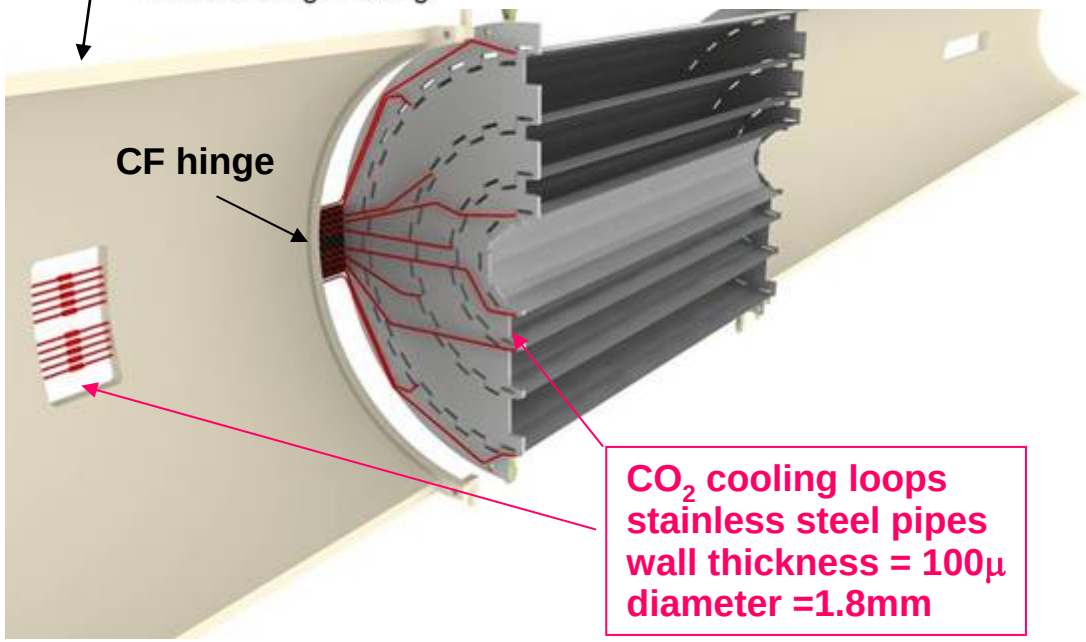
BPIX / FPIX Envelope Definition & Insertion into CMS





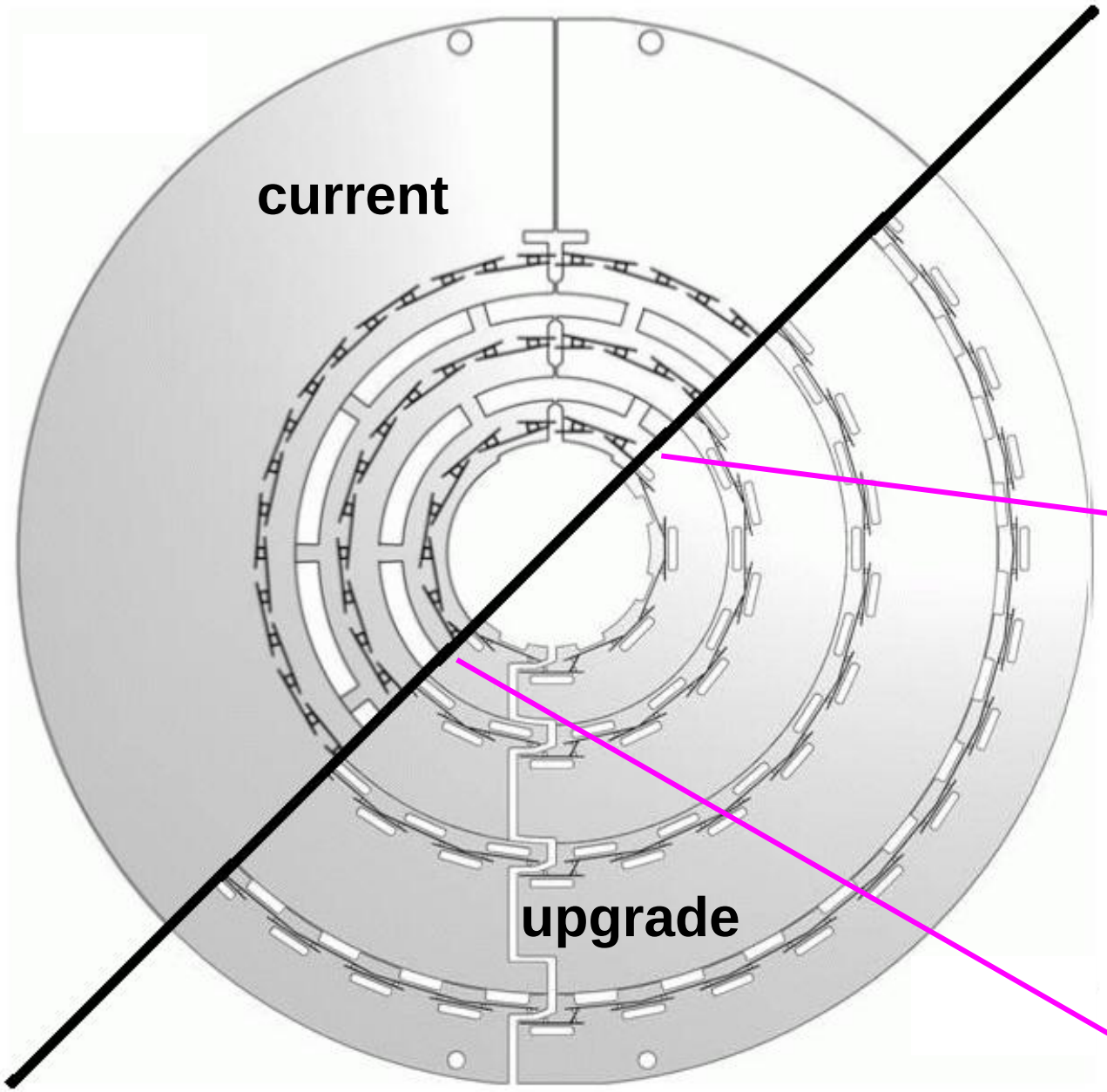
Insertion of new system verified





BPIX Upgrade Mechanics

→ 1216 modules → 81M pixel
(1.6 x present BPIX)



baseline

- Full module type only

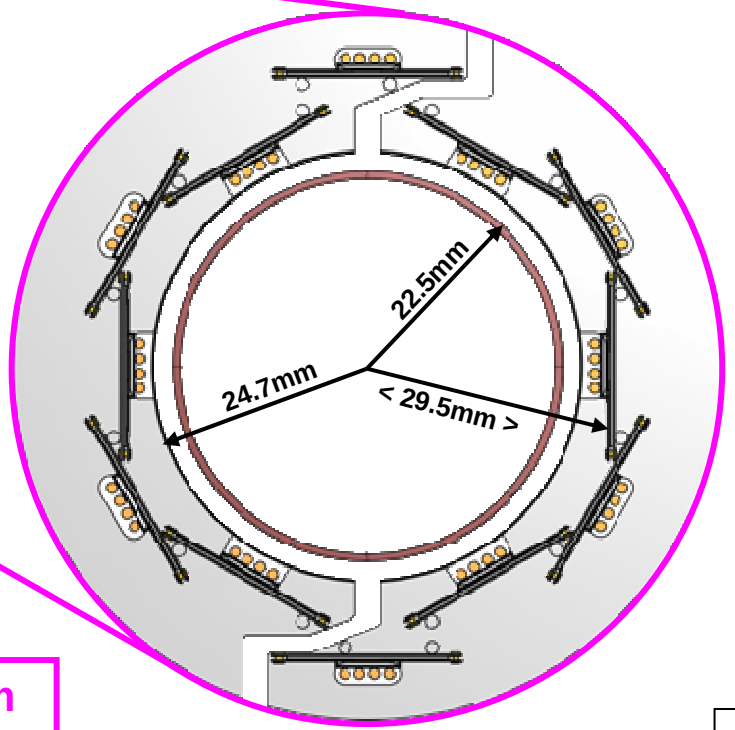
Layer 1: R 39mm; 16 faces

Layer 2: R 68mm; 28 faces

Layer 3: R 109mm; 44 faces

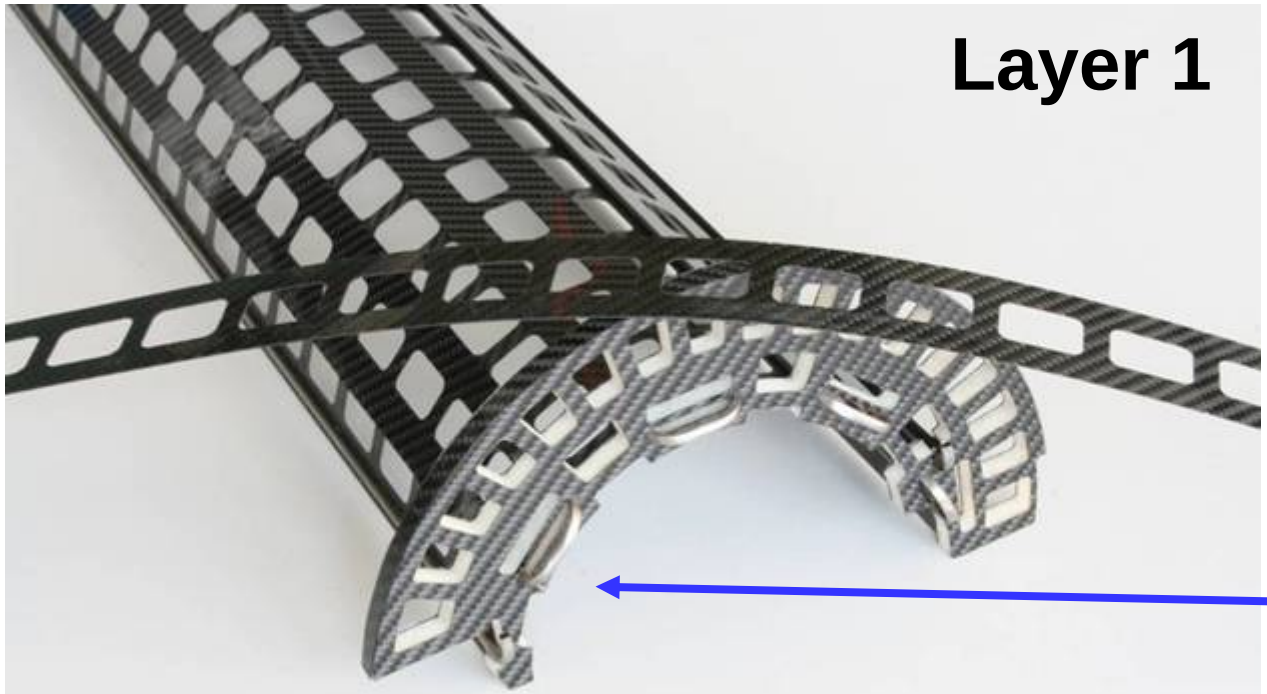
Layer 4: R 160mm; 64 faces

Clearance to beam pipe 4mm (present)



If beam pipe r < 22.5 mm → 1st Layer: 12 faces <R>=29.5mm

Ultra Light Mechanics BPIX Prototype

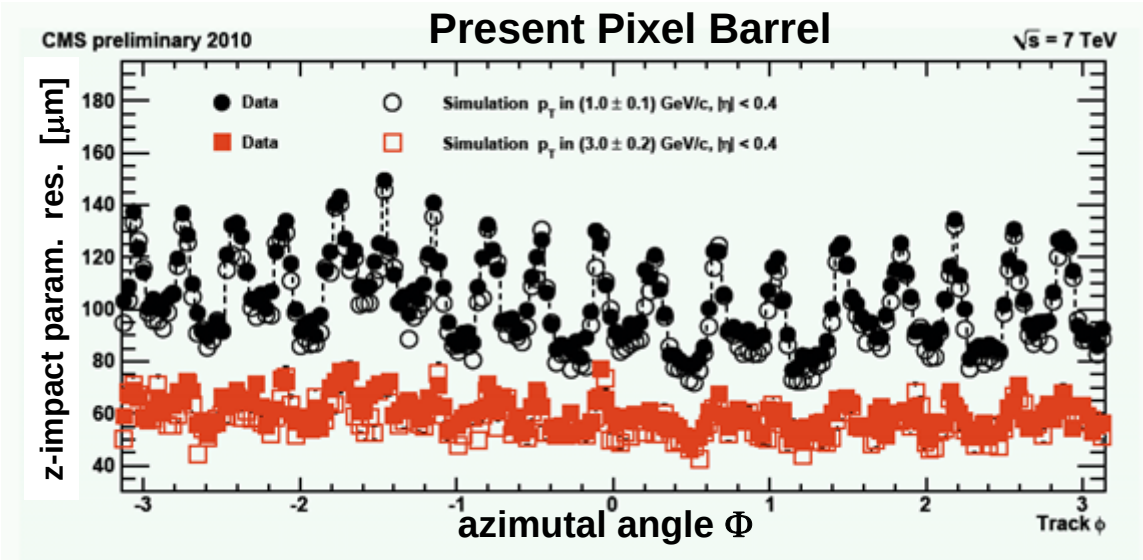


100 bar pressure tested
Tubes, 50μ wall thickness

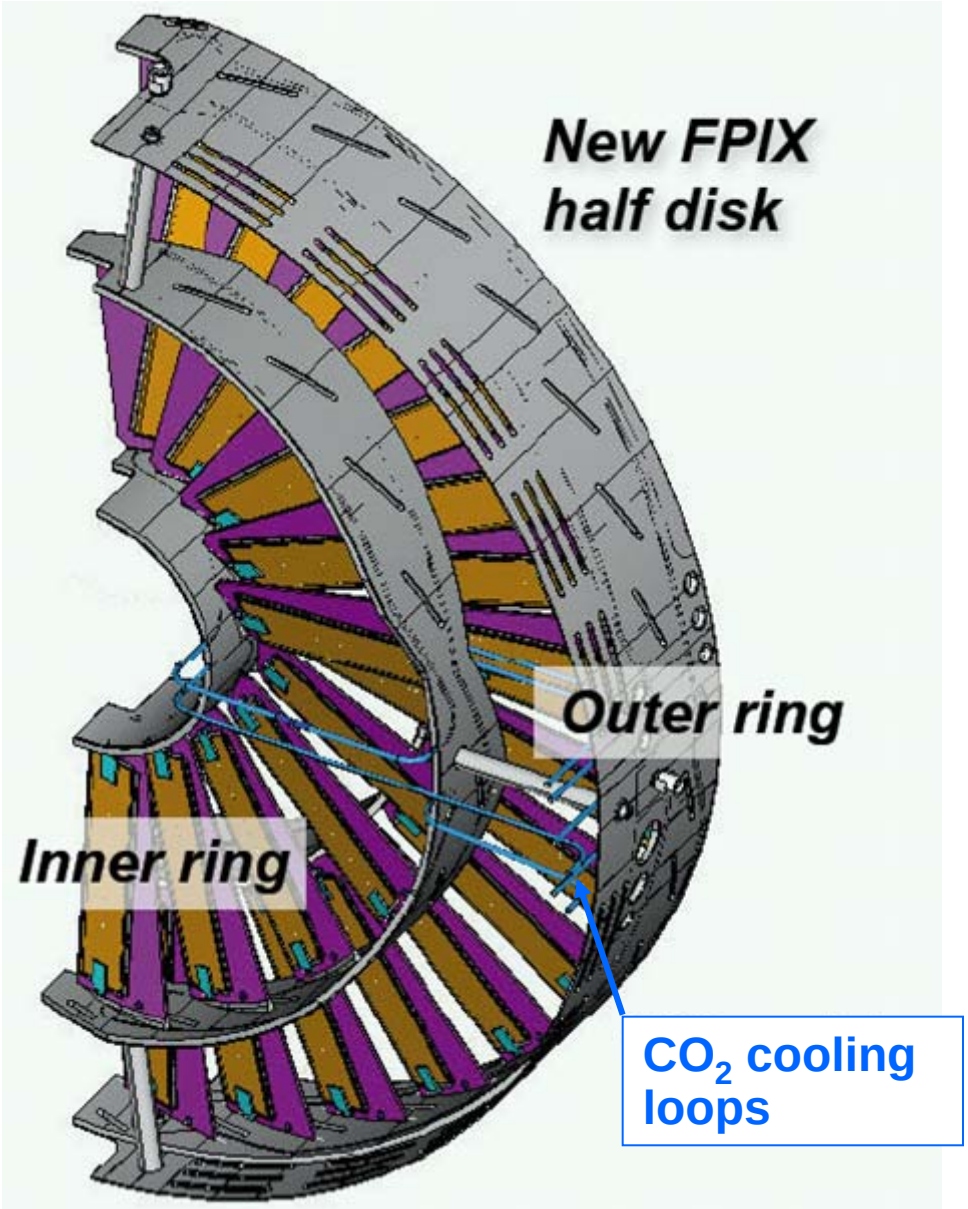
Weight Layer1 42g + 7g CO_2 → 30% of old first layer X/X_0

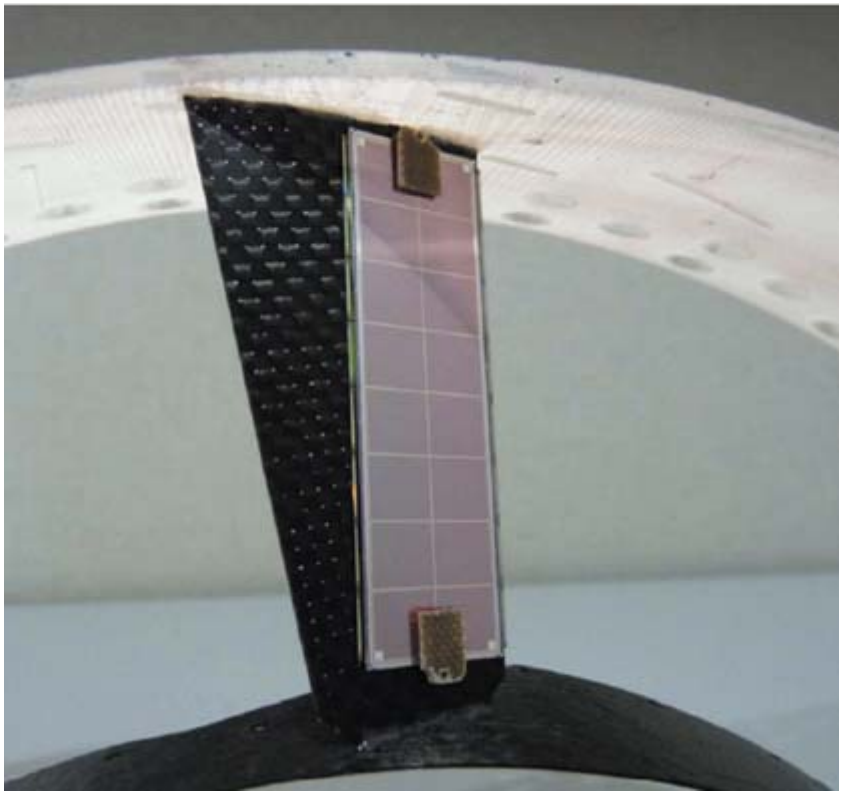
Low mass CO_2 cooling pipes

→ less multiple scattering in impact parameter resolution



FPIX Mechanics & Prototype



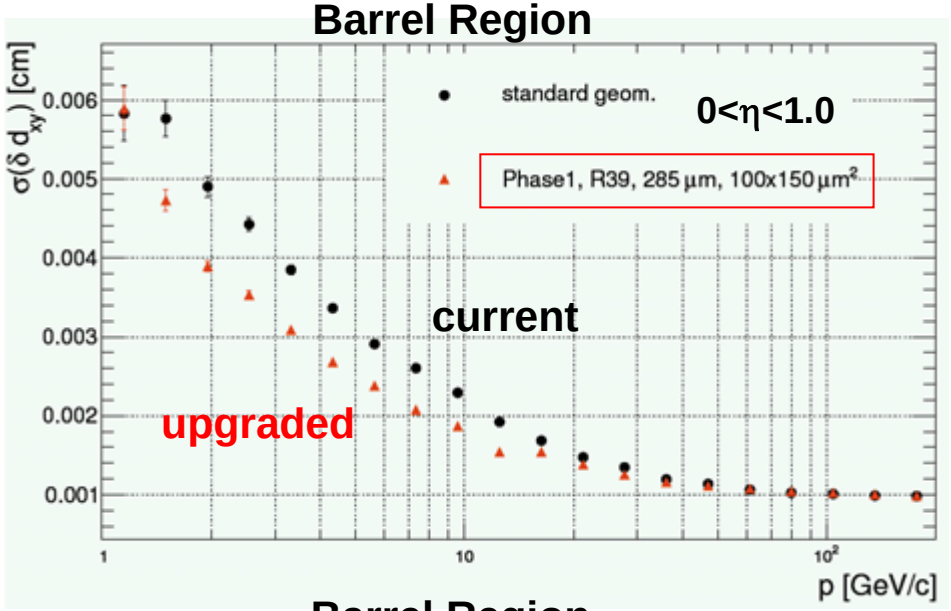


- inner & outer ring for easier replacement
- 6 disk of 112 sensors each → 672 modules
- one module size with 2x8 ROC / module

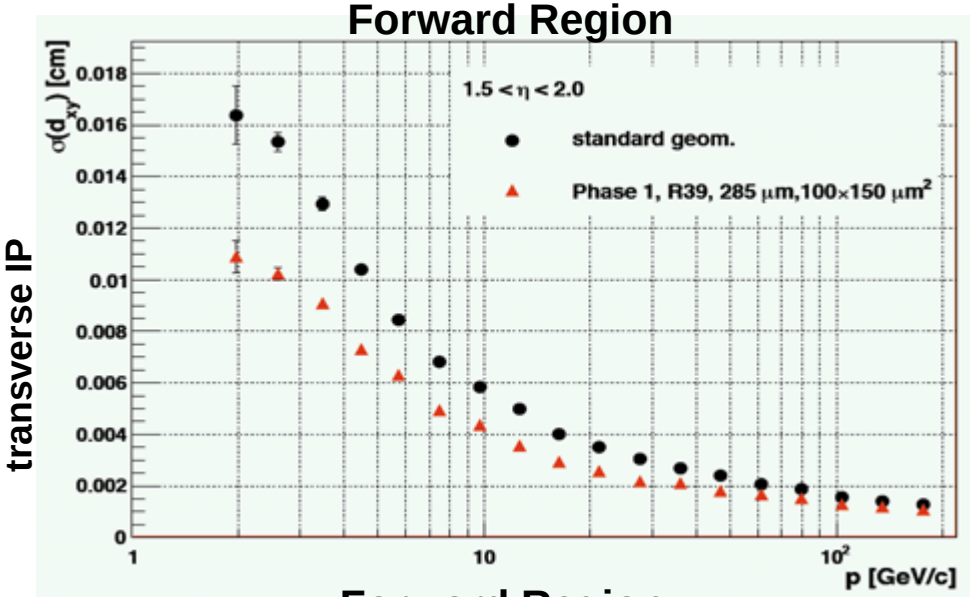
→ 10'752 ROC's ~ 44M pixel (2.5 x old FPIX)

Impact Parameter of old / new Pixel System

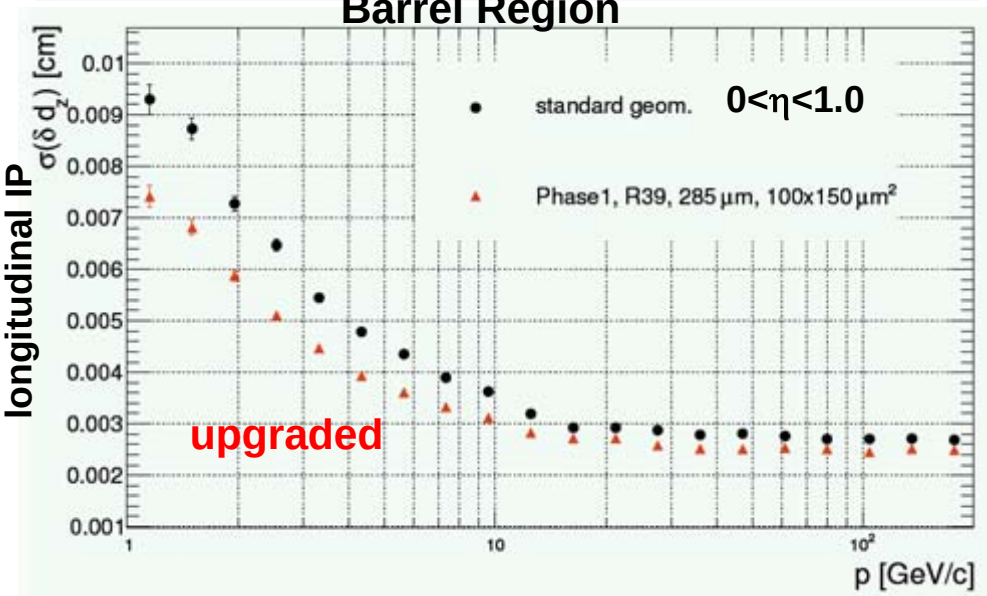
transverse IP



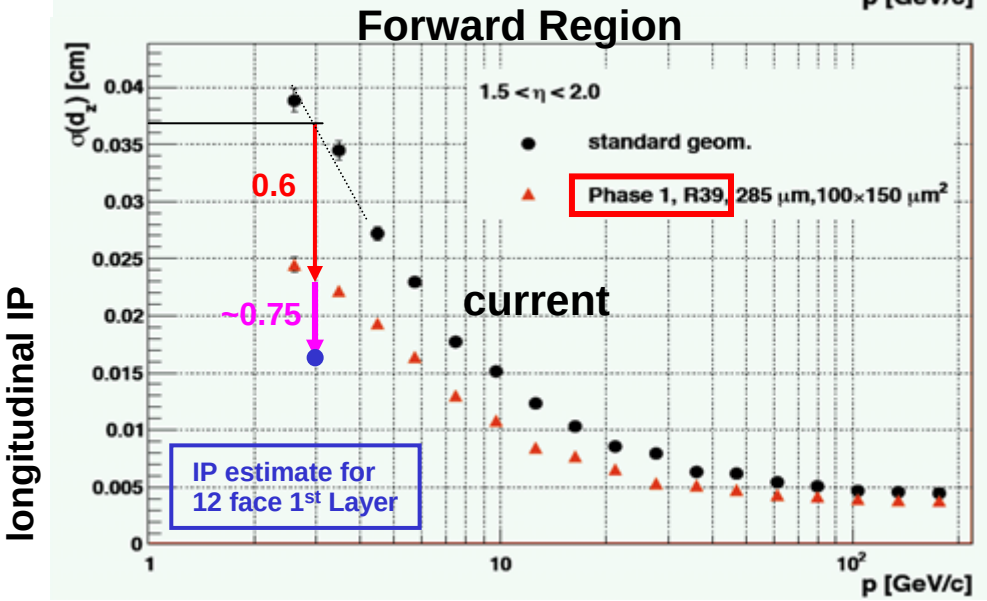
transverse IP



longitudinal IP

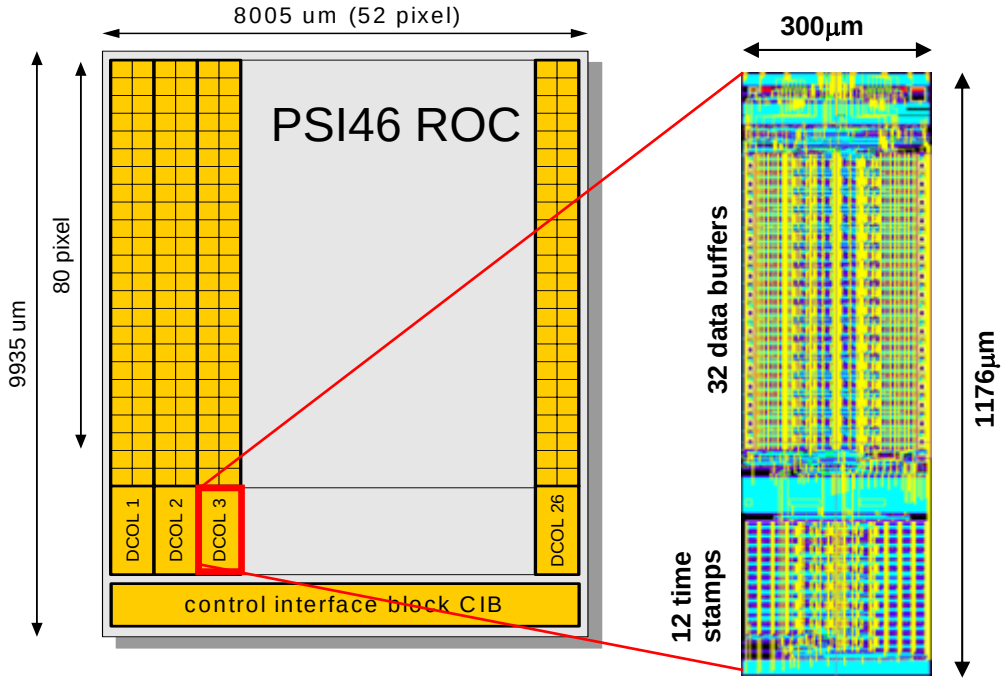


longitudinal IP



Beam pipe r<23mm : 16 faces to 12 faces → reduce MS term by ~0.75 → total 0.75x0.6 = 0.45 !

Upgrade of Pixel Readout Chain



Present ROC for 1st Layer:

Luminosity	bx-spacing	Data Loss
$1x10^{34}cm^{-2}s^{-1}$	25nsec	4%
	50nsec	16%
$2x10^{34}cm^{-2}s^{-1}$	25nsec	15%
	50nsec	~50%

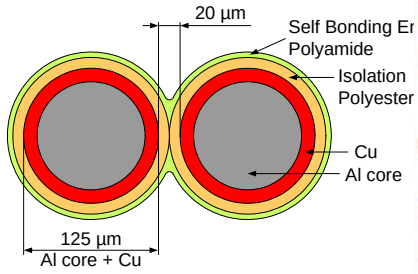
50nsec operation of LHC was not planned in original ROC architecture in 1998.

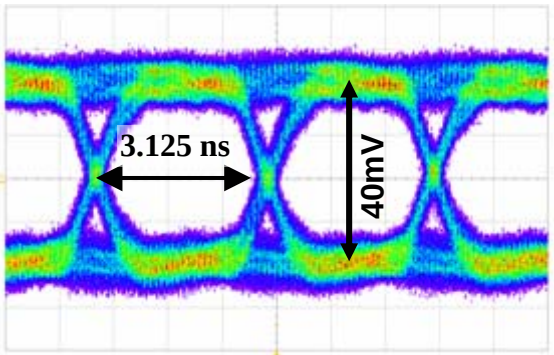
Data losses removed by ROC changes:

	Status
1) increase depth of	
- data buffer 32 → 80	done
- timestamps 12 → 24	done
2) add readout buffer	done
3) 160Mbit/sec serial binary data out	now
4) deal with PKAM events → DAQ resync	

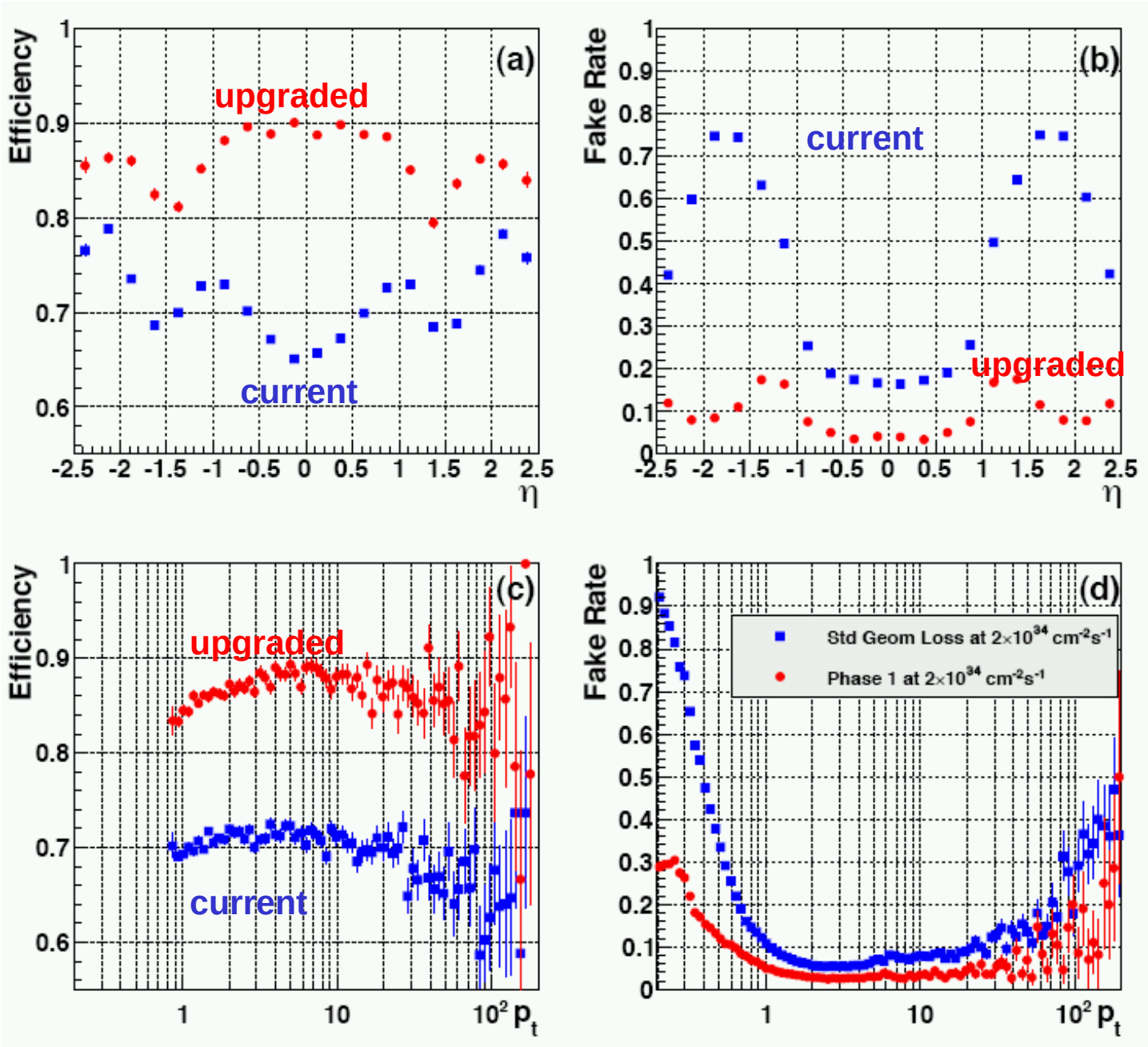
µ-twisted CCA pair (**C**opper-**C**ladded **A**luminum)

- 1m long low mass link at 320MHz , chips done !





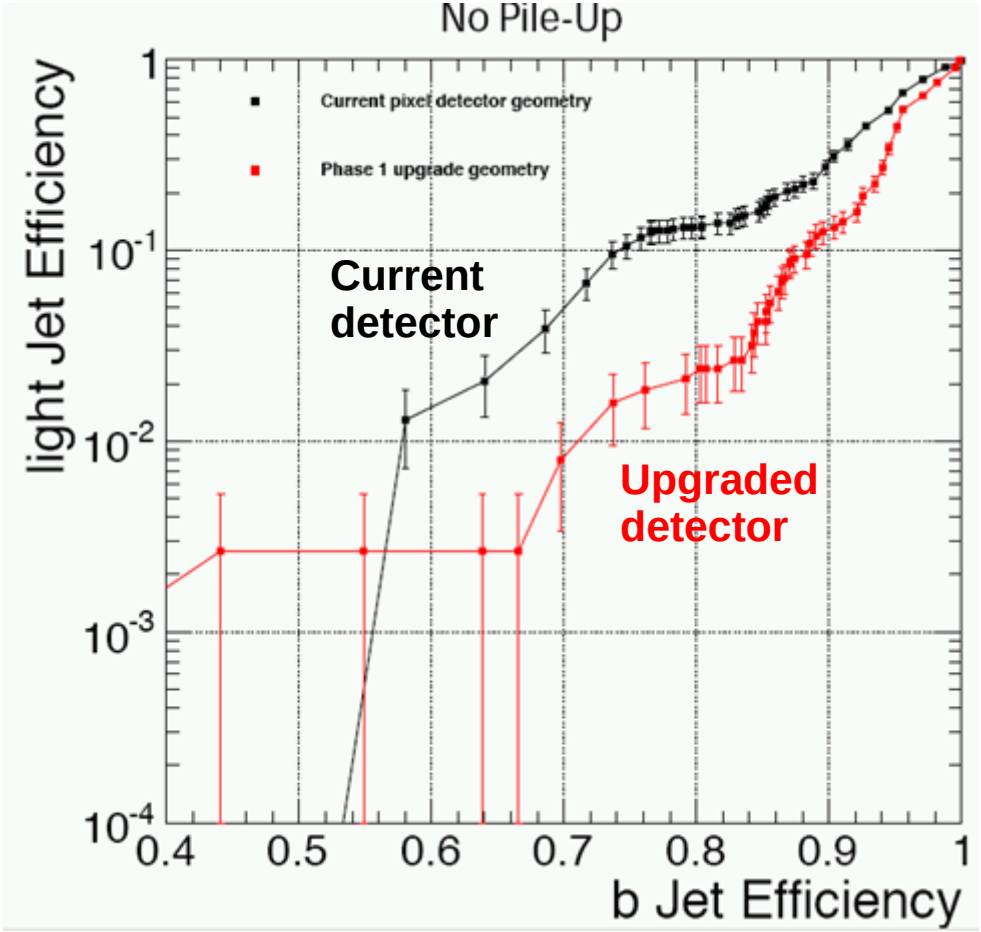
Current / Upgraded Pixel Track Seeding at $2x10^{34}cm^{-2}s^{-1}$

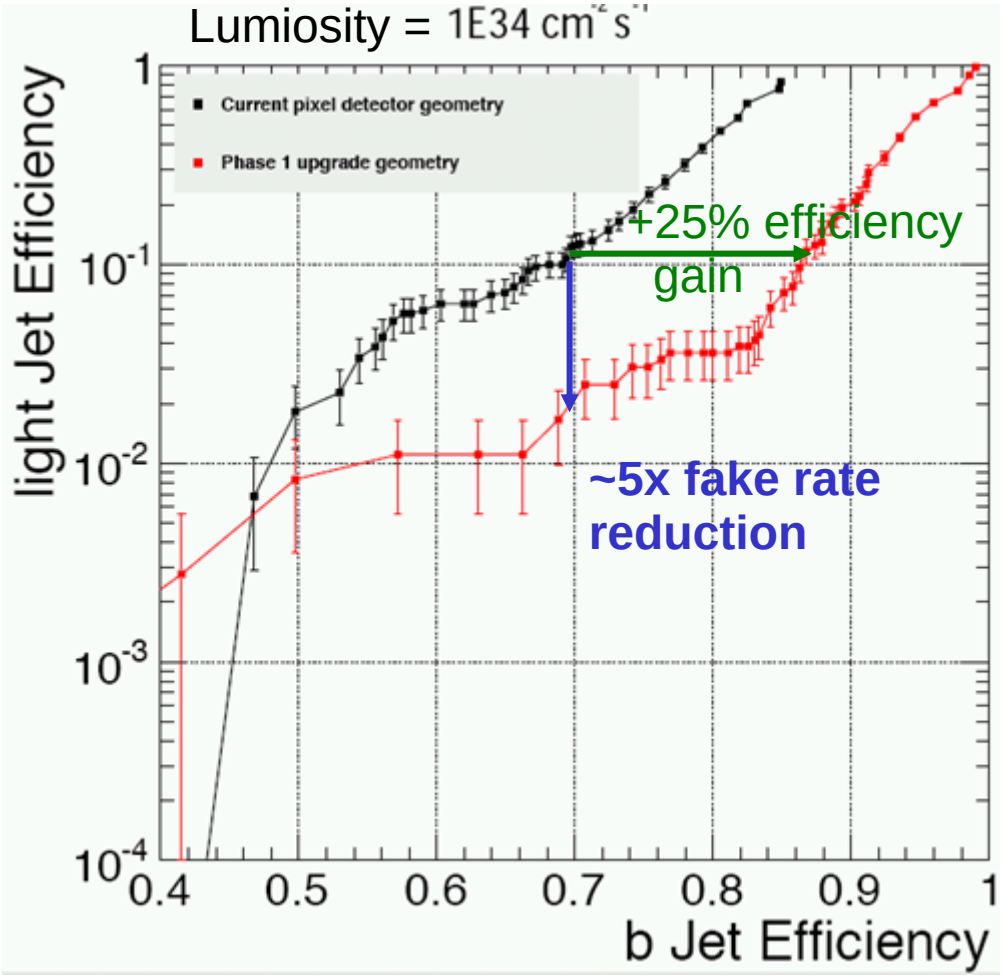


Reduced data loss and quadruplet seeding improves efficiency and reduces fake rate !

b-tagging of Current / Upgraded Pixel System

ttbar $80<p_t<120$ GeV Combined Seondary Vertex Tagger





Efficient b-jet tagging crucial to many physics analysis

e.g. 4-b-jet channel → **fake rate reduction by factor ~600** or **~2.4 x signal gain**

Summary & Conclusions



• Pixel upgrade to 4 hit system significantly improves and robustifies pixel track seeding & vertexing

• Reduced and displaced material budget significantly improves impact parameter resolution and therefore vertexing and b-tagging.

• Pixel stand alone tracking crucial in HLT. The 4 hit upgrade will boost HLT triggering capability of CMS. (~ 4x better $\Delta p/p$)

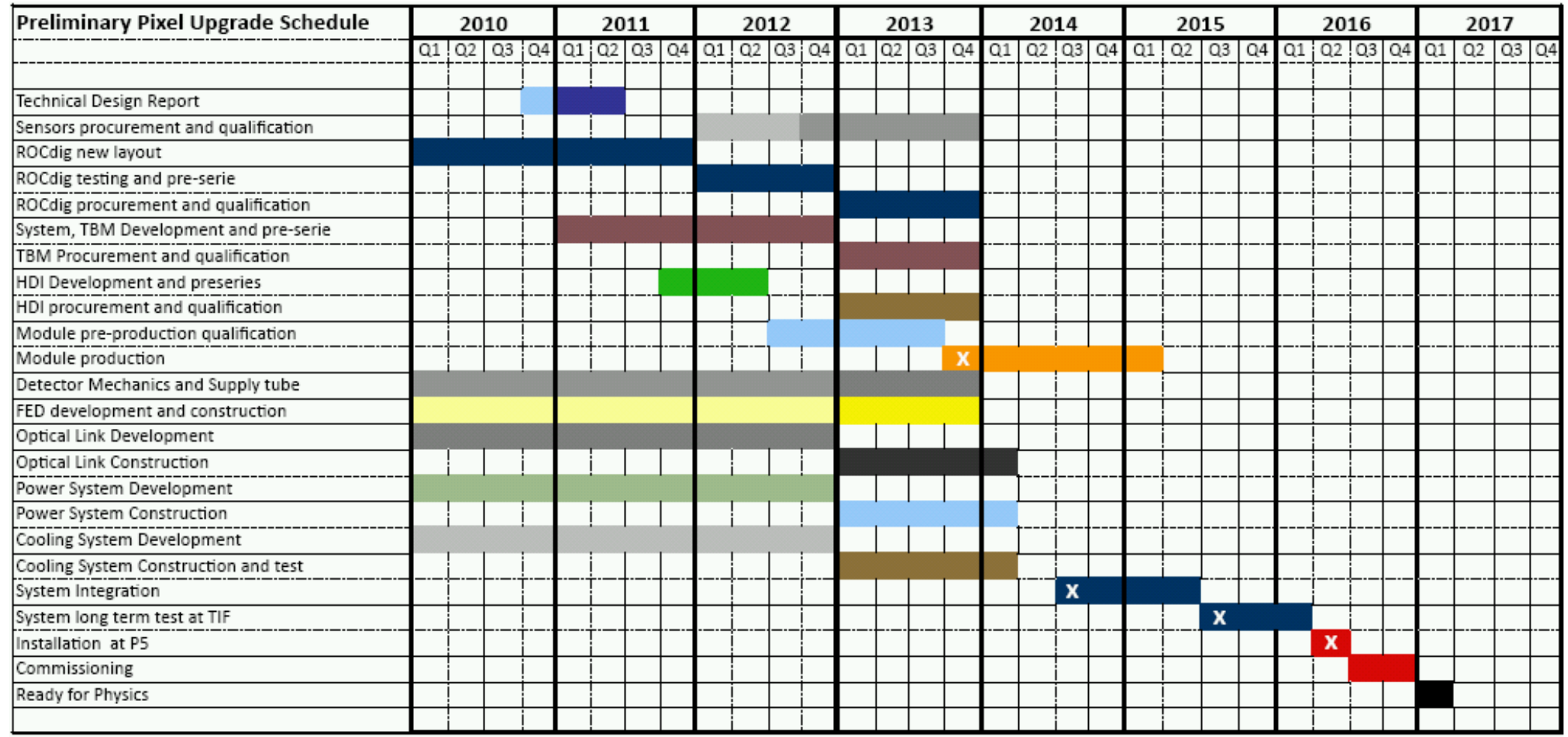
• LHC operations beyond the standard mode (25nsec) and luminosities of $1x10^{34}cm^{-2}s^{-1}$ poses serious limitations of the current pixel system.

• Data flow limitations by increased instant luminosities (50nsec or $2x10^{34}cm^{-2}s^{-1}$) and 4th Layer require changes of the present pixel readout chain (ROC changes & Optical 40MHz analog coded → 320 Mbit/sec digital)

• Improvements in pixel sensor materials (MCz) allows more radiation tolerant modules.

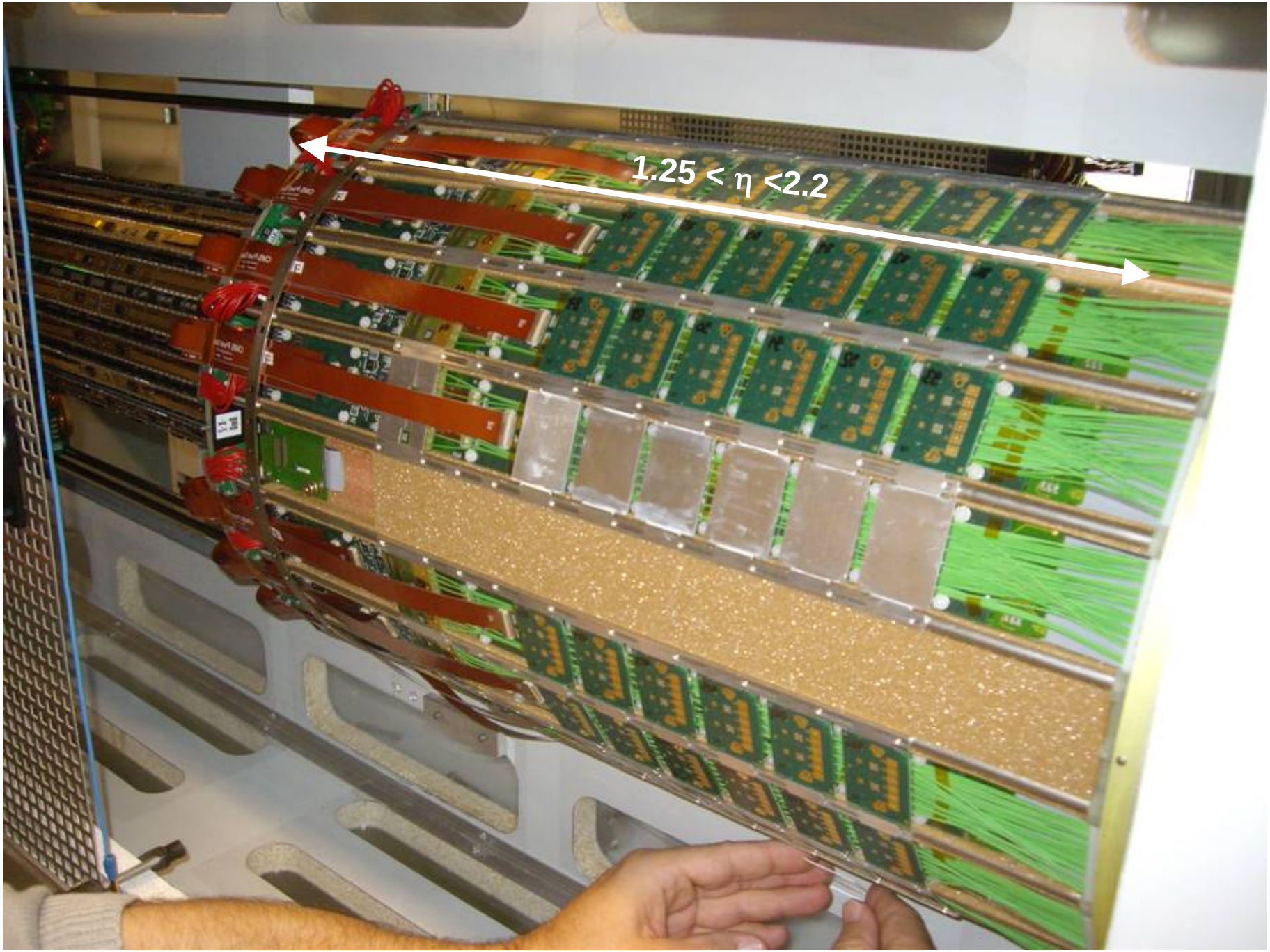
• In preparation of a Phase II Pixel a “fall forward” Layer 1 upgrade with 75μx100μ pixel size and new ROC architecture is considered. (~2019)

Pixel Upgrade Schedule



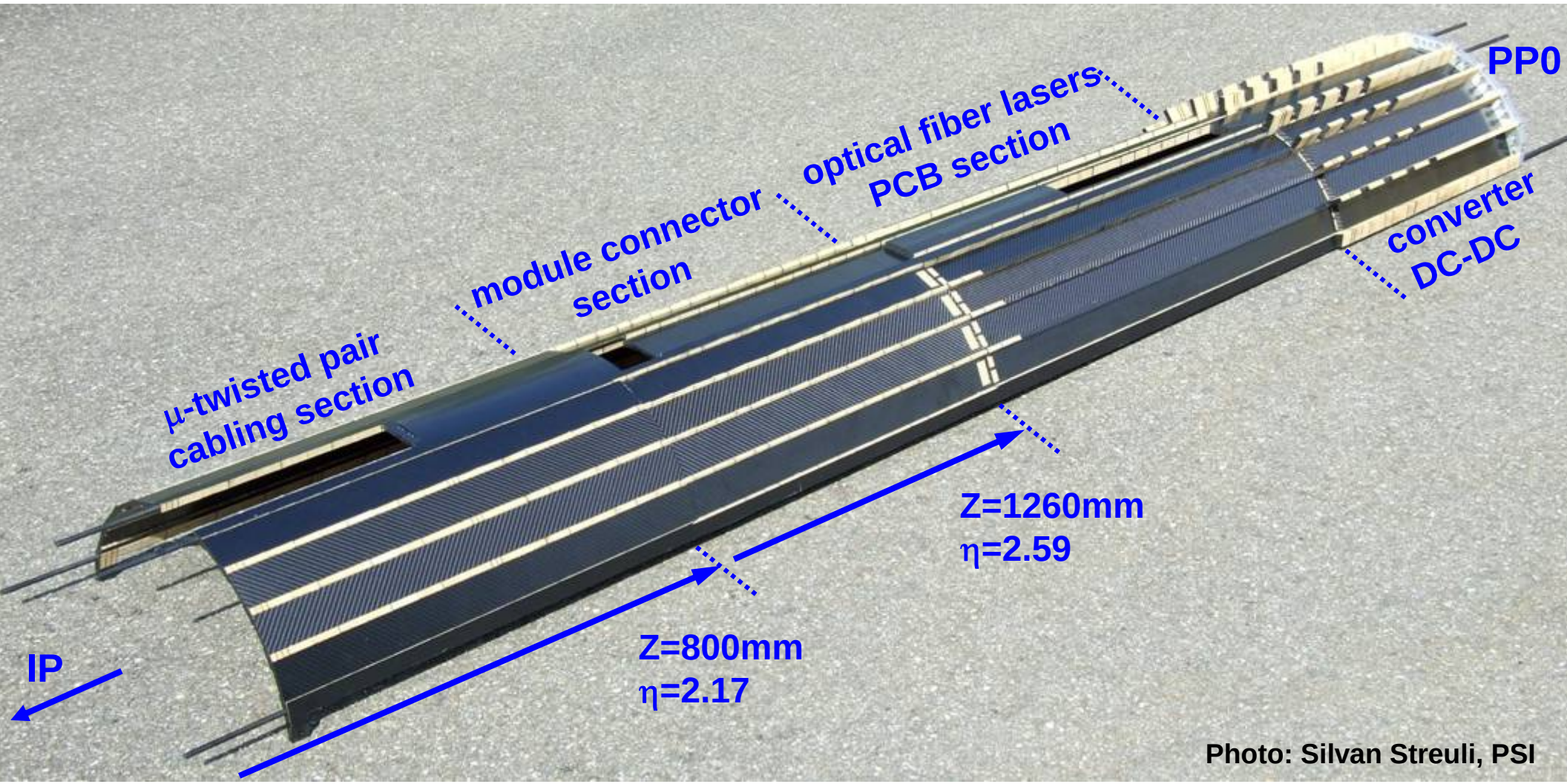
Spare Slides

BPIX & Supply Tube with AOH, DOH, PCBs & Fibres



Upgrade low mass BPIX Supply Tube

First Prototype completed in Mai 2010

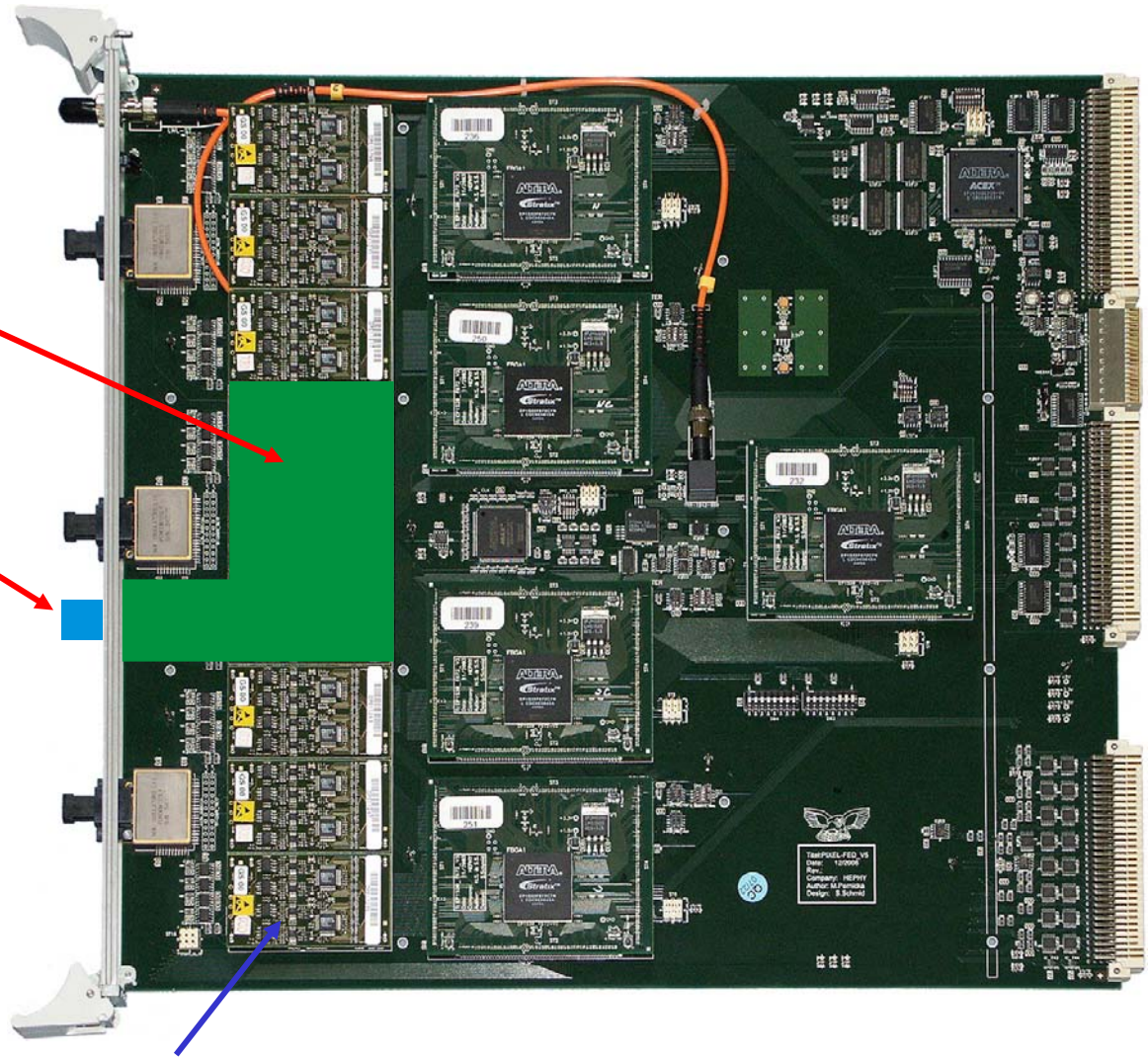


Modification of Pixel-FED

HEPHY, Vienna
H. Steininger
M. Friedl

- Keep single slot size
- Keep VME base board

New daughter board
(instead of 3 ADC cards)
including Zarlink receiver

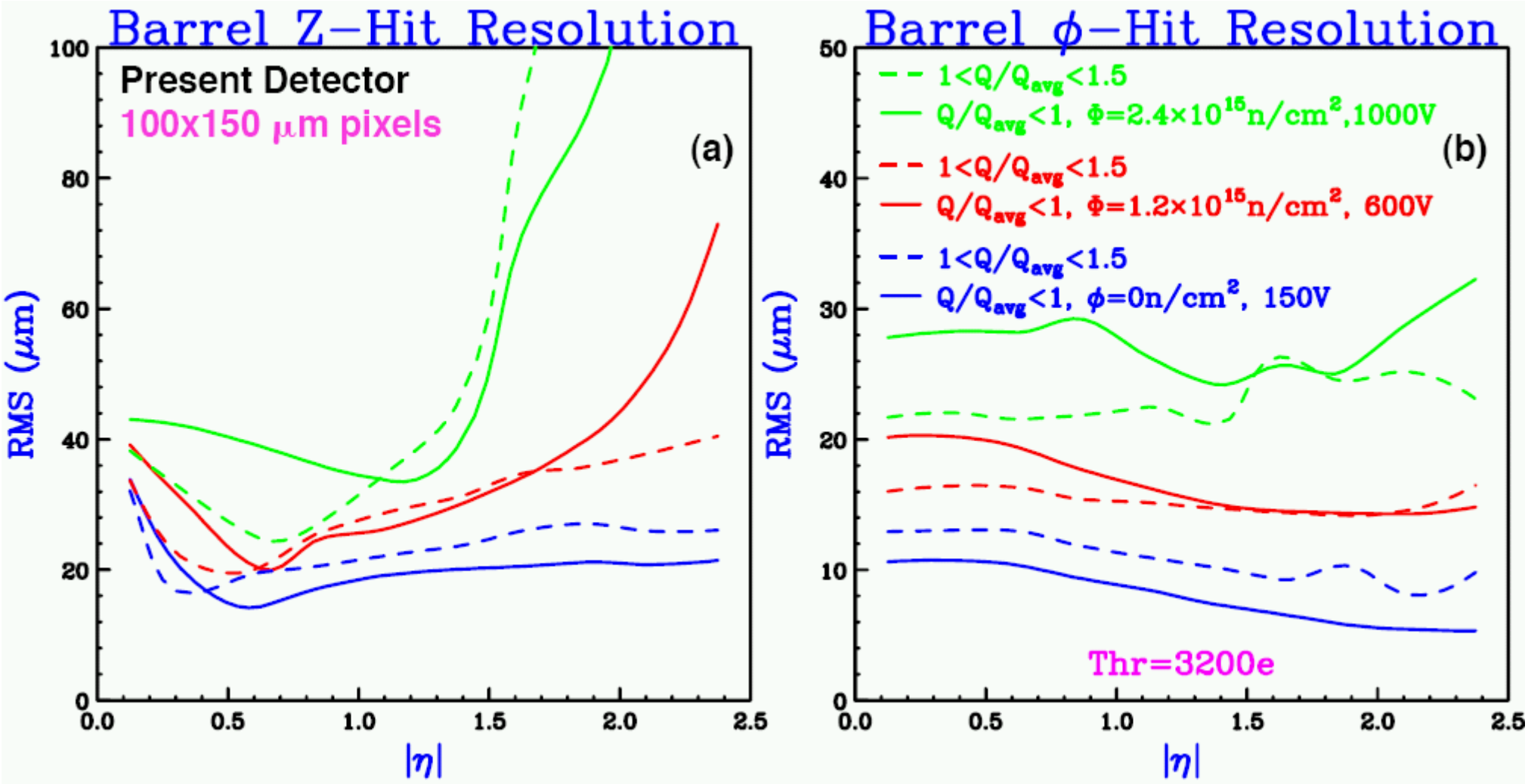


- Don't need to remove current ARx12 → allows easy swapping between old and new systems

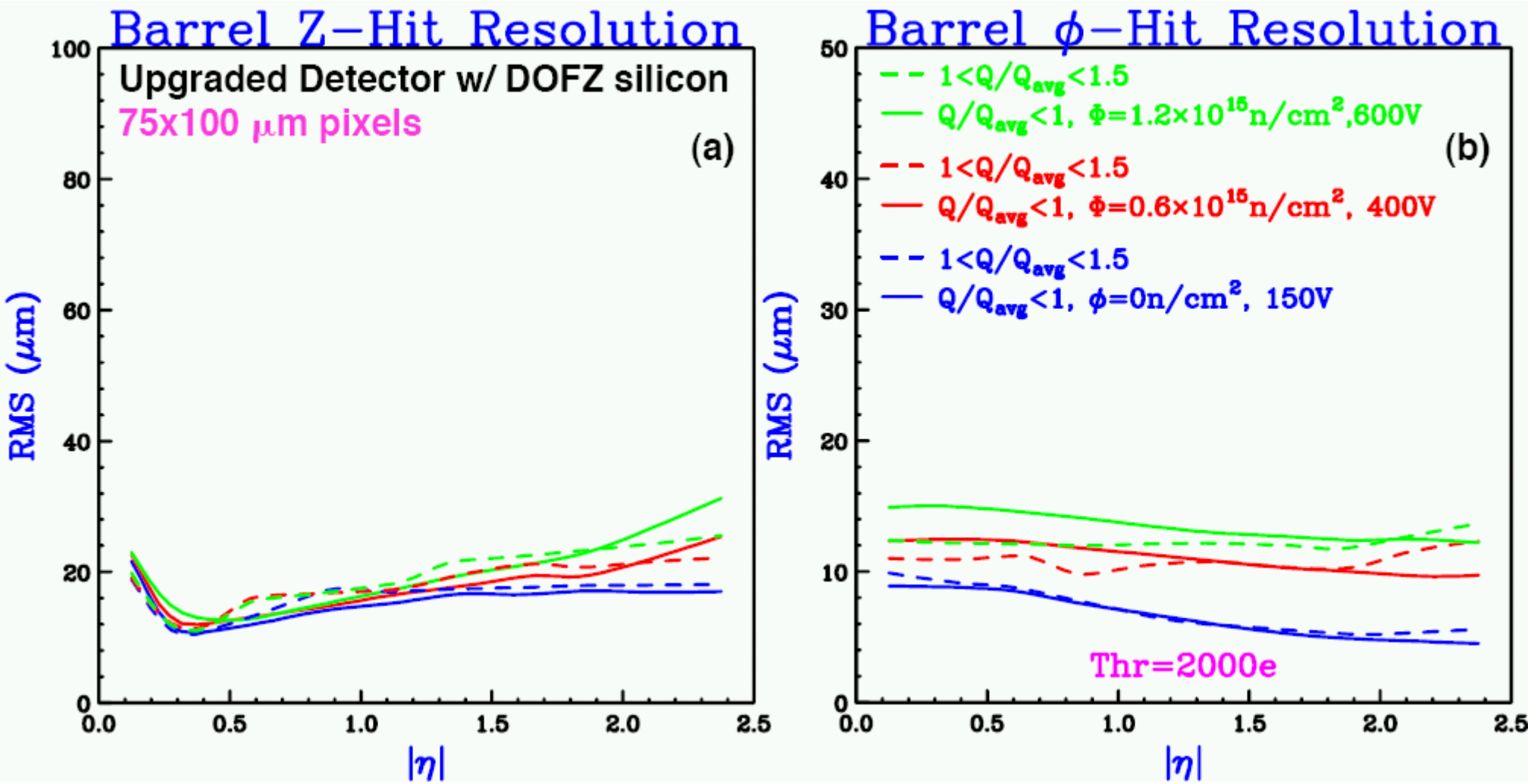
- Need new front panel in any case

Replace ADC cards with new deserializer piggy-back cards

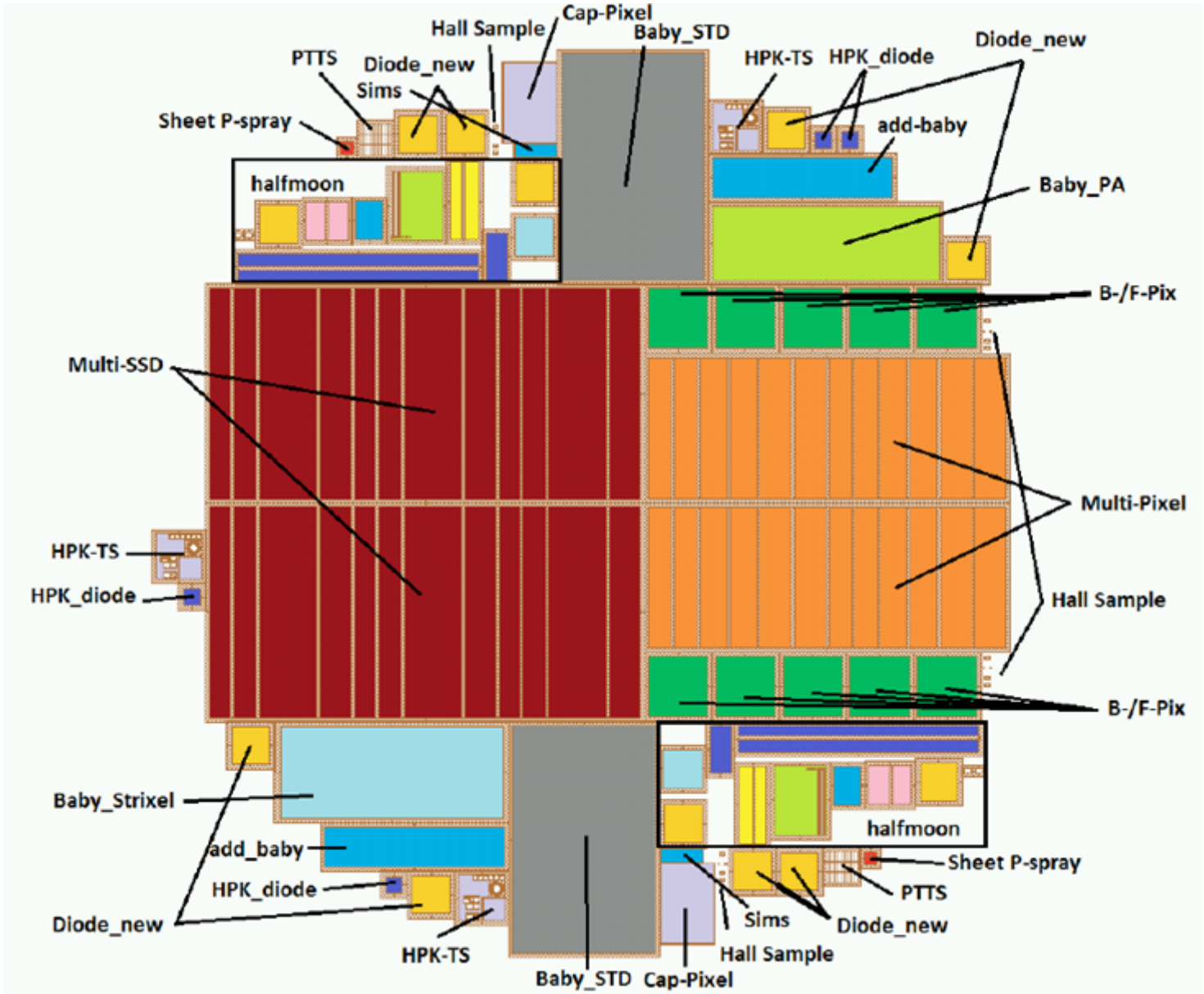
Current Pixel Barrel Resolution



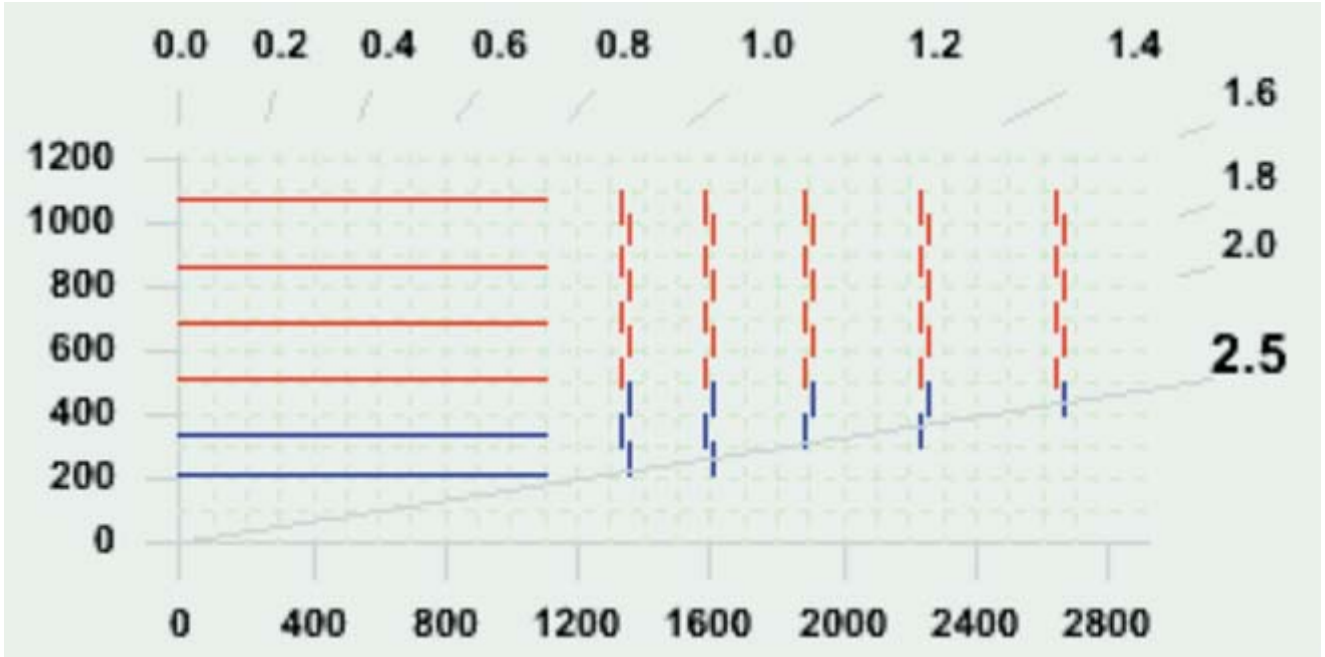
Small Pixel Resolution (75μx100μ)



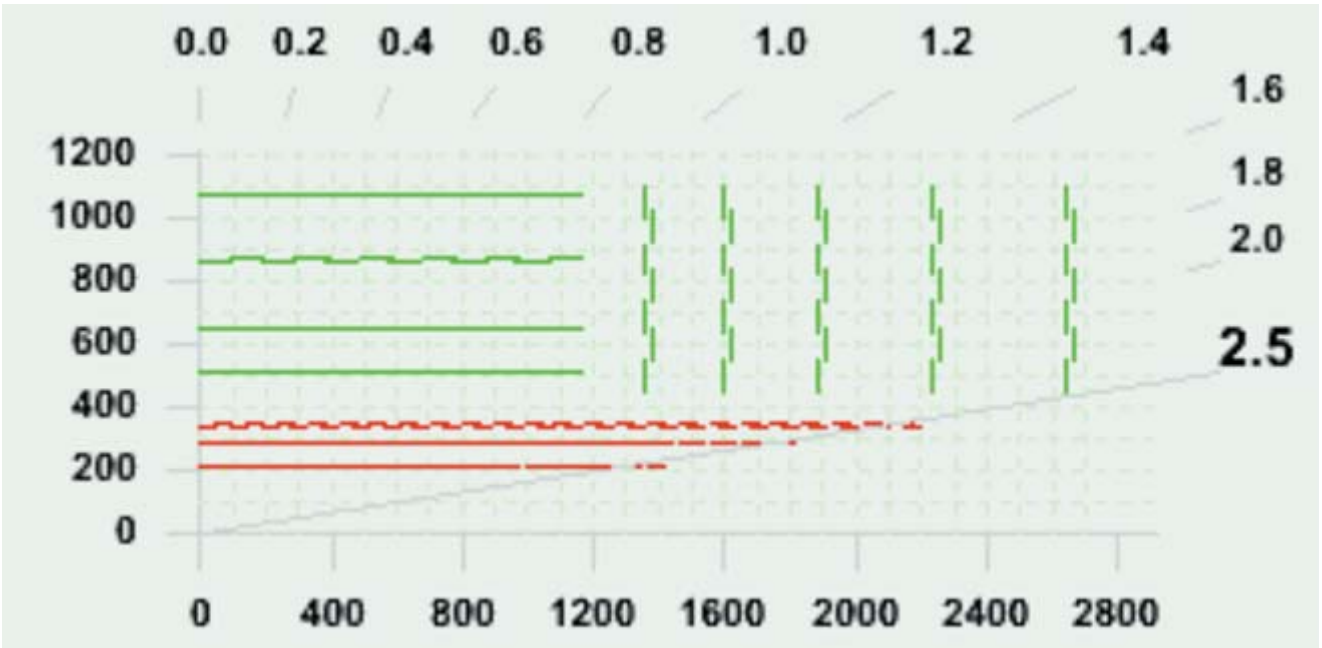
Hamamatsu Sensor Submission



Phase II Tracker Layouts with p_t-modules

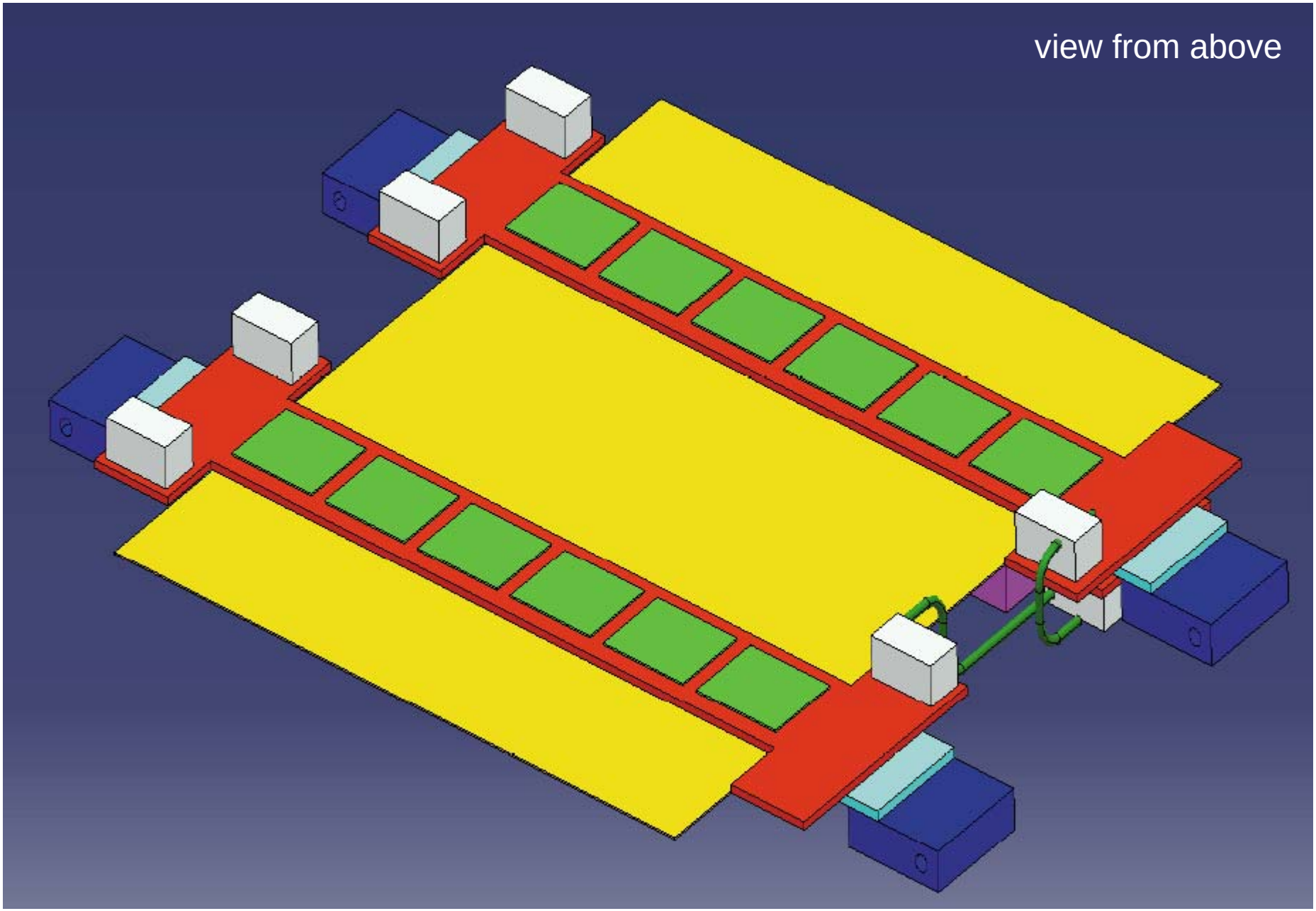


p_t-module in outer part

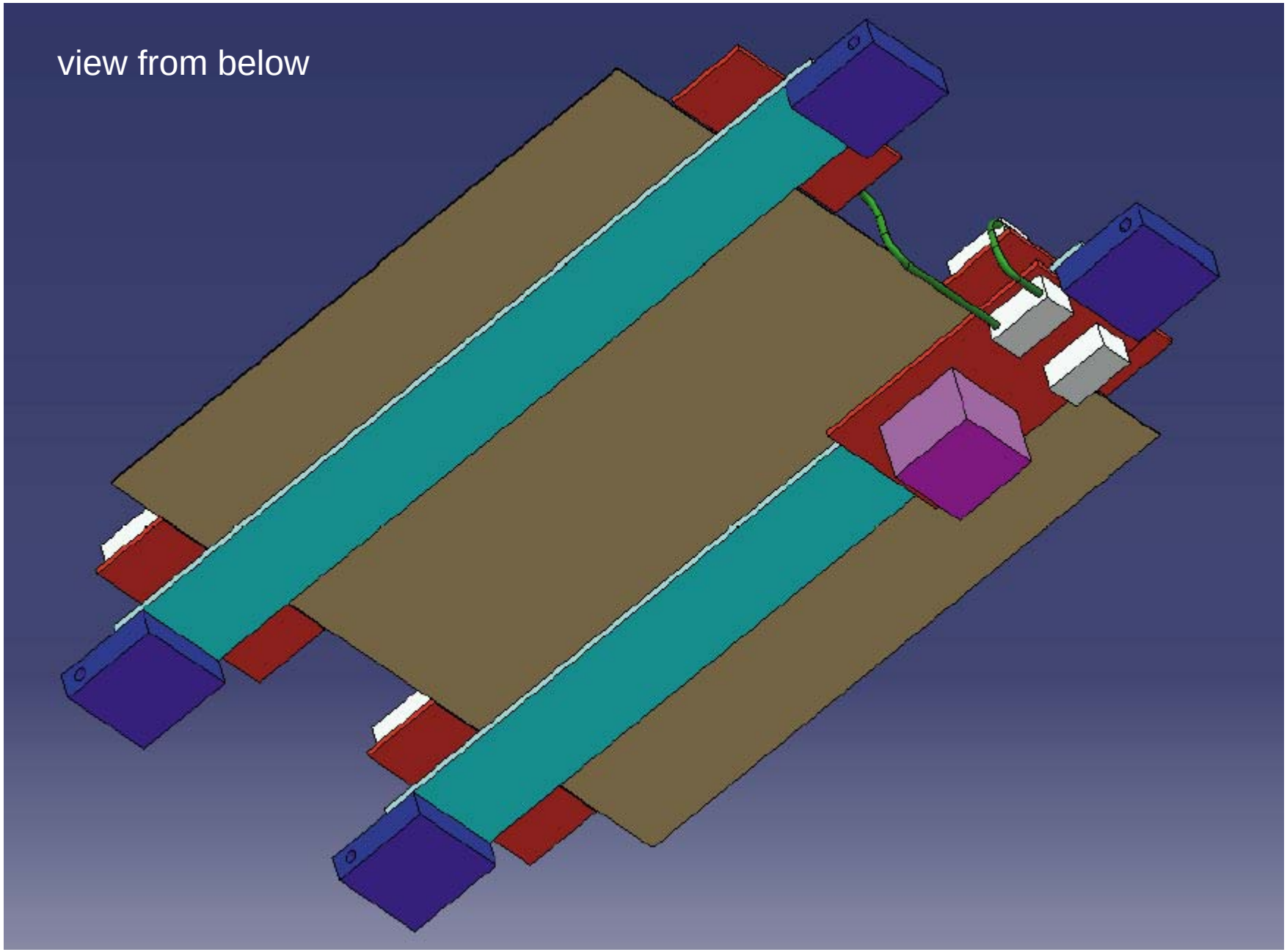


p_t-module in inner part

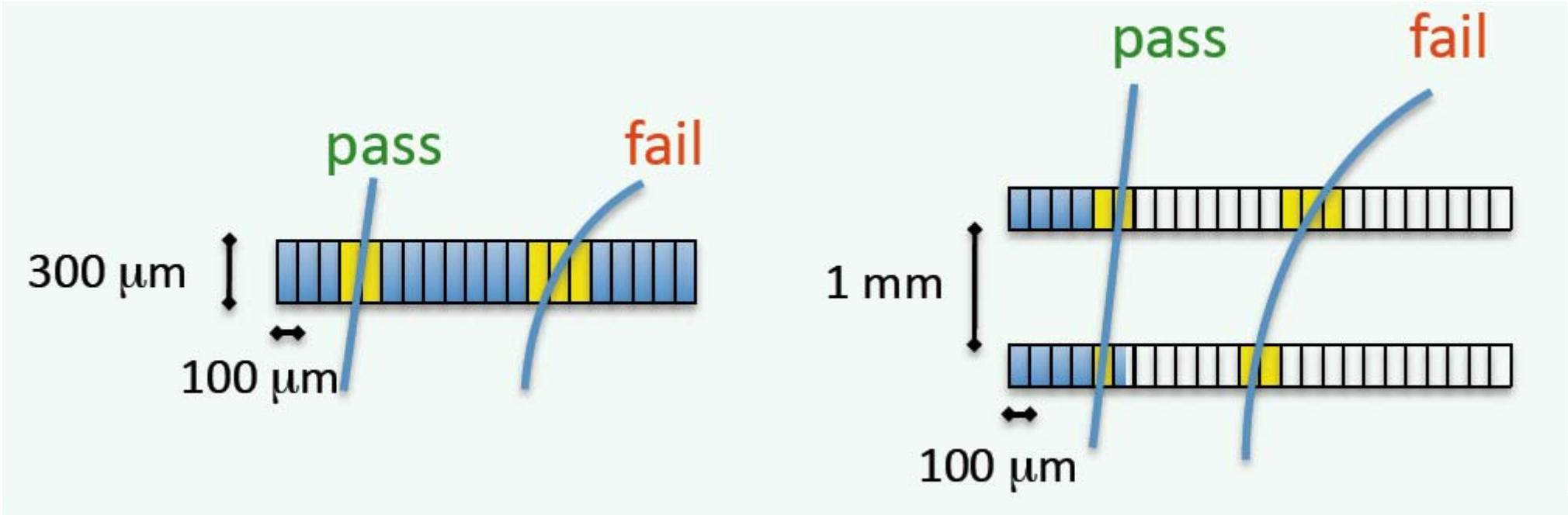
Short Strip Module with CBC ROC

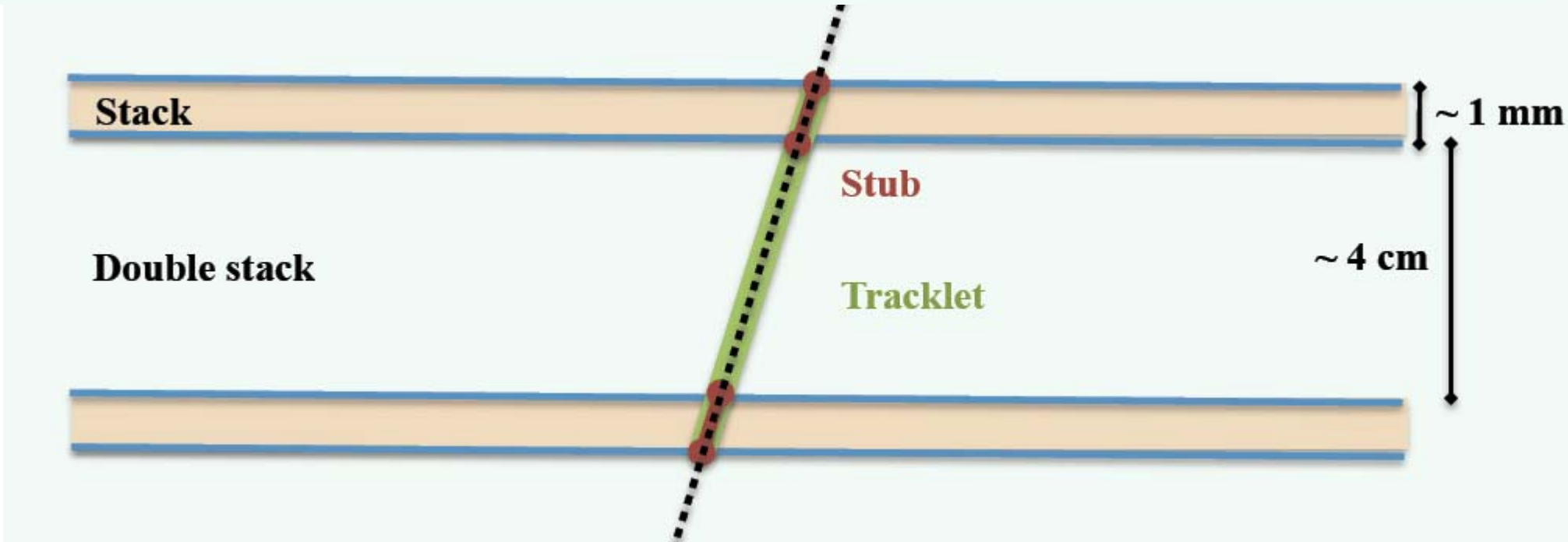


Short Strip Module with CBC ROC

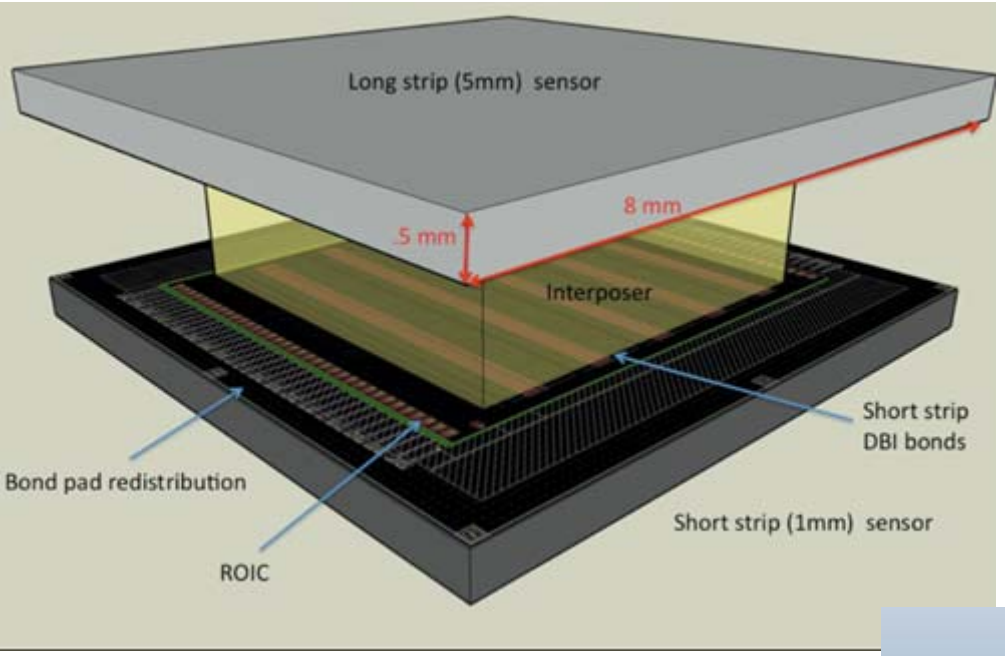


p_t-track discrimination

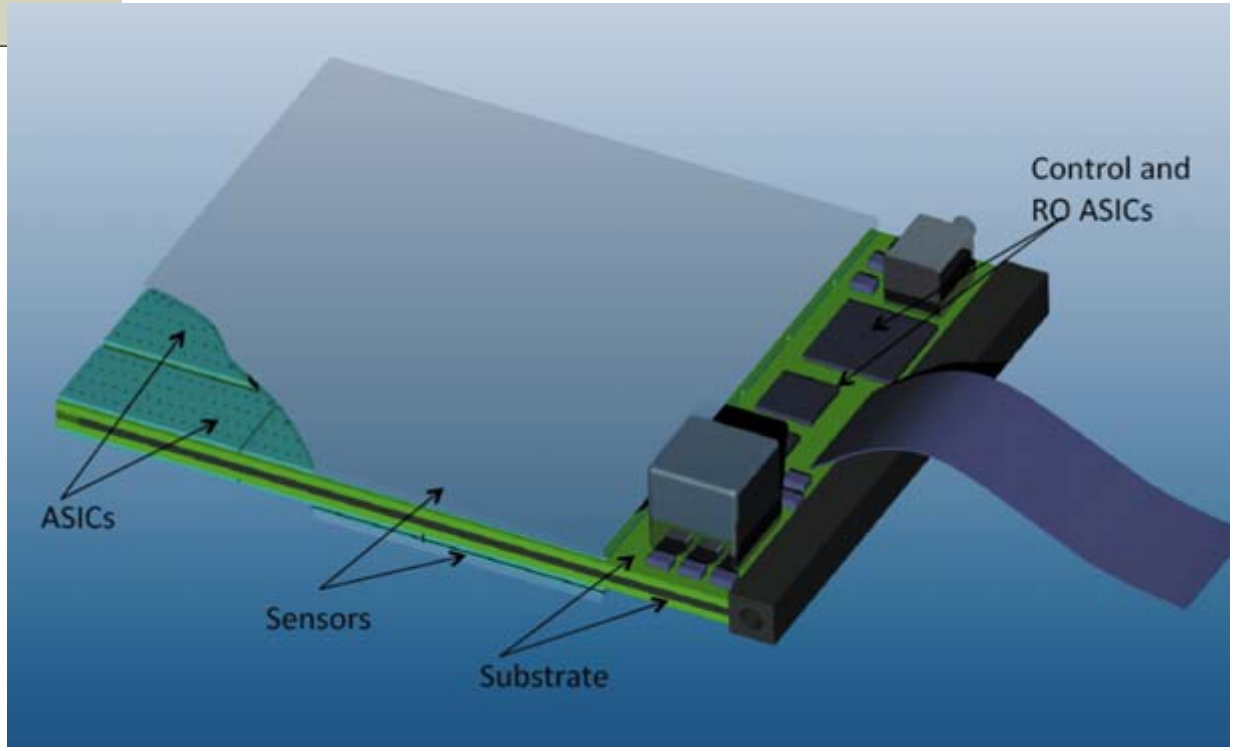




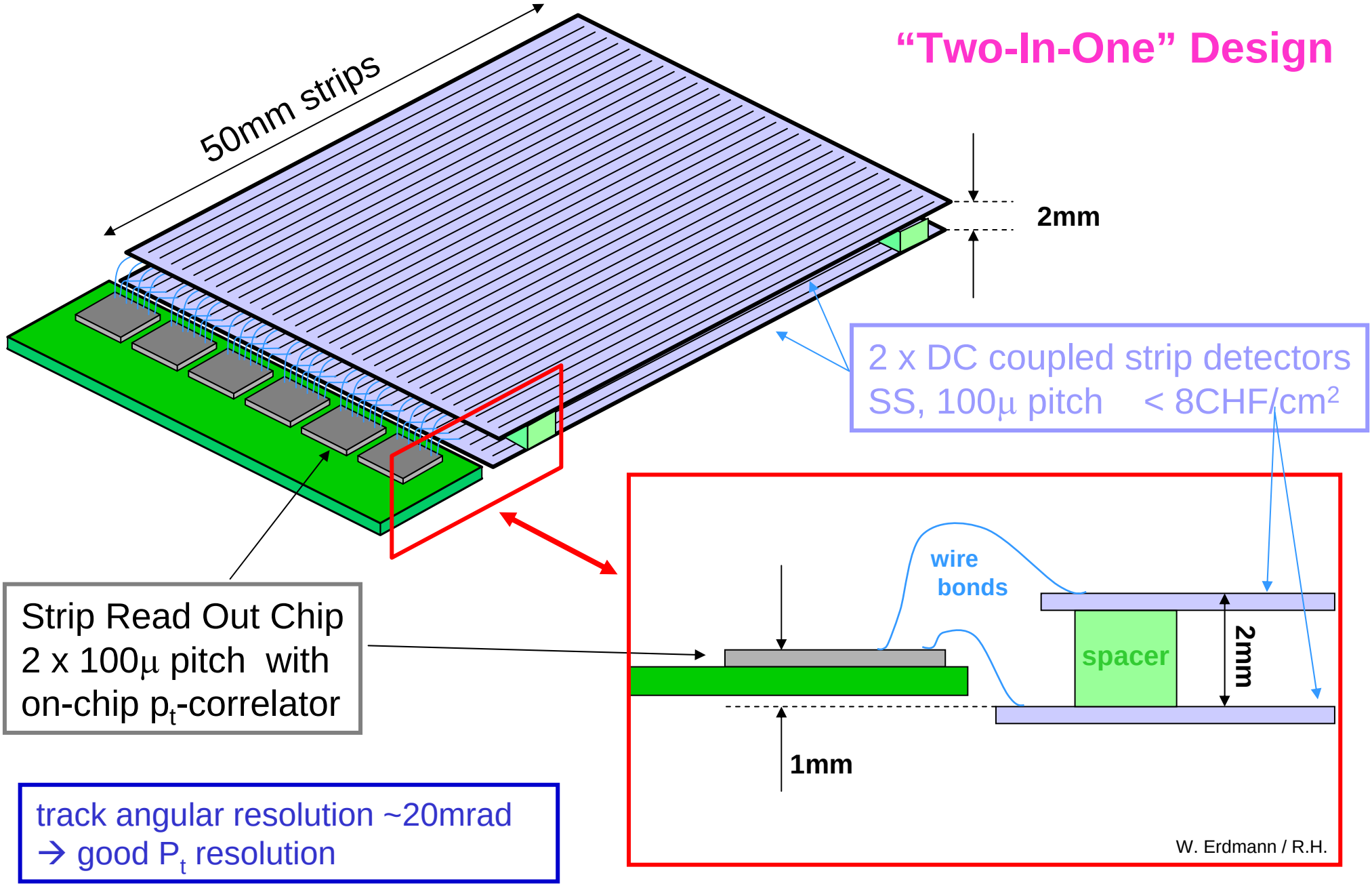
Pixellated p_t - Module



Principle



Pt - Trigger for TOB layers



track angular resolution ~20mrad
→ good P_t resolution

http://indico.cern.ch/contributionDisplay.py?sessionId=7&contribId=44&confId=85484