Plans for an upgraded CMS Pixel Detector

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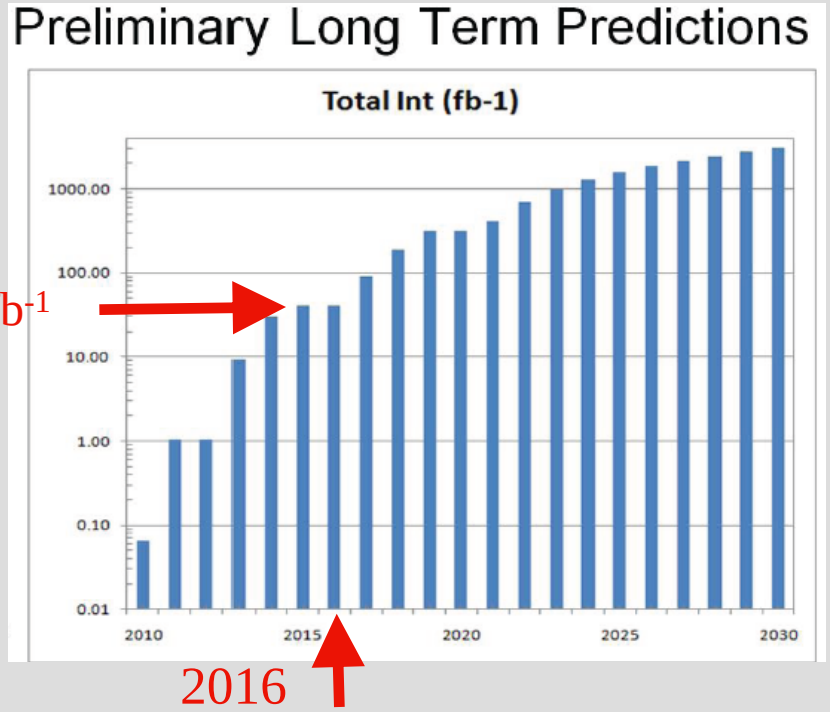
for the CMS Collaboration

Sept 6, 2010

CMS and LHC

The CMS detector is performing well



LHC plans

2010-2011 run at 7 TeV peak lum<2×10^{32} $cm^{-2}s^{-1}$

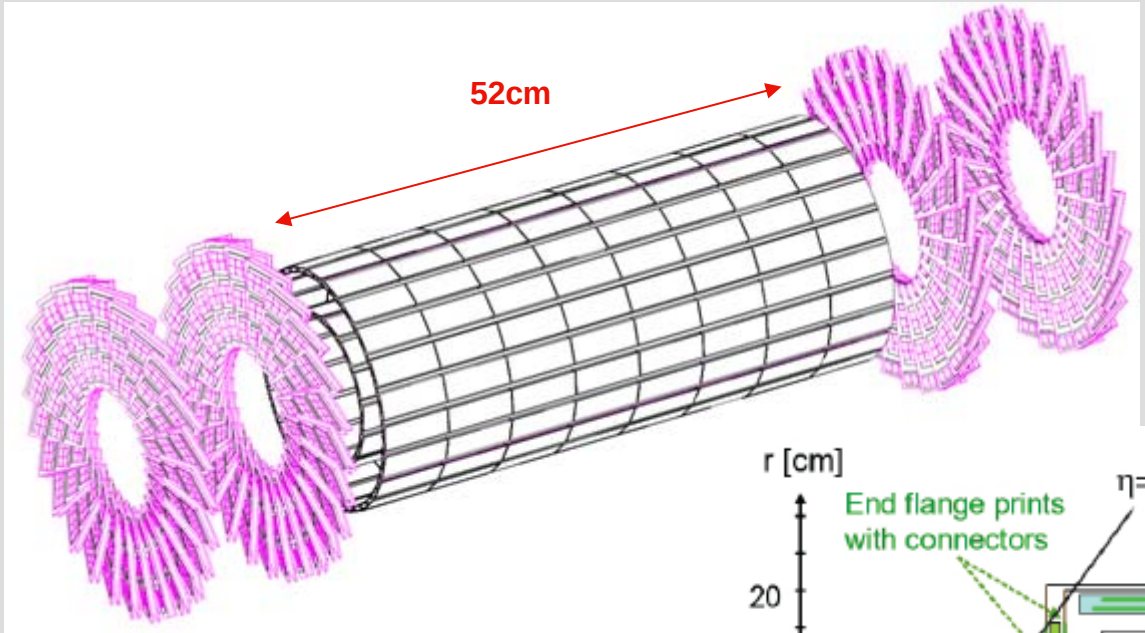
2012 shutdown

2013-2015 run at 14 TeV peak lum <1×10^{34} $cm^{-2}s^{-1}$

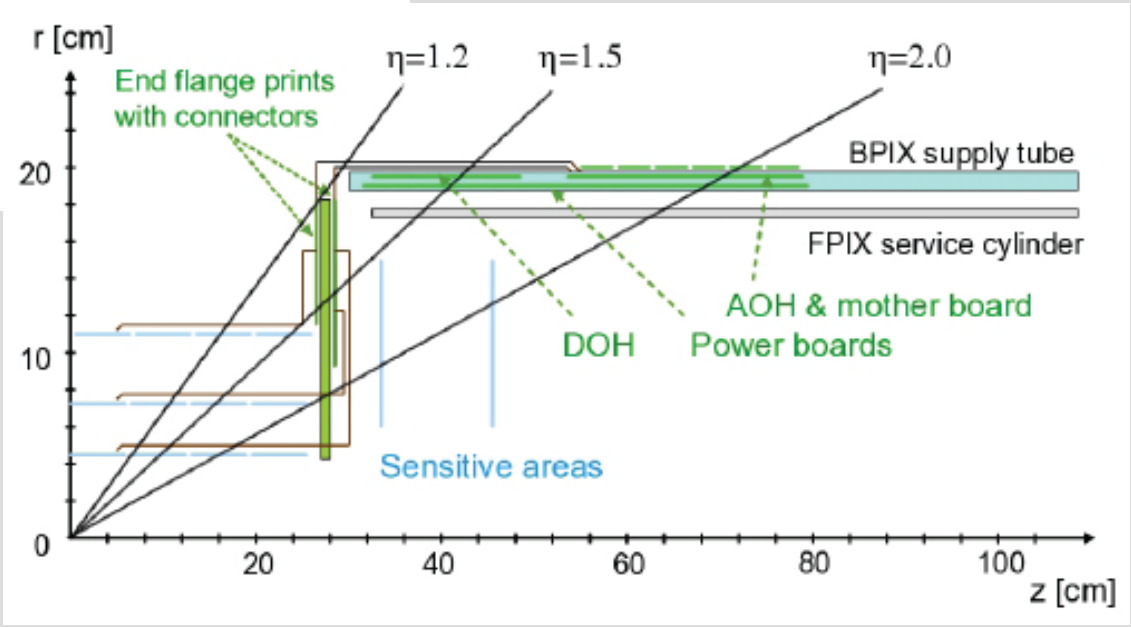
2016 shutdown

2017-2020 run at 14 TeV peak lum 1-2×10^{34} $cm^{-2}s^{-1}$

Current CMS Pixel System



3 Barrel layers
2 Forward disks on
on each side

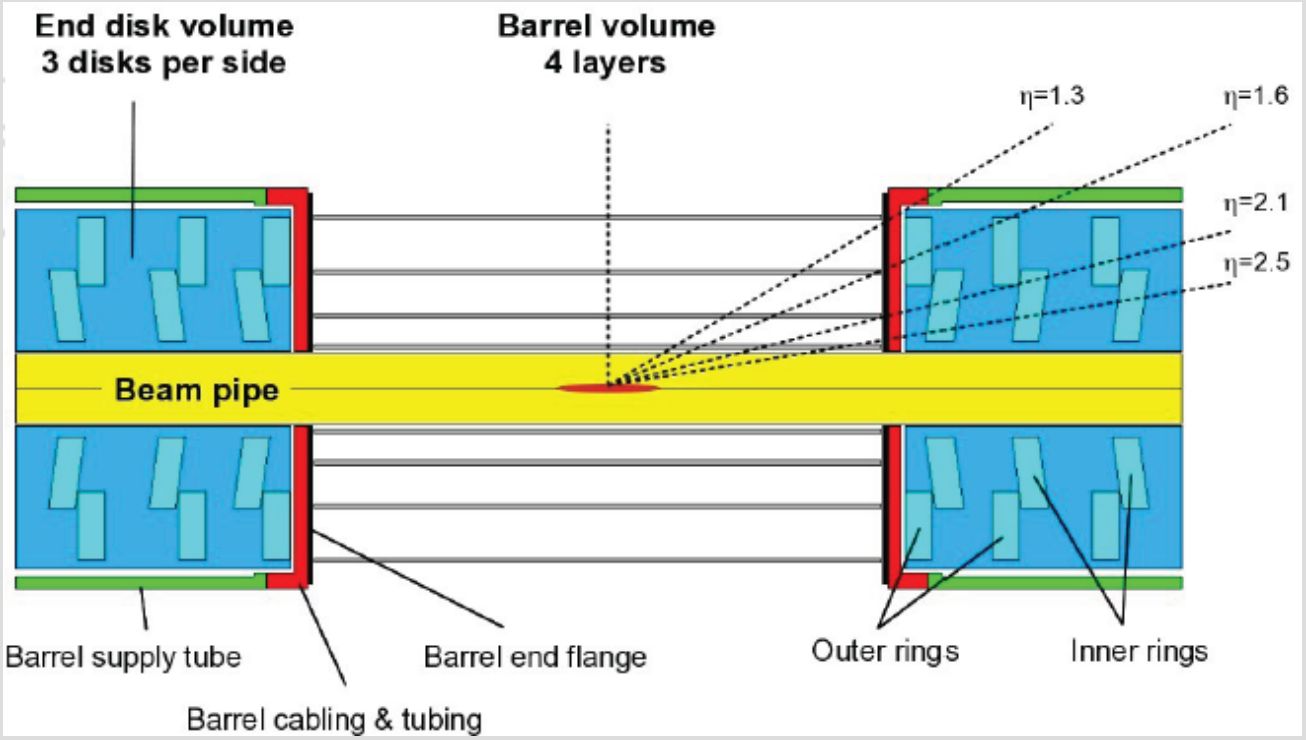


Total ~ 1 m² → 65 Mega Pixel
(~ 20G transistors)

Performing well!

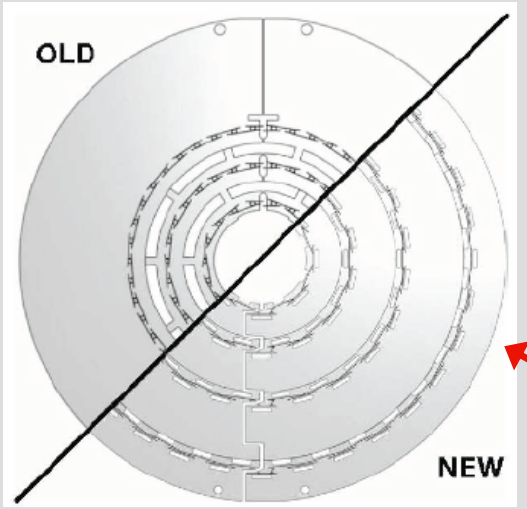
Goals for pixel upgrade

- Reduce material
- Reduce deadtime as luminosity increases from readout chip
- Increase 3 hit coverage
- Replace sensors to decrease radiation damage



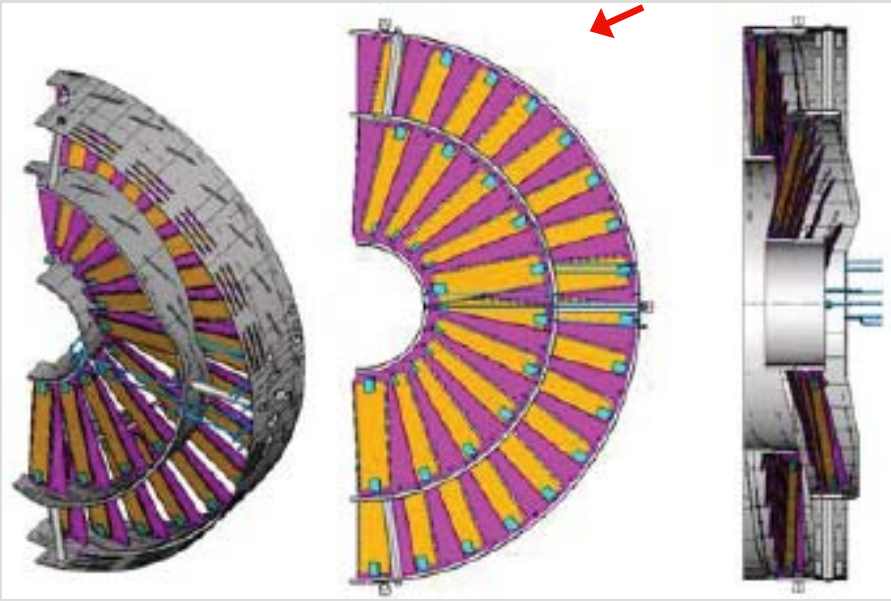
Reduce Material

- Ultra-light mechanics
- CO_2 cooling (instead of C_6F_{14})
- Eliminate endprint in barrel by using twisted pair cables and move barrel services out in Z

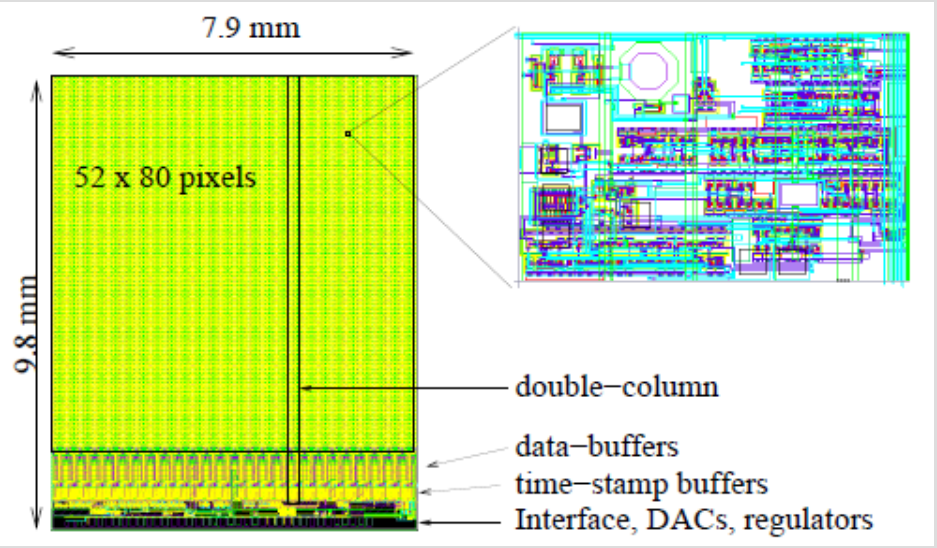


Barrel

Forward



Reduce Deadtime

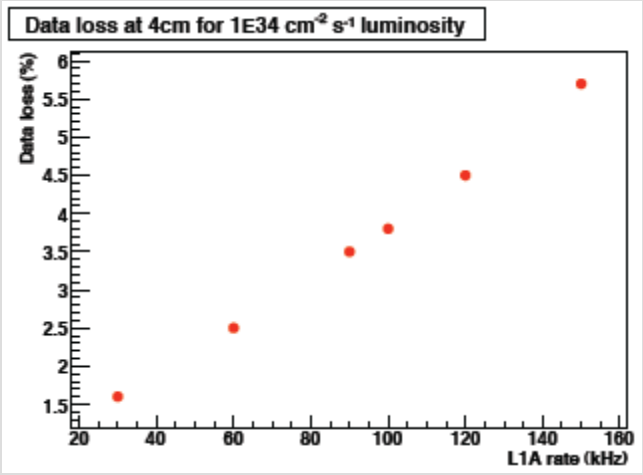


- The current detector was designed for maximum luminosity

$$\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$$

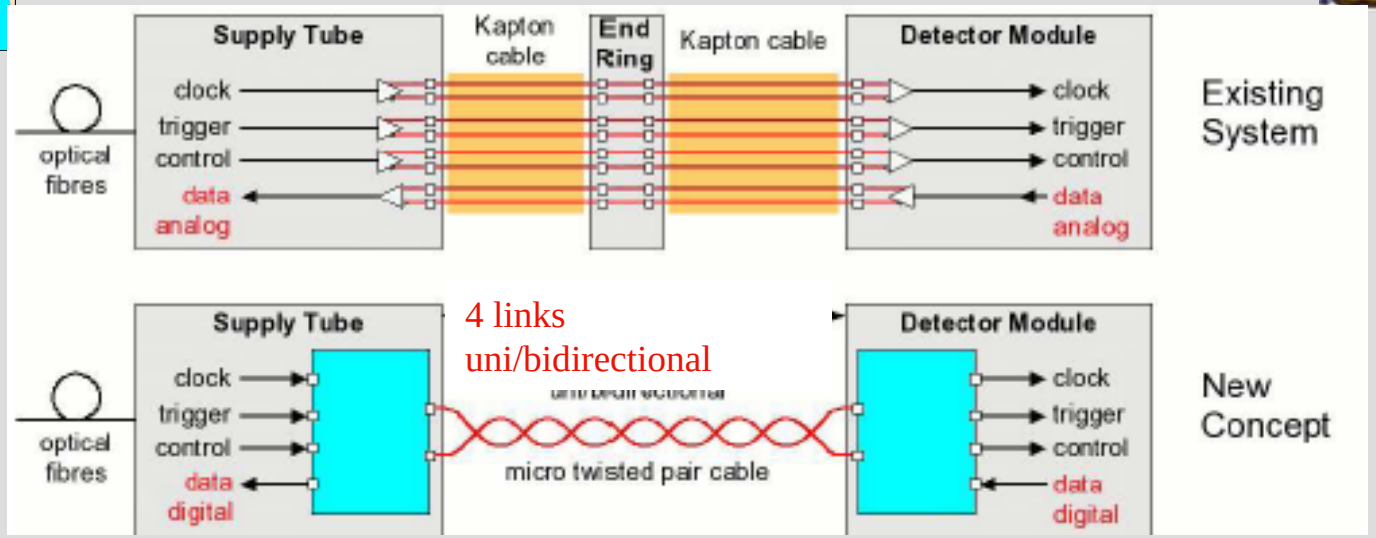
with the PSI46 readout chip (ROC)

- At L1 trigger rate of 100kHz with $2\times10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ expect 16% data loss
  - Column drain deadtime
  - Readout deadtime



→ Make new ROC (0.25μm) with larger buffers

Increase 3 hit coverage

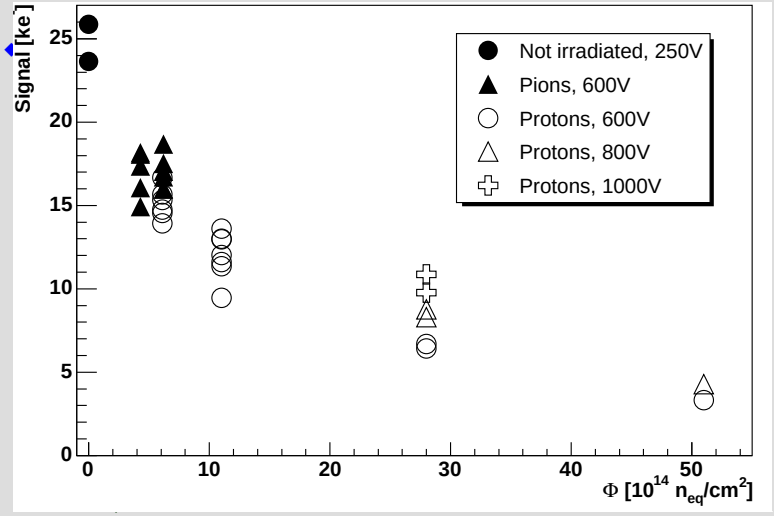


10-15% loss in 3 hit coverage for $\eta < 1.5$

→ Make 4 layer barrel, 3 end disks

- But services are limited by cable plant
- Change optical readout from 40 MHz analog to serialized 320MHz binary
  - New ROC needs 8 bit ADC, 160 MHz digital readout
  - Have micro-twisted pair cables take signals to reduce material

Replace sensors to decrease radiation damage



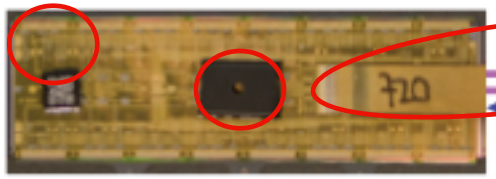
Current sensors are n+ on n

- Electron collection allows for operation after space charge sign inversion even without full depletion
- The expected radiation fluence per year at 10^{34} $cm^{-2}s^{-1}$ for the innermost layer is 3×10^{14} $n_{eq}/cm^2/yr$
- Specified to operate at 6×10^{14} $n_{eq}/cm^2/yr$

Use similar sensors for 2016, but fine tune design

- No other good options, yet
- Hit detection efficiency and resolution expected to deteriorate
- May need to replace innermost layer before the end of Phase I. Therefore assure that the layers can be installed independently but the sensors may perform fine
- See later talk by T. Rohe in this conference

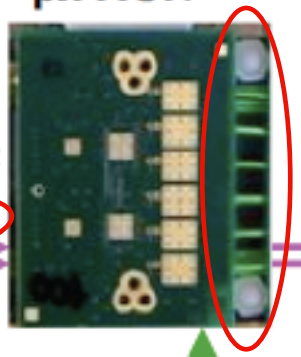
CMS Pixel System



320 MHz binary

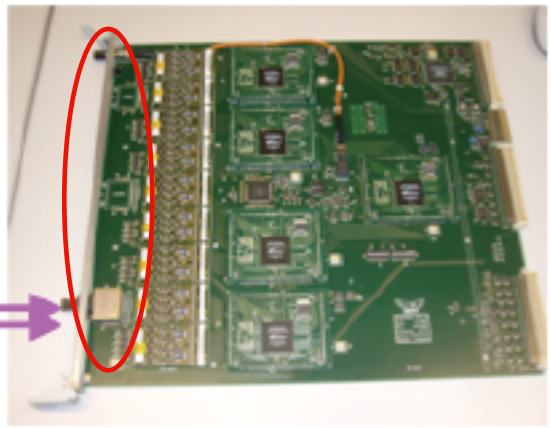
40 MHz analog out

px-AOH



320 MHz binary optical

40MHz analog optical



px-FED

A

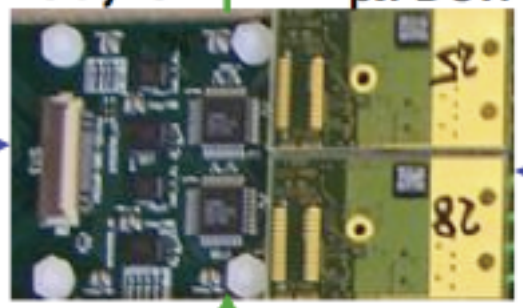
B

40MHz clock, trigger fast I²C commands

I²C

PLL Delay25

px-DOH



px-FEC

I²C

CCU

trk-FEC

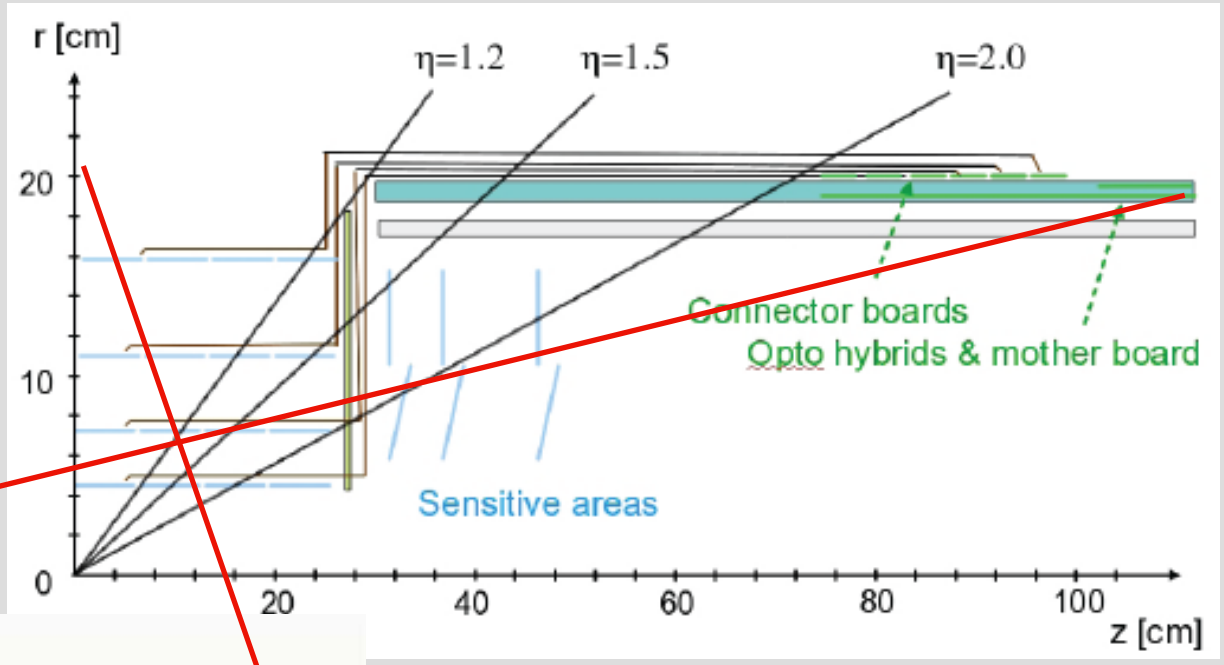
New Phase 1 System:
0-suppressed serial binary data readout at 320MHz, same data structure

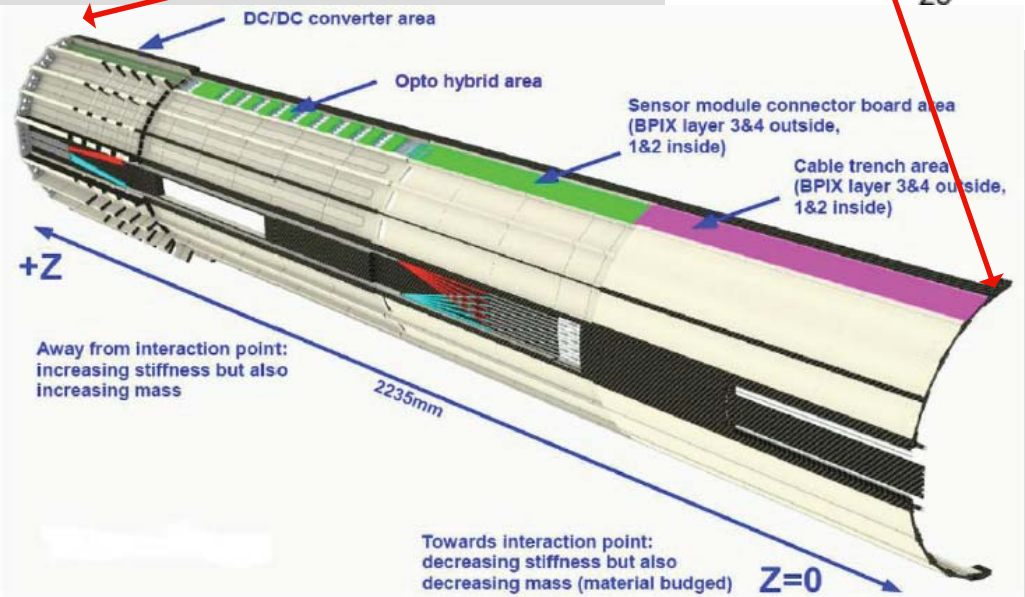
Current System:
0-suppressed analog coded data readout at 40MHz
Fast control links at 40MHz
Slow control links (tracker FEC)

The layout in Z

The services are complex

There are twice as many ROCs as present system





To limit resistive power loss on loss on 50m long cables

Start at higher V and low I

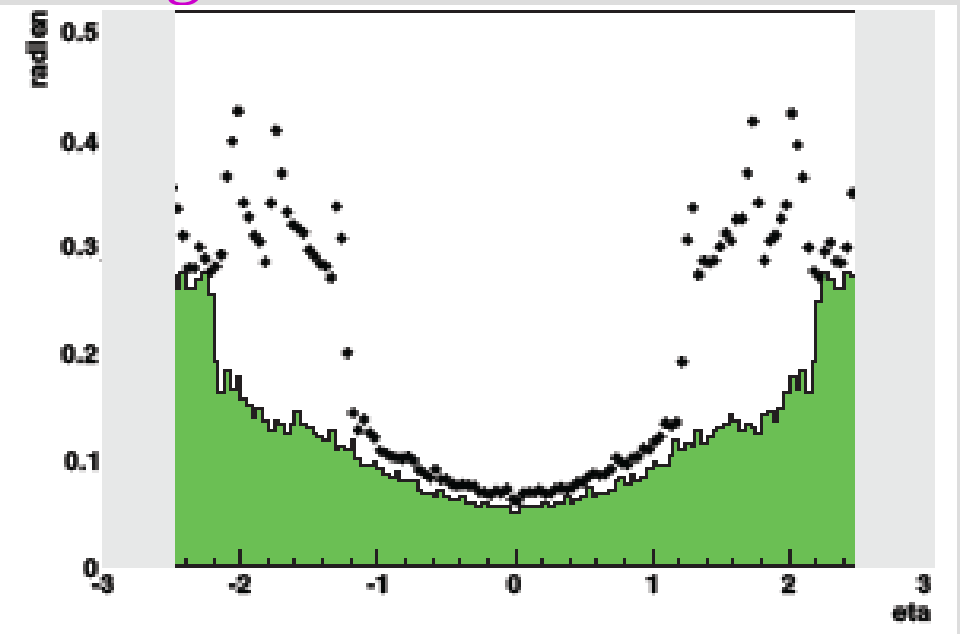
near detector put DC/DC buck

DC/DC buck converter

Reduction of Material?

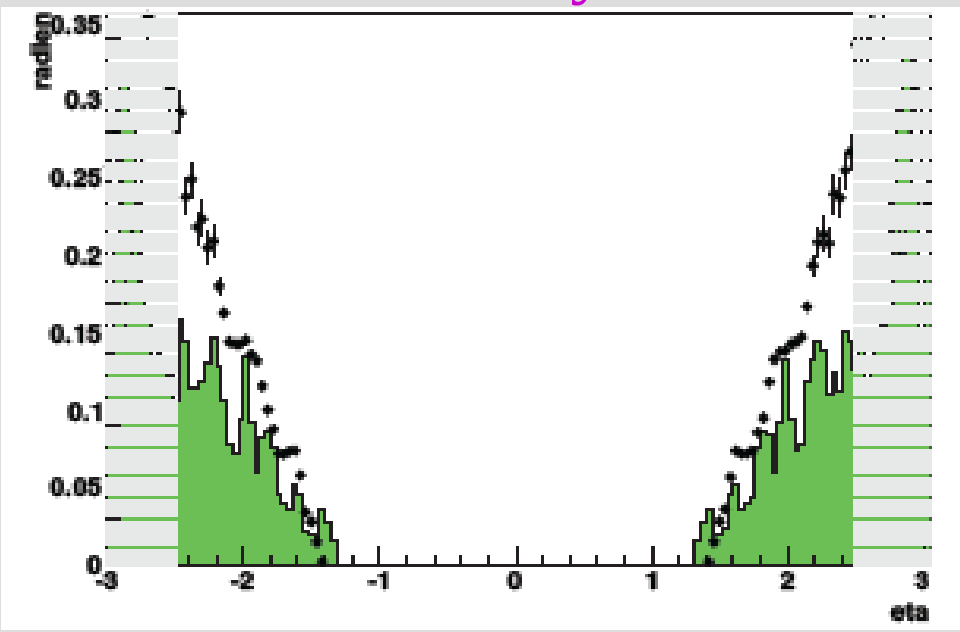
Barrel

weighs 2.4 times less



Forward Disks

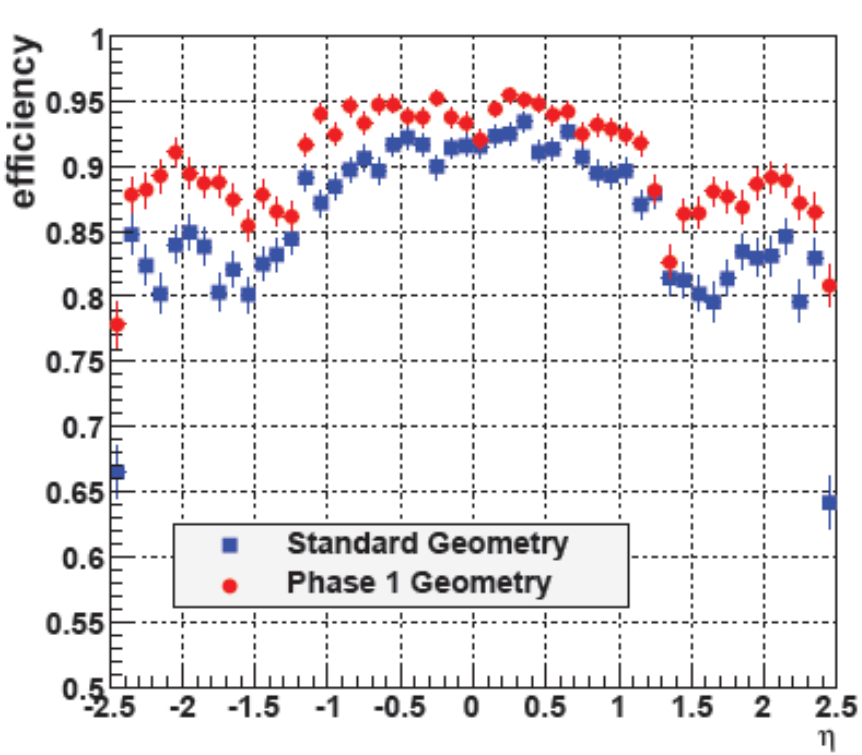
mass reduced by 40%

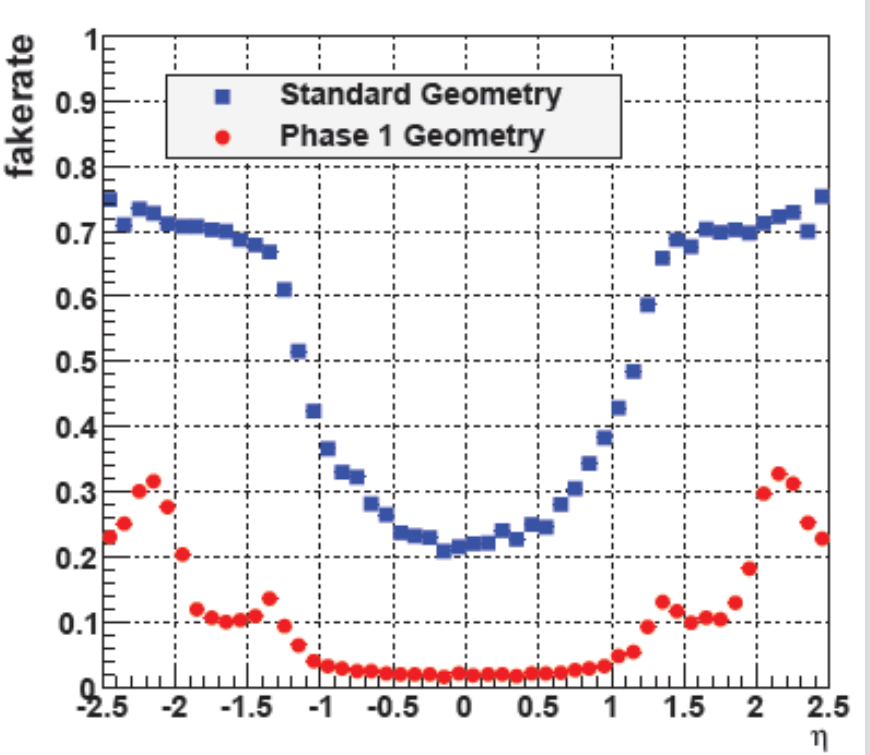


Radiation length ◆ present ■ upgrade

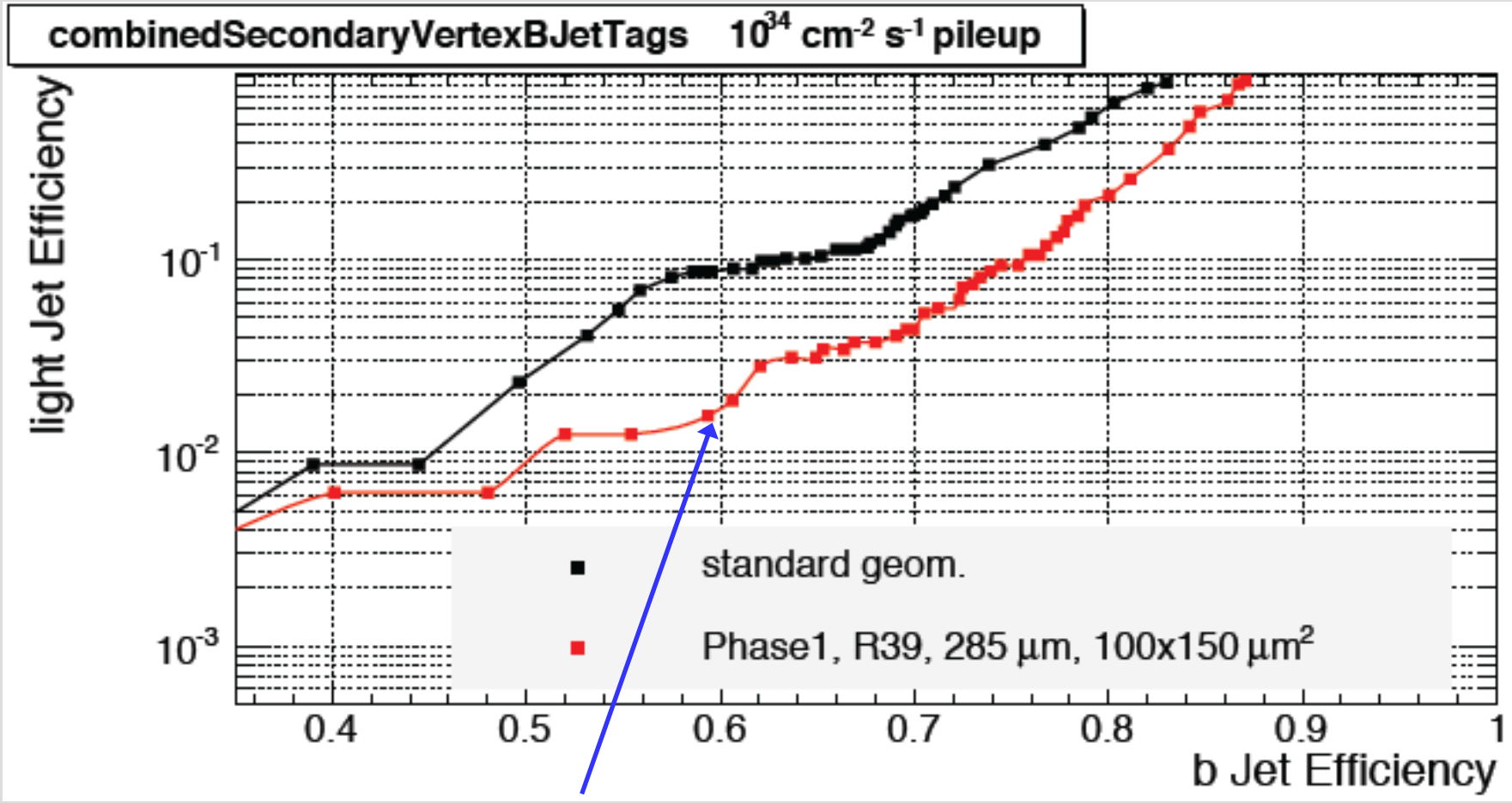
Performance - Tracking

- Improve track seeding efficiency by 8% for $\eta<1$
- Fake tracks dramatically reduced



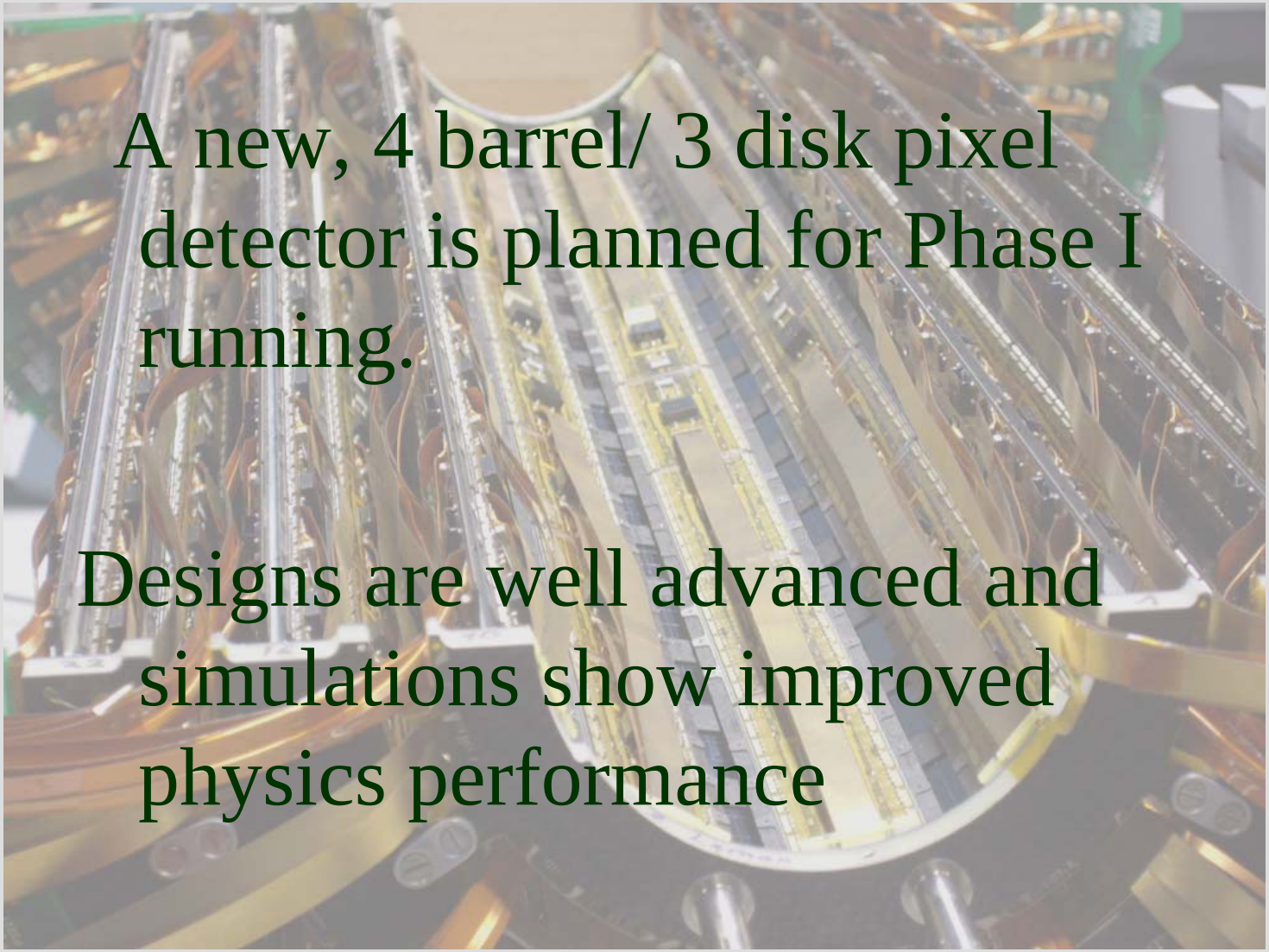


Performance – b-tags



Reduce fakes by factor of 6 for b-id efficiency of 60%

Conclusions



A new, 4 barrel/ 3 disk pixel detector is planned for Phase I running.

Designs are well advanced and simulations show improved physics performance