



FPix Phase 1 Pixel Data Rates

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Inputs



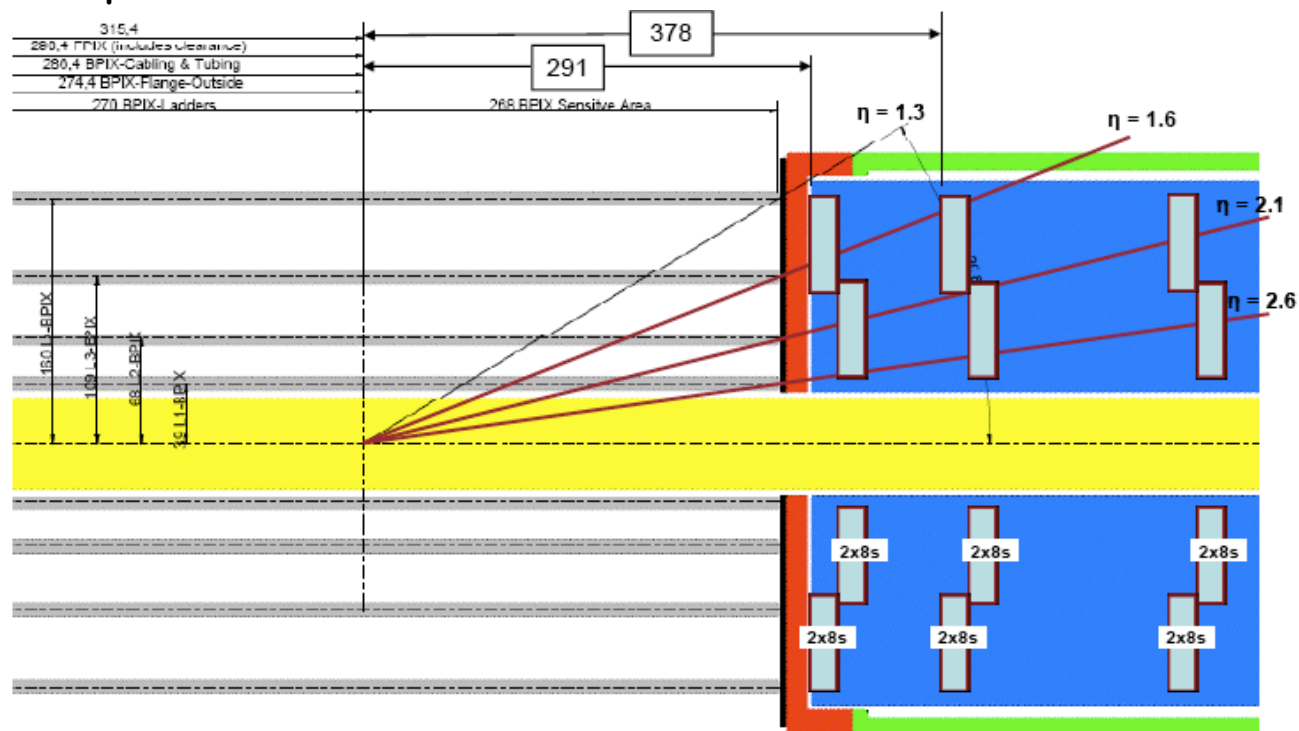
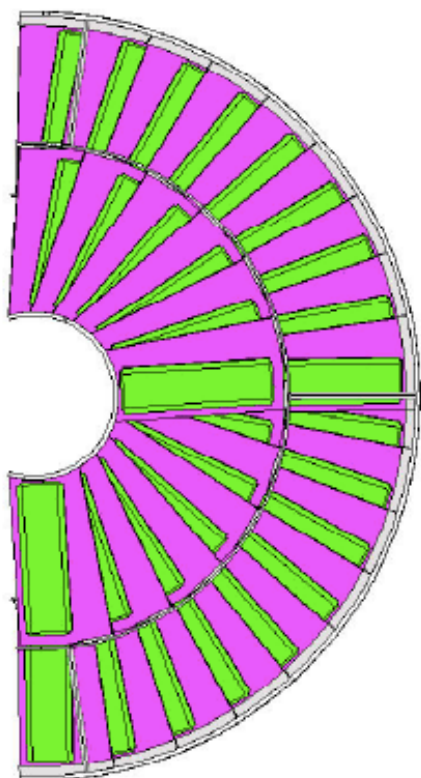
- **Defining Phase 1:**
 - 4 layers +3 disks giving 4 pixel hits for $|\eta| < 2.5$
 - Reduced material
 - LHC peak Luminosity $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- **Constraints & Goals**
 - Detector Infrastructure is same as present
 - Optical fibers, power cables, cooling pipes
 - Level 1 trigger rate is same as present (100kHz)
 - Evolution of present readout chain
 - Make minimal changes to accommodate 4th layer, 3rd disk
 - Minimum downtime from physics
 - Keep existing operational knowledge for detector
 - E.g. ROC tuning algorithms
 - Meet time & resource constraints (~2014—)



Layout & Counting Channels



- One Half Disk
 - (22 inner +34 outer) 2x8 modules = 896 ROCs
- Six Full Disks
 - 10752 ROCs (present system is 4320 ROCs)
 - Factor of ~2.5 over present FPix



Note: current FPix 4 disks at Z: ±345 and ±465 mm

Simon Kwan - Fermilab

TKUpgrade Mtg - CERN - 4/23/09

2



Evolution of Readout Chain



- Overview of elements
 - ROC 40 MHz analog → ROC 160 MHz digital
 - TBM → digital TBM 320 MHz merges 2 ROC token chains
 - AOH becomes digital link at 320 Mbps
 - Highly desirable to have new lasers
 - No recycling, available for integration and fast install
 - Pixel FED:
 - fast ADC/decoding FPGA replaced by deserializer FPGA
 - New faster optical receiver
 - Present S-Links must run faster or be replace with new link to central DAQ
 - This is actually the bottleneck for dataflow



Channel Counting & Data Rates



- Number of channels

- FPix has 2.5 more ROCs in Phase 1 than present
- I'll use $56=22+34$ Blades/disk for estimates

$$\frac{10752}{4320} = 2.5$$

- Services did plan for 3 disks

- Fibers and cables available (BPix needs a few more fibers too)
- If 32 ROCs/Link, $N_{\text{Links}} = 336$ (was 192) ; ~10 FEDs (is 8)
- If inner disk goes to 16 ROC/link, $N_{\text{Links}} = 468$; ~13 FEDs
- Number of FEDs fits in current crate
 - Room for two additional VME crates, if needed

- It fits, but will it work?

- Geometric coverage will affect occupancy

- Inner radius reduced (to 39mm from 58.7mm)
- Outer radius increased (to 161mm from 144.6mm)
- Disk 1 closer to IP, Disk 3 farther
- $|\eta| < 2.6$, increase of 0.1 unit ; more actually for third disk



FPix DAQ Data Rate Estimates



- From geometry in current Phase 1 simulation
 - Use digis to measure data rates
 - Look at bottlenecks in ROC/TBM/Link/FED/S-Link
- Should measure occupancy at 14 TeV (pending LHC)
 - Compare to simulation (tune generator)
 - Can't apply directly to Phase 1 -- Expect reduced material to help with rates
- Can make first estimates including new geometry now
 - Caveats:
 - Used FastSim as FullSim and pileup not yet working/available
 - The geometry is newly available; numbers are still preliminary
 - I need to examine the results in detail
 - » Check geometry (and interpretation thereof)
 - » Check full simulation vs fast simulation



Data Rate Estimates



Numbers normalized to one 2x8 module

Disk	Inner		Outer	
	(hit/mod/evt)	Link Rate ¹ (Mbps)	hits/mod/evt	Link Rate (Mbps)
1	11.3→22.6	27.1→54.2	5.5→11.0	13.2→26.4
2	11.2→22.4	26.8→53.6	5.6→11.2	13.5→27.0
3	9.3→18.6	22.4→44.8	5.7→11.4	13.6→27.2

¹Link Rate 100kHz L1, 24 bits/hit; headers add 22.4 Mbps

- **Inputs:**

- Fast Simulation (pTmin=50 MeV , loopers ON)
- $N_{pileup}=40$ ($L\sim 2\times 10^{34}$) plus one single muon

- **N.B. Full/Fast Sim ratio is not 1.00**

- Take a factor of 2 in what follows (unscaled → scaled)

- **Implications**

- Inner Disk ~ Barrel layer 3 ; Outer Disk ~ Layer 4
- Joining two modules on a fiber looks doable from the rates



Optical Link BW Estimate 2×10^{34}



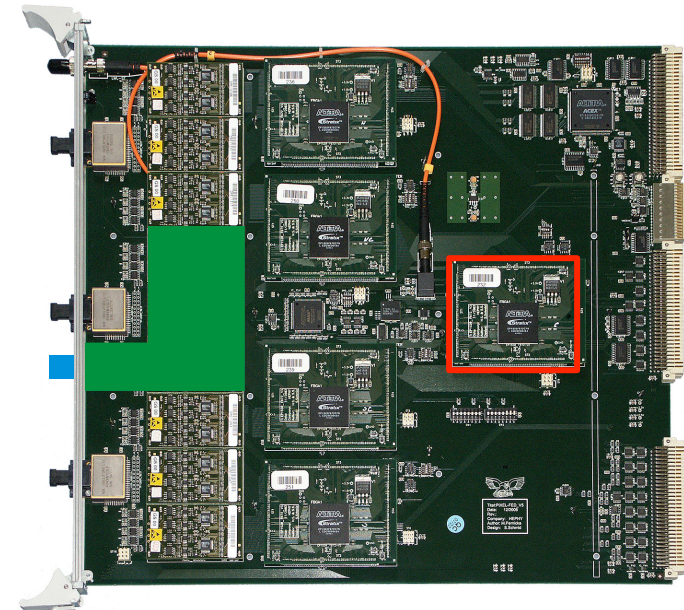
- FPix Phase 1 Using 16 ROCs per link
 - At 100 kHz L1A, the average link rate is 41.0 Mbps
 - At 100 kHz L1A, Inner disk Link rate is 76.6 Mbps
 - A 320 Mbps link is 24% utilized
- Can consider using one link for two modules
 - Link rate just doubles to an average of ~50%
 - Outer disks have even lower rates
 - With the present simulation(!)
 - Need to compare with data from 14 TeV p-p collisions
 - Still need to check full simulation
 - Proper handling of loopers, delta rays, out of time hits
 - Healthy skepticism is warranted



FPix FED Date Rate Estimate 2×10^{34}



- Combining 36 inputs in FED, output to CMS DAQ
 - Pixel Hit word is 32 bits ; average of 30.3 hits/link (32 ROCs)
 - Data Rate = (4 B)(30.3)(36)(100kHz) = 436 MB/s (3.5 Gbps)
 - Radial averaging is legitimate here (36 inputs can be balanced)
- FED output bandwidth to CMS DAQ
 - Currently 64 bits @ 80 MHz = 5.12 Gbps (seems OK!)
 - Possible new center FPGA daughter card, if needed
- S-Links from FED to CMS DAQ
 - Attaches to VME mezzanine card
 - One per FED
 - Current Spec is 200 MB/s (1.6 Gbps)
 - Bottleneck in system for pixel data



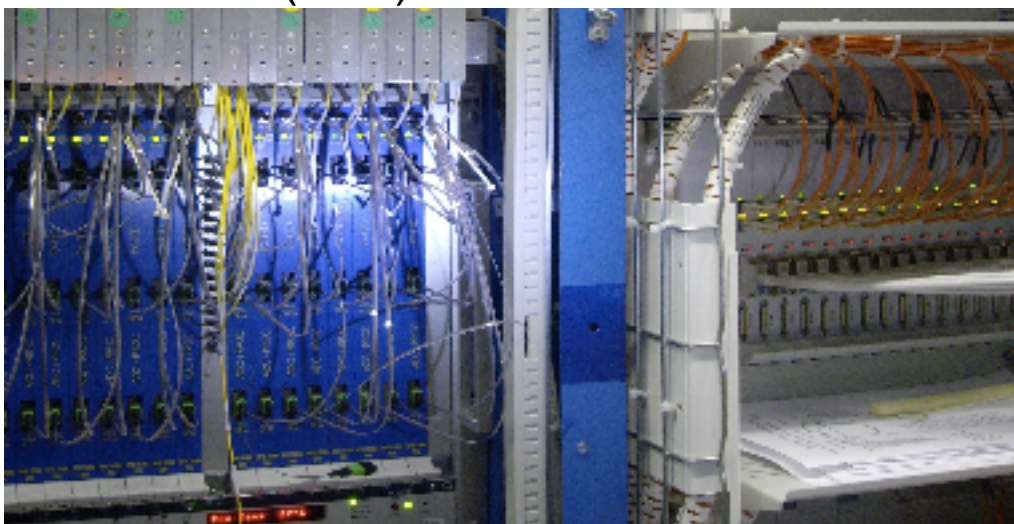


S-Link Upgrade/Replacement

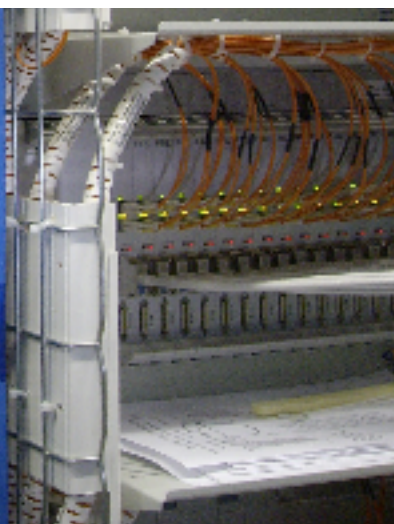


- Link to CMS DAQ
 - S-Link Spec: 200 MB/s , so naïve factor of >2 below need
 - Current thinking (15 May SLHC DAQ meeting)
 - C. Schwick thinks 300 MB/s is very possible
 - Have tested to 400 MB/s on bench - \sim estimated need
 - Upgrade to DAQ links very likely (Phase 1 pixel a test case?)
 - Consider new sender cards and physical protocol e.g. 10-100 Gbps e-net
 - FED interface on VME mezzanine stays the same

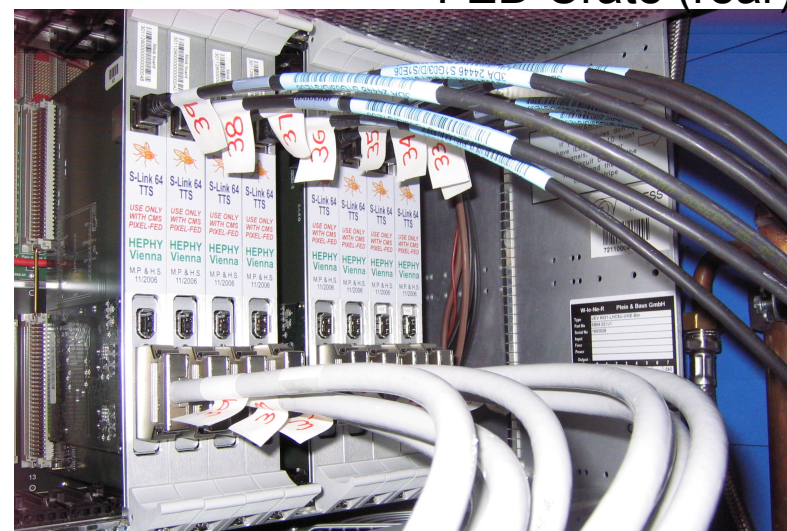
FED Crate (front)



FRL Crate



FED Crate (rear)





Summary



- DAQ design for phase 1 is underway
 - Common with BPix: ROC, TBM, Optical Link, FED update
 - Available fibers just enough(?) & VME crates are OK
- For proposed FPix 56 Blade/half-disk layout @ 2×10^{34}
 - 32 ROCs/link: optical links are at 50% of capacity
 - Maybe too close, so consider 16 ROC/link for inner disk
 - FED output bandwidth close to limit (5 Gbps)
 - S-Links need upgrade or replacement (>3 Gbps)
- All conclusions are (very) preliminary, and updates require full simulation of actual geometry
 - Measurement of zero-bias 14 TeV collisions in current geometry needed to tune MC ; very important normalization