System Concepts for Doublet Tracking Layers

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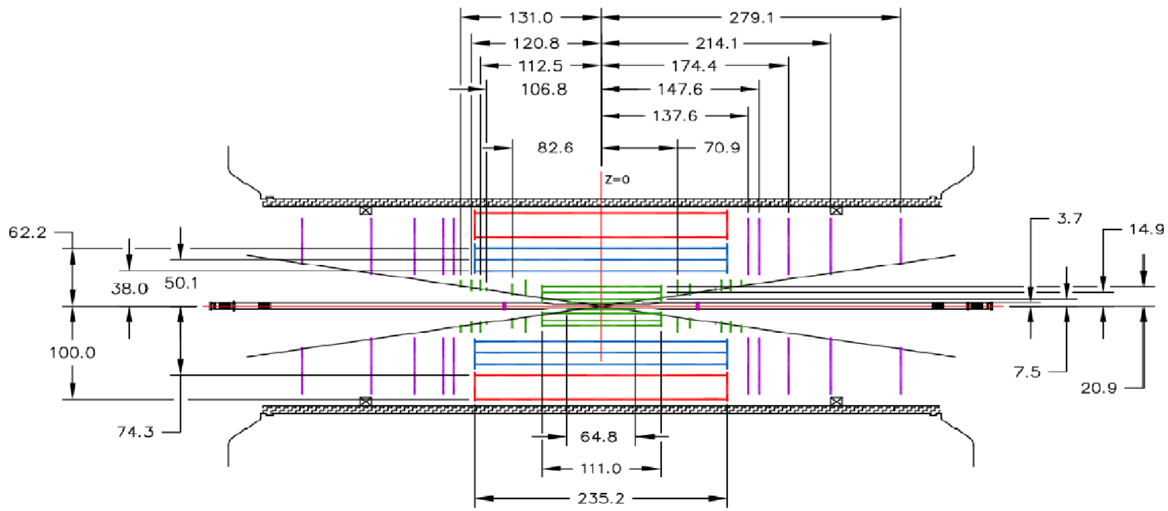
Outline

- Introduction
- Layout
- The present stave design and features
- Assumptions/Issues
- Trigger rate study
- A trigger stave concept and implications

Introduction

- Over the past 4-5 years ATLAS has carried out an R&D program to develop a tracker for the super-LHC
- Many critical aspects and technologies have been addressed – layout, mechanics, mass, cooling, sensors, electronics, DAQ, assembly
- The tracker is designed around two-sided integrated multi-modular “stave” and “petal” elements.
- A stave or a petal is a natural doublet structure and could also be a basis for a local trigger
- Here we consider the implications of, and for, this design, on a local doublet based tracker trigger

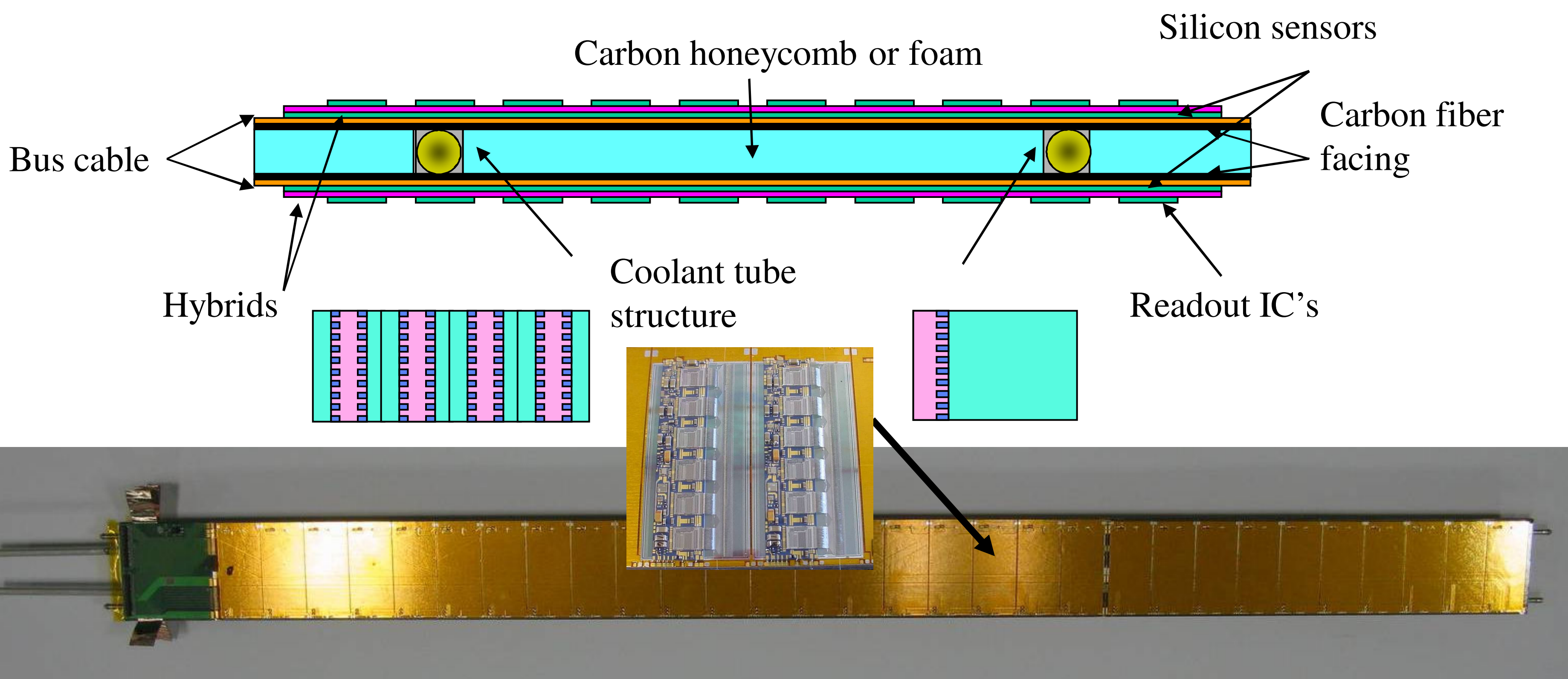
Current s-LHC Tracker Layout



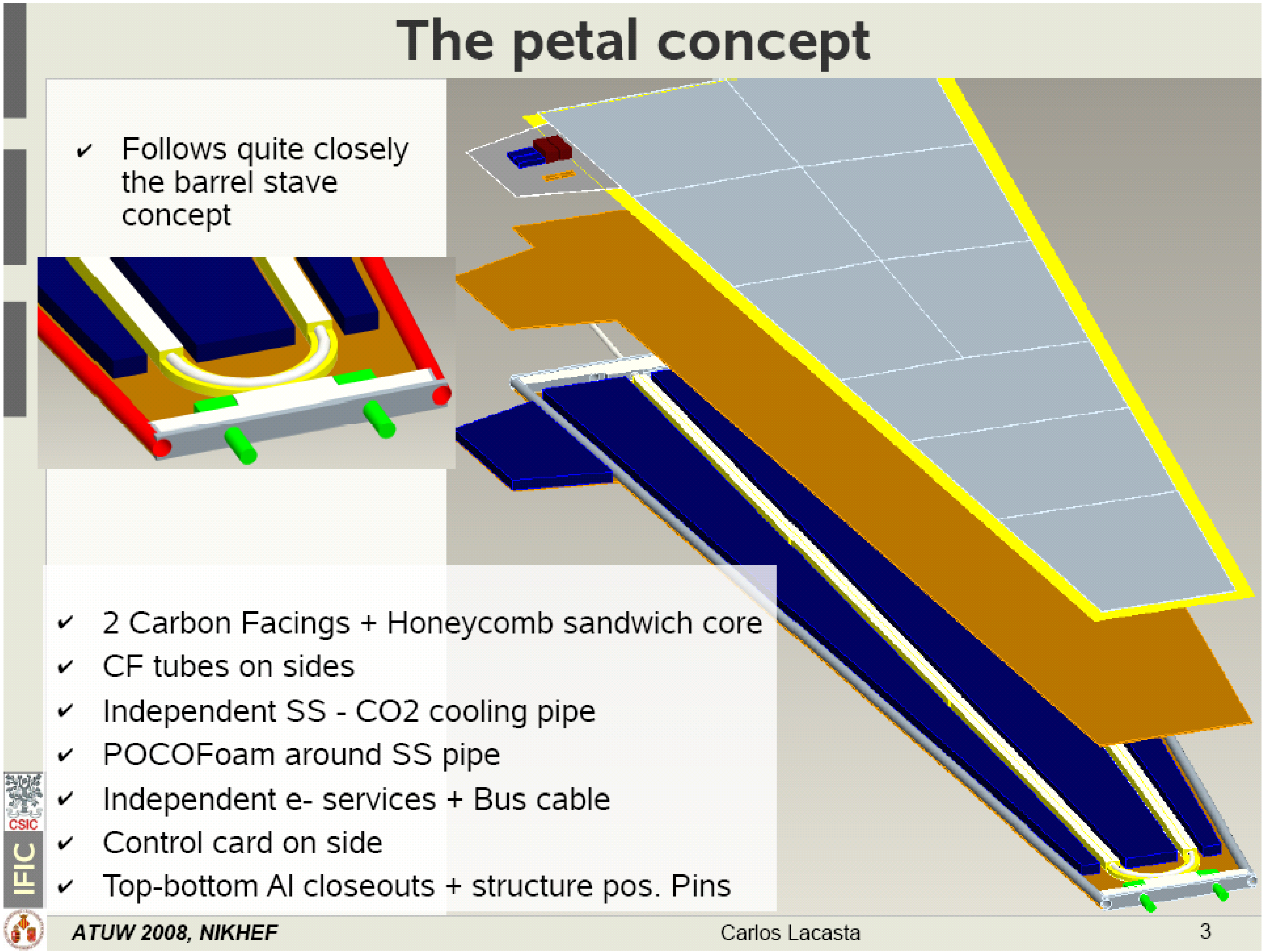
- 5 double sided barrel layers
  - Inner layers: 3 of 2.5 cm = short strips
  - Outer layers 2 of 10 cm = long strips
- 5 double sided disk layers
- Basic substructure is a "stave" or "petal" being a highly integrated electrical/mechanical/thermal element holding many "modules"

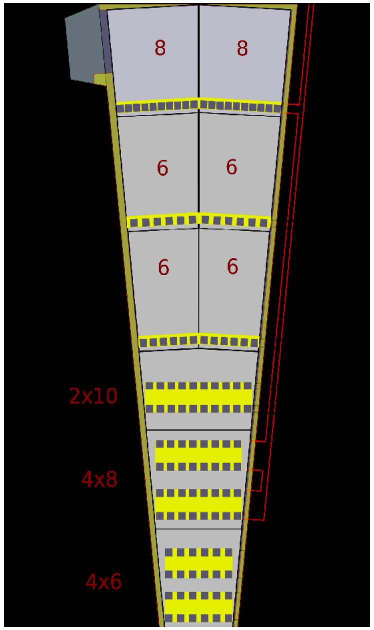
Stave Concept

- Approximate dimensions
  - Short- (~2.5 cm), Long-strips (~10 cm): length 1.2 m, width ~ 11 cm
  - Thickness ~ 3-5 mm
- Laminate of core, electrical bus, sensors, hybrids, chips
- Mass 2.26 (1.73)% X0 (34% core, 66% electrical+sensors)



Forward Petals

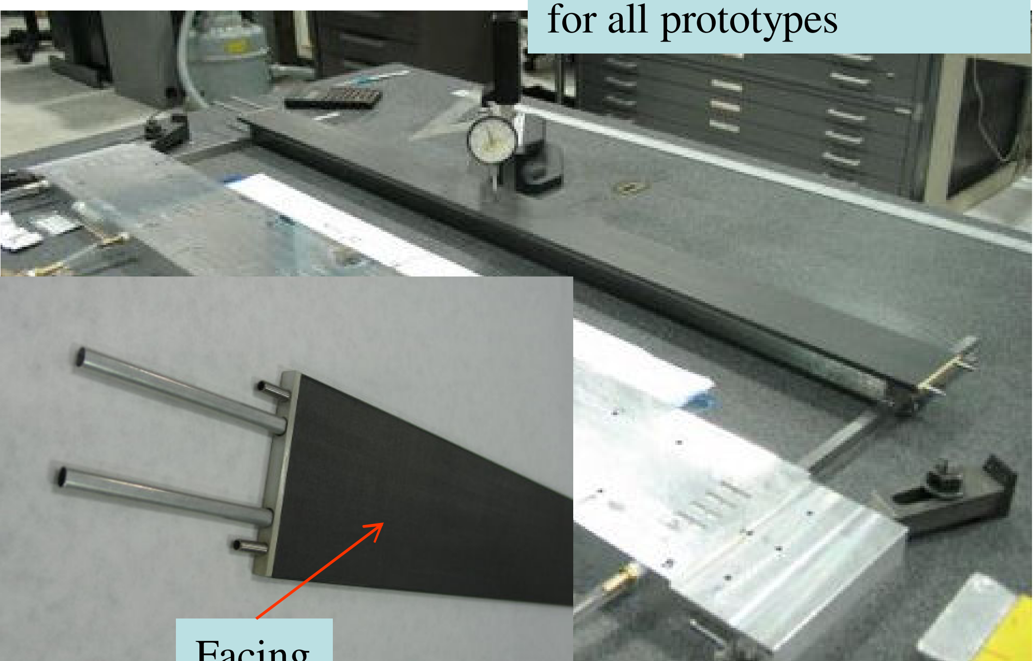


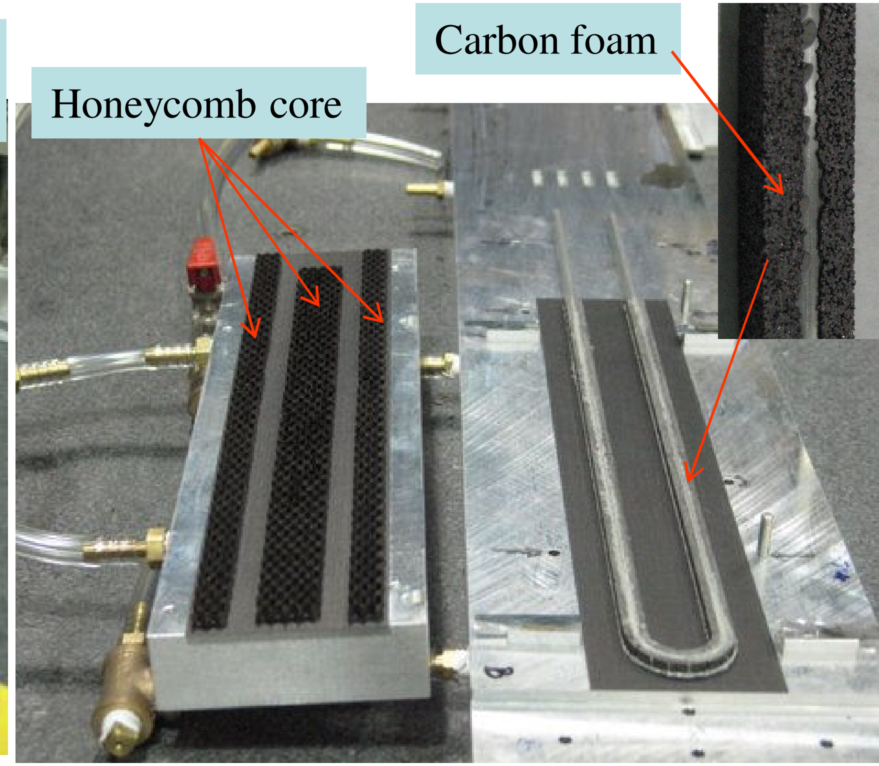


Elements of Stave/Petal Technology

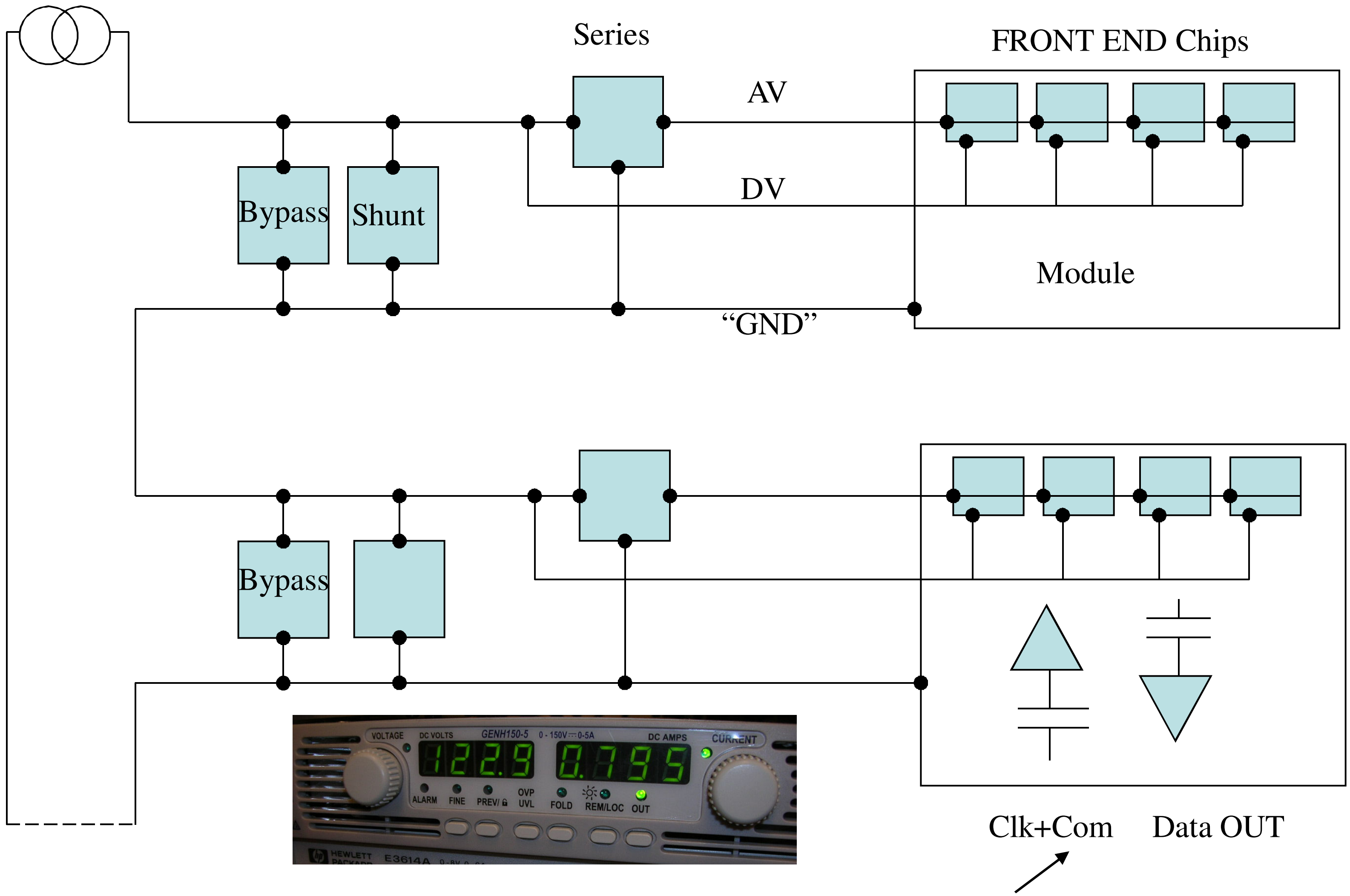
- Low mass thermo-mechanical cores
  - Assembly and materials
  - Measurement
  - Simulation
- Embedded electrical services
- Distributed multi-drop LVDS transmission
- Alternate powering, control and protection
- Low mass, surface attached hybrids
- Fine pitch interconnections
- Multichannel Parallel DAQ and test systems

Core Construction





Serial Powering



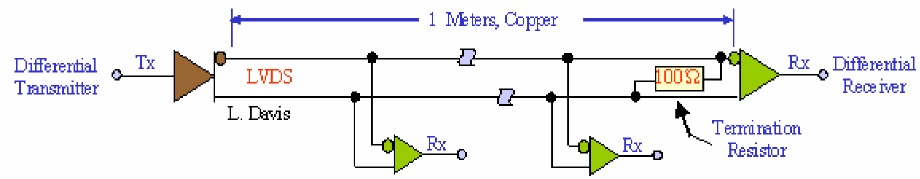
Requires AC coupled data and TTC

Berkeley Lab

Embedded Bus Cables

Al shield

End of Stave Card



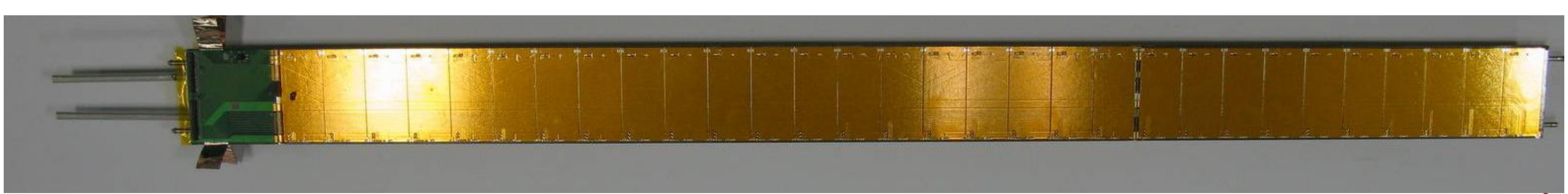
Data readout: 1/hybrid

Clock & Command lines

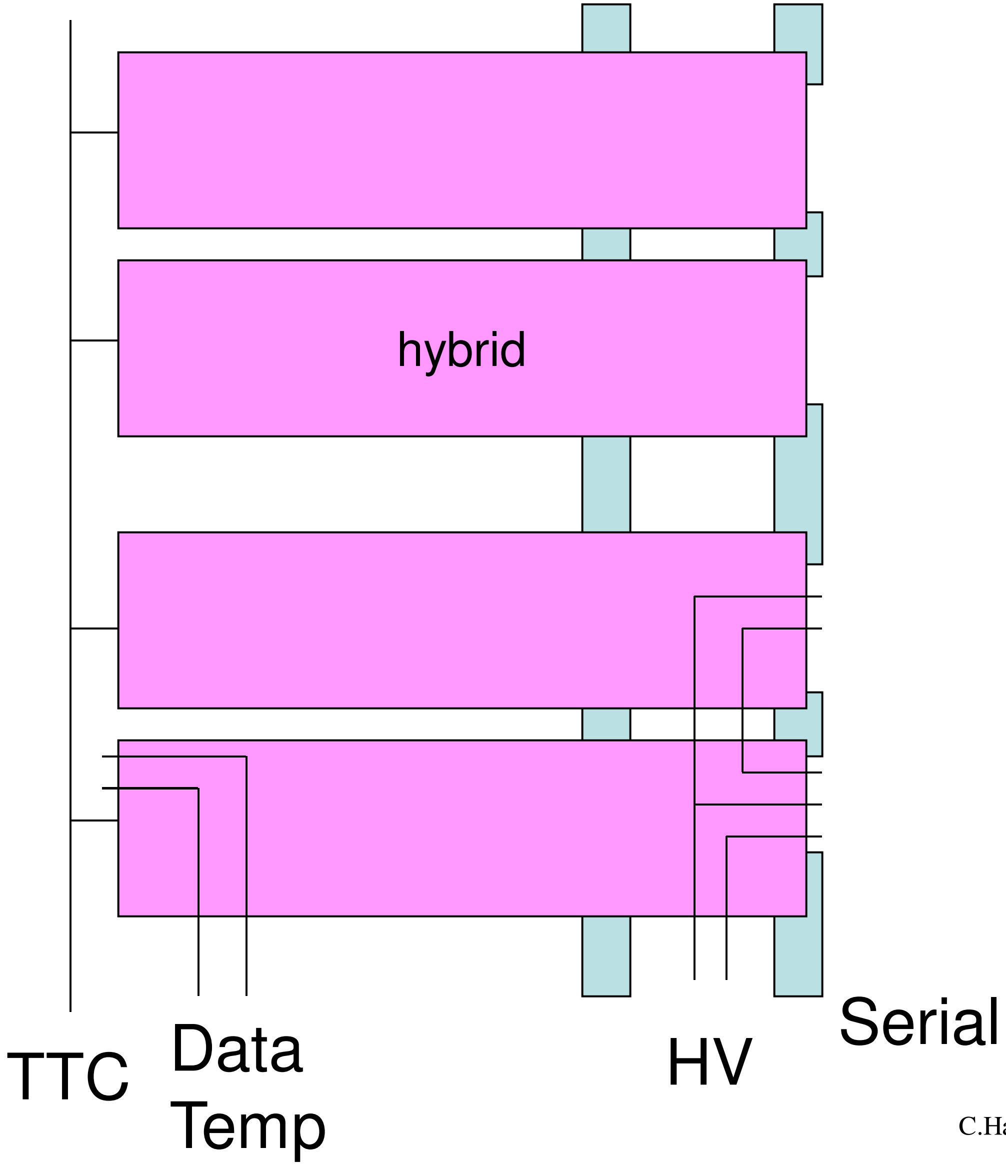
Serial current return

Serial current link

HV distribution

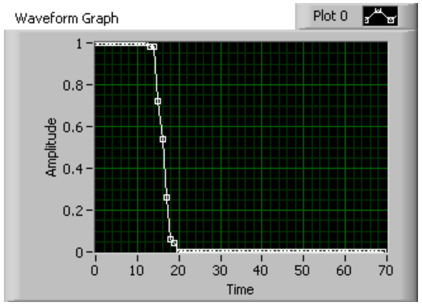


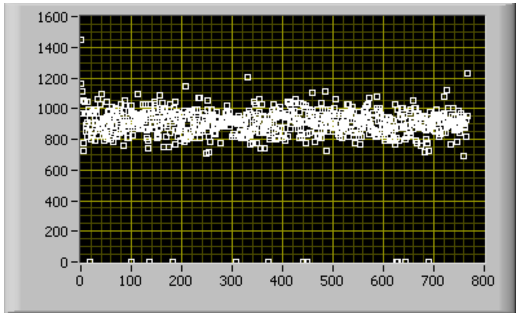
Wiring Geometry

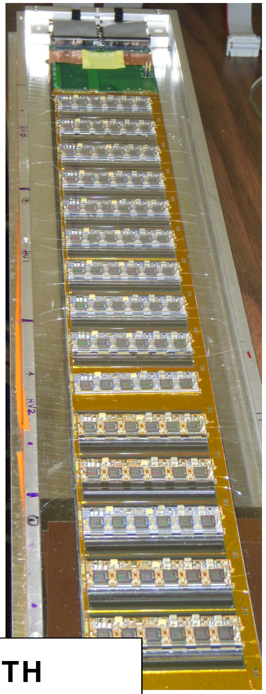


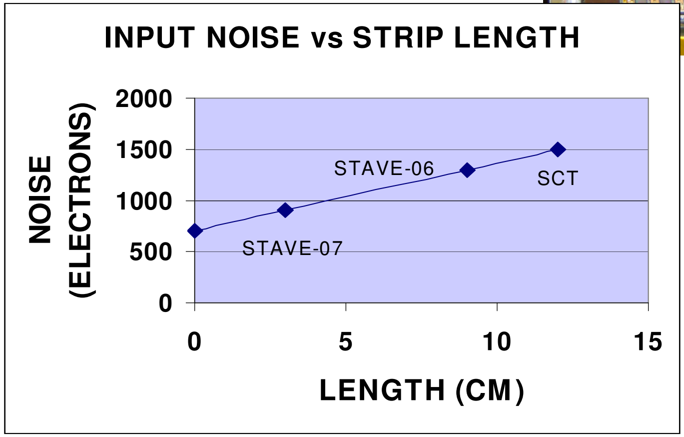
Tests of Staves and Modules

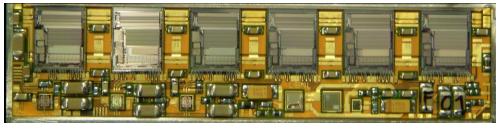
- Electrical performance studies
  - Noise
  - Grounding, bias, and shielding
  - Signal propagation
- Module is serially powered, with AC coupled data and control
- Good noise and interference performance observed on stave
- Tested with a range of substrates, thicknesses, directly glued to sensor

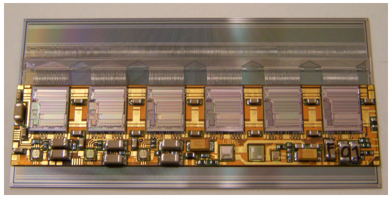


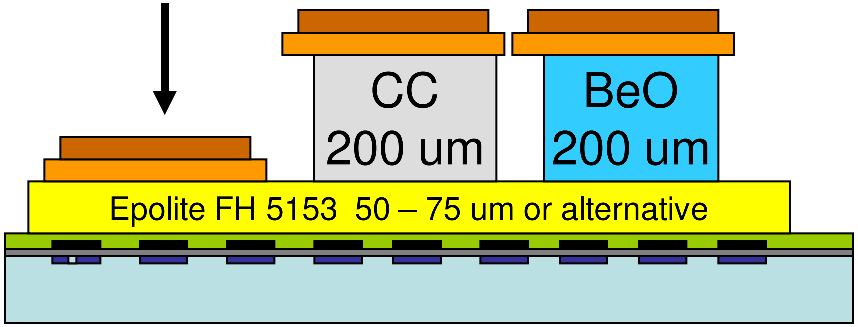












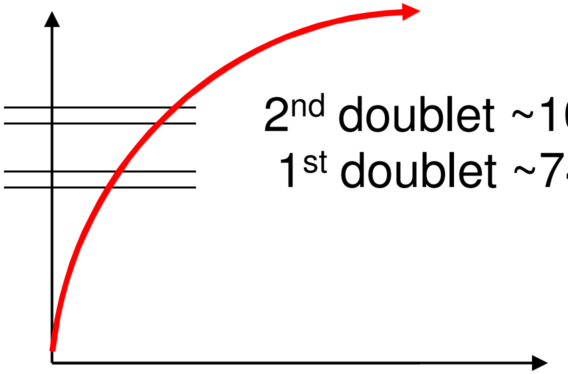
Assumption and Issues

- Focus here is on doublet silicon strip tracking layers at large radius (70-100 cm) with local correlation circuits.
- Assume “long” strips (5-10 cm) with ~few mm radial separation
- Without a trigger system we currently have:
  - A minimal mass design
  - Each of 5 stave layers with axial/stereo sensors
  - 2.5/10 cm Z granularity well matched to the expected sLHC occupancy and the bandwidth of a practical frontend/data transmission system
  - A design meeting thermal requirements with direct cooling of the sensors.
  - Embedded digital data paths without undue interference and coupling.
  - Practical alternative powering designs (serial and DC/DC) which significantly reduce services
- What is the impact of a local doublet trigger and what can we retain?

Implications

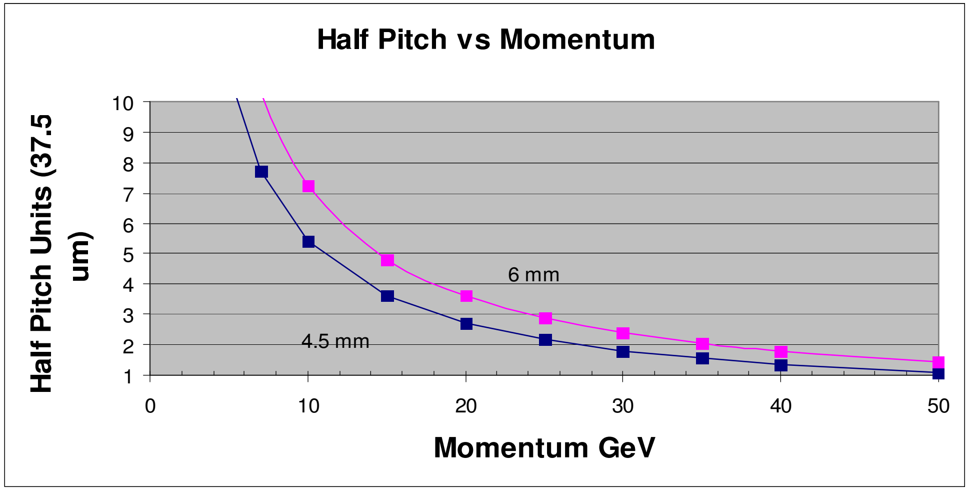
- Is the 10 cm strip geometry sufficient?
- Is the trigger rate, real/fakes manageable?
- What is the impact on the readout bandwidth?
- Can we afford to lose axial/stereo layers in favor of axial/axial layers?
- How much mass is added?
- Are the interconnections practical?
- What are the electrical implications of sending fast hit data around for correlation?
- What is the effect on cooling and thermal performance?

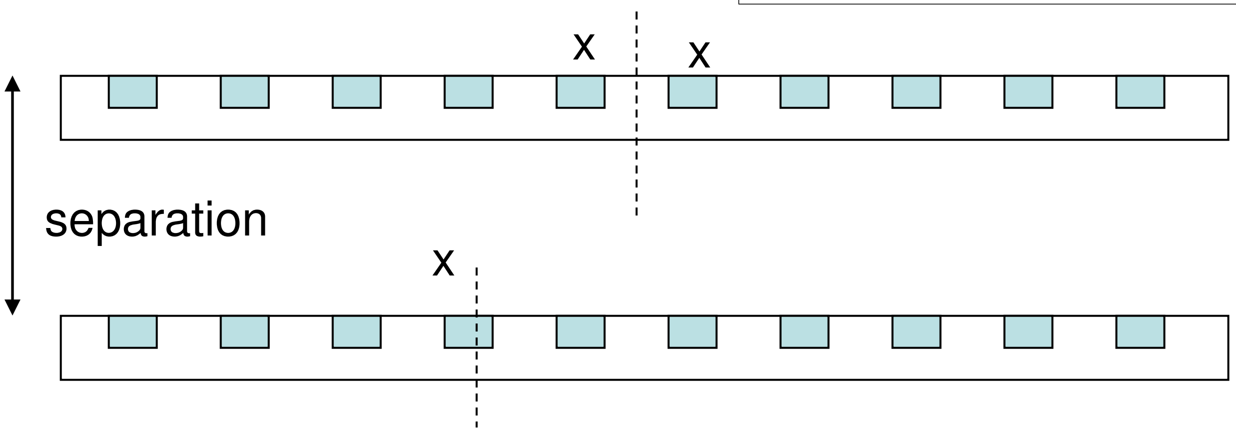
Basic Concept



2^{nd} doublet ~100 cm
1^{st} doublet ~74 cm

Simple calculation at 100 cm



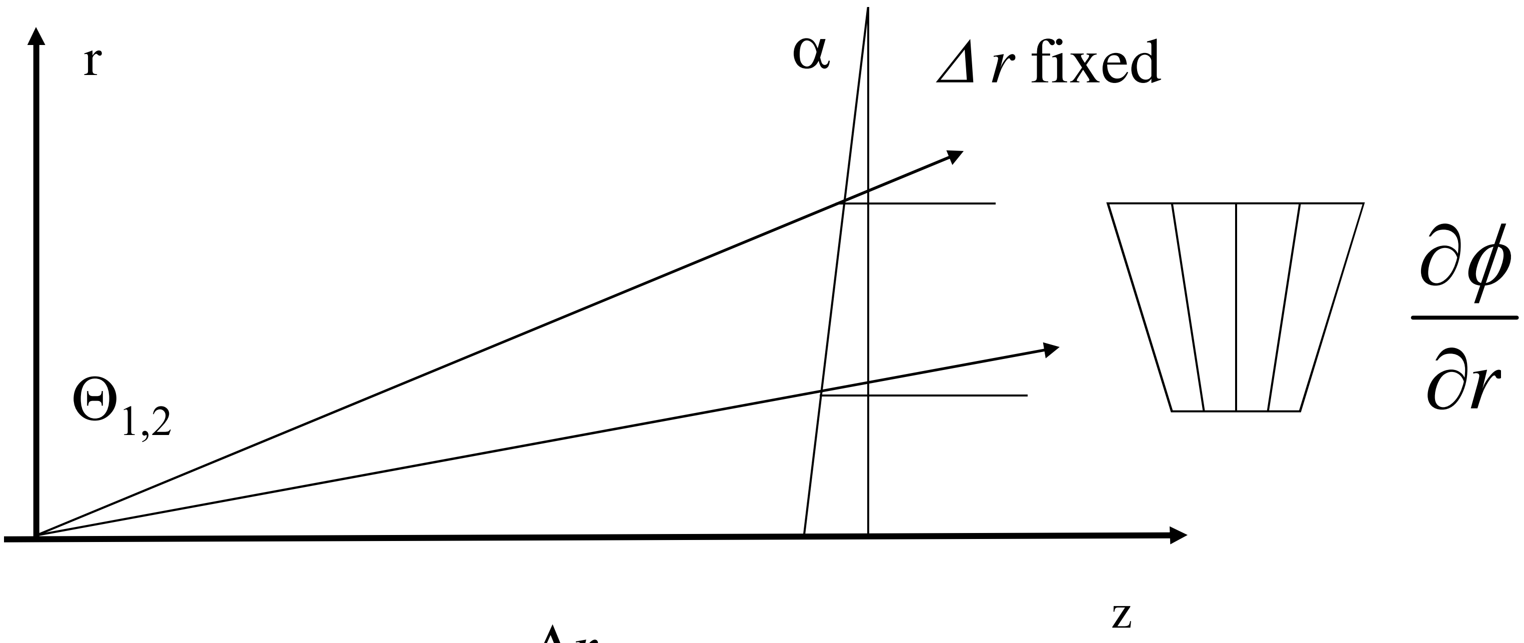


In a binary scheme the natural binning unit will be a half-pitch

Allow 1 or 2 strip clusters

For reasonable pitches, sensor separations, and momenta find ~2-5 bins
Local module output could be 3 bits : 7 bins + 1 sign

Petals Configured as Trigger Doublets



$$\tan \alpha = \frac{\Delta r}{z \tan \Theta_1 \tan \Theta_2}$$

Description of Simulated Layout

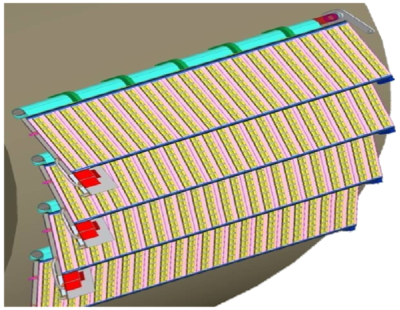
- sLHC outer barrel modules
- L4 =100 cm, L3 = 74.3cm
- 10 x 10 cm module
- 4.5 mm radial separation within module
- 75 micron pitch
- Not tilted
- Material = present SCT (over estimate)
  - Case 1: all material is before layer
  - Case 2: all material is within layer
- Single particle samples, 1 GeV π,γ,n and 20 GeV μ

Simulation Results

- Ran 10K single particles/type through a GEANT4 simulation
- Layout is a mix of the present SCT material (mass) with an sLHC layout
- Trigger Hits are defined as doublets with a ≤ 2 strip window, 1-2 strip cluster
- Raw Hits are defined as all hits (=200 for efficient charged, no interactions)

	Trigger Hits per 100 particles	Trigger Hits per 100 particles	Raw Hits per 100 particles
	Material in front	Material within	Material within
1 GeV γ	1.44	0.71	75
1 GeV π	1.16	0.71	214
1 GeV n	0.09	0.05	117
20 GeV μ	-	89	217

Simulation Results



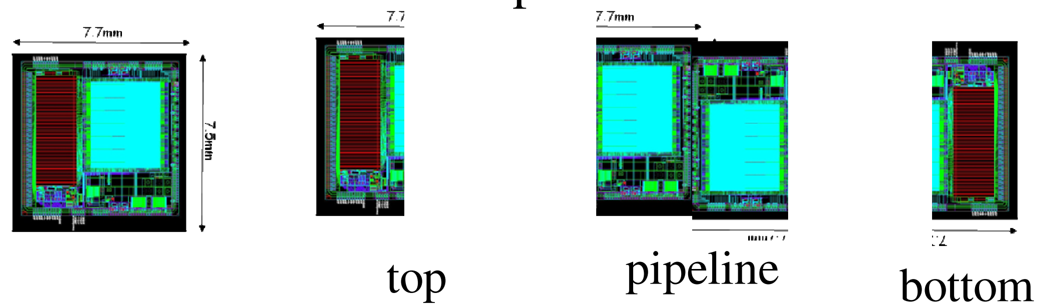
- Want to be efficient for stiff charged tracks: OK
- Keep material out from in front of layer
- Normal data is read out at 100 KHz
- Trigger data is read out at 40 MHz
- Want the data rate from triggers (real and background (min-bias)) to be of same order as the normal data rate
- Find this to be ~2 : so twice as much trigger background as real (100 KHz) L1 triggered data
  - Need to run proper min-bias samples
  - Need to vary layout (separation, trigger criteria, material…)

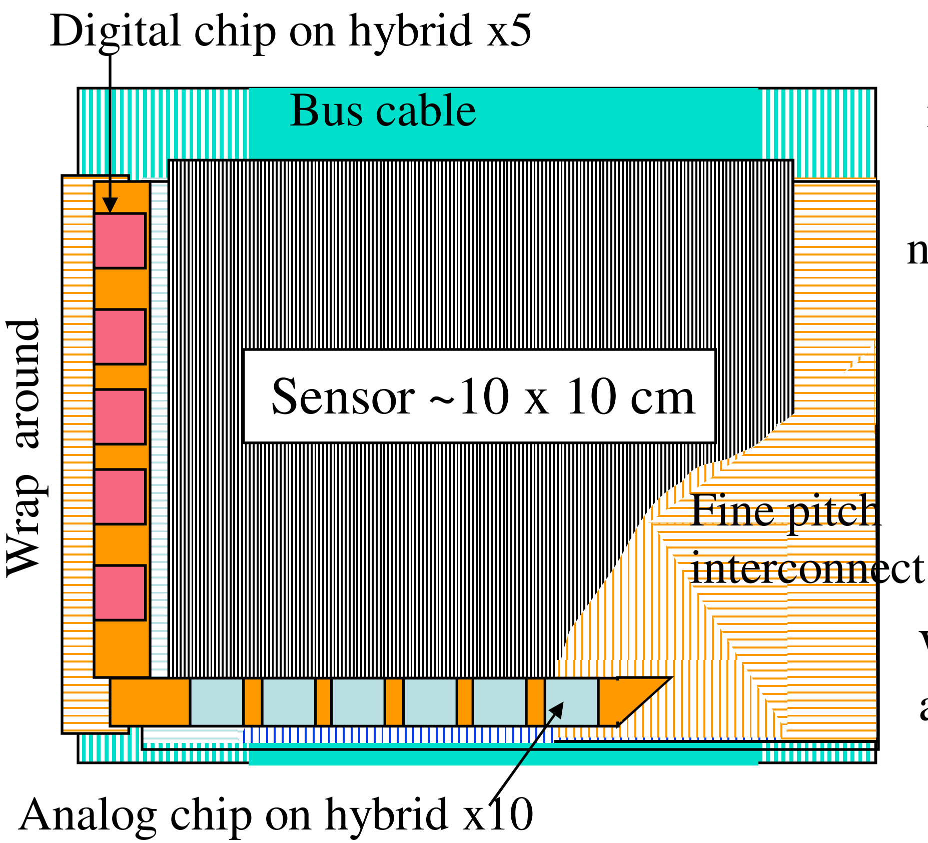
$$400 \times \frac{(TRate(1\,GeV\ \pi) + TRate(1\,GeV\ \gamma))}{(Raw(\pi) + Raw(\gamma))} \approx 400 \times 0.005 \approx 2$$

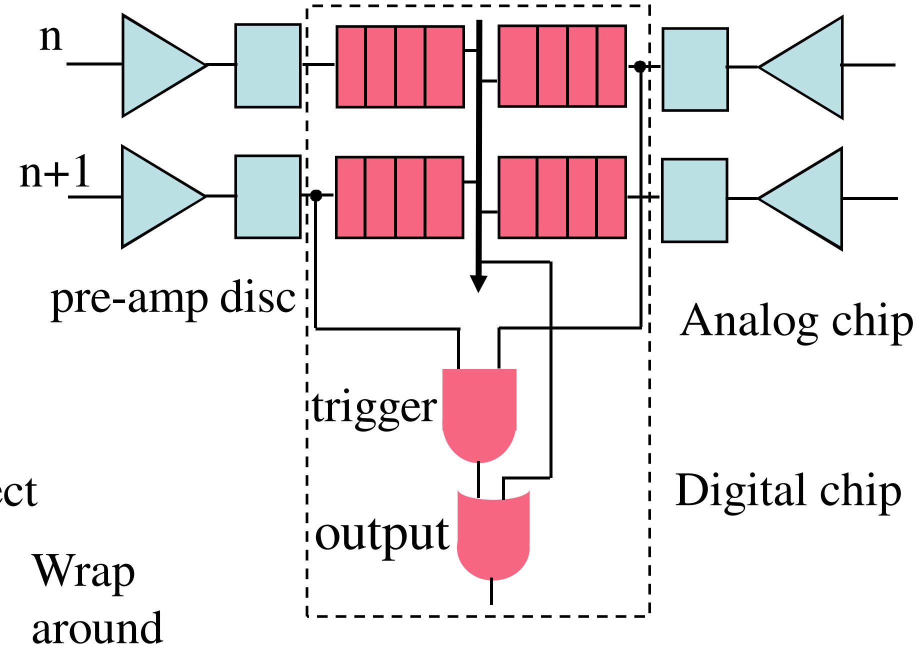
Technical Concept

Split the readout chip and use embedded fine pitch interconnection

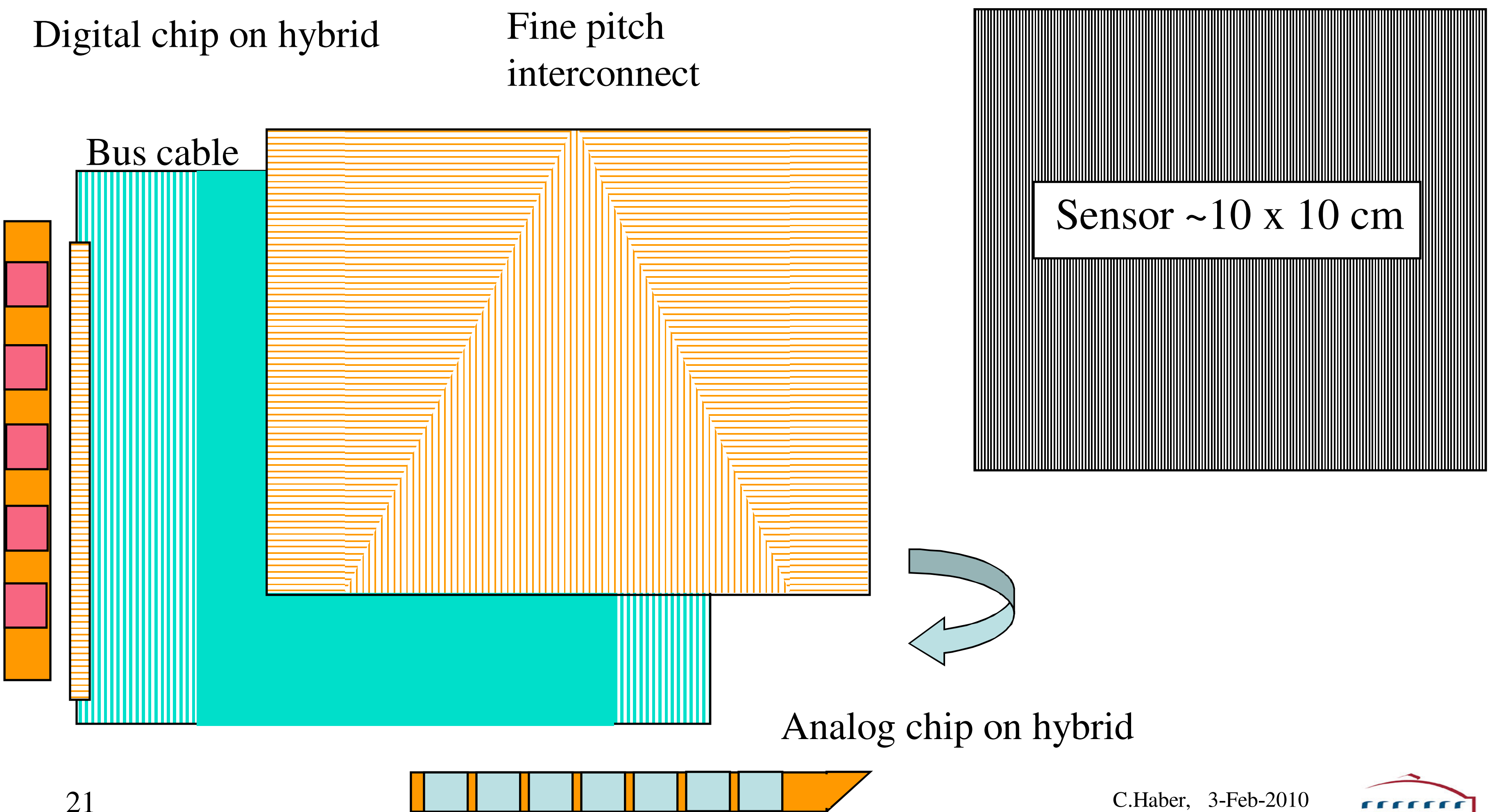
ABCn
Binary readout



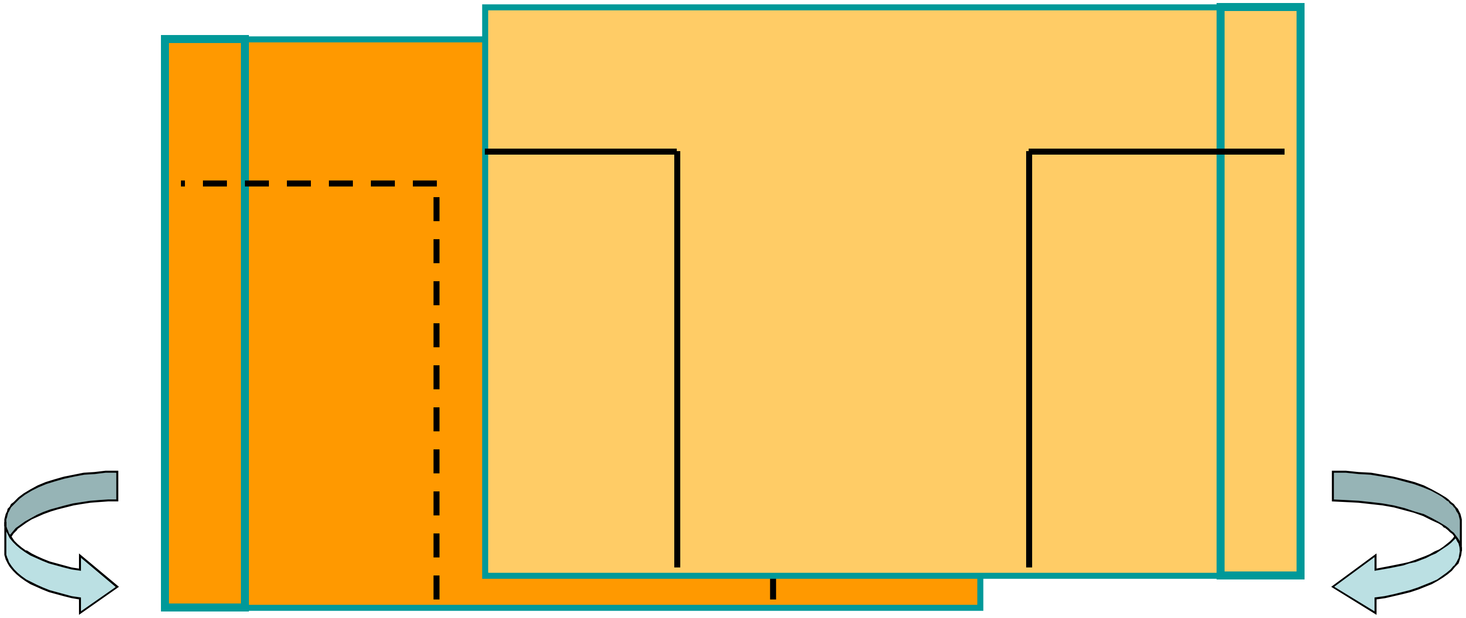


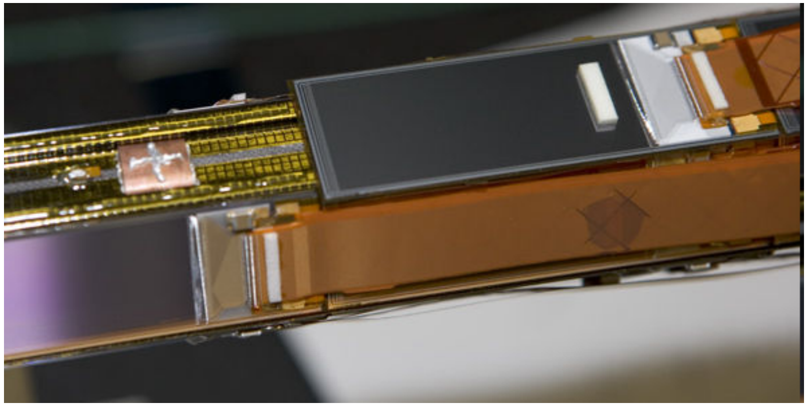


Technical Concept



Structure of Interconnect/Wrap-around



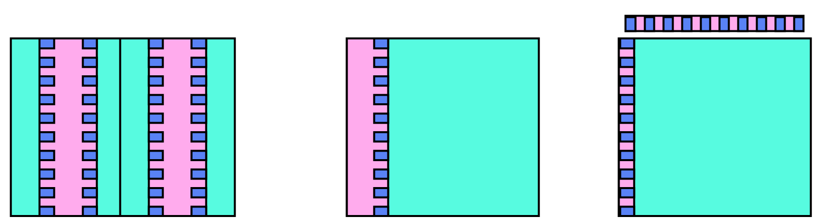


Fine pitch interconnect method used for D0 Layer0, CDF Layer00 projects, and BaBar

Impact

- Consider effect of additional chips and interconnect material on the stave
- Compare to material estimates studied earlier as part of ongoing stave R&D
  - Effect of trigger components is not large
- Of potentially more concern are thermal and electrical interference
- Impact of axial/axial vs axial/stereo not yet known

Stave	Flex SS	Flex LS	Flex LS + Trig
Core	0.73	0.73	0.73
Module	1.49	0.96	1.07
Glue	0.04	0.04	0.04
Total %Xo	2.26	1.73	1.84

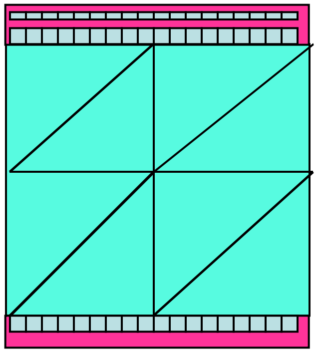


Conclusions

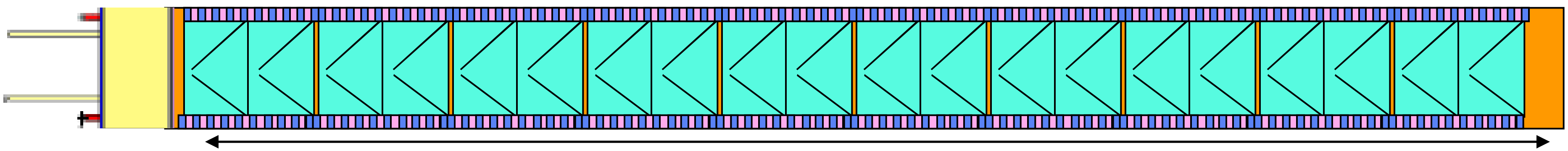
- Stave/petal element is a natural basis for local doublet trigger
- Electrical/interconnect concept is a small perturbation on existing mechical design
- Additional mass is not significant, keep mass within or behind
- Need to study electrical interference aspects
- Implications for data rates and bandwidth need more detailed and realistic simulation but do not yet appear severe
- Overall optimization of tracker needs consideration

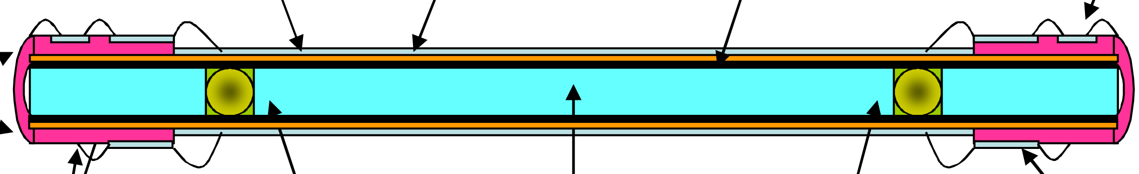
Extra Slides

Short Strip Concept for a Trigger Stave



Double metal sensor module
Idea is to read out strips from both edges using double metal layer
A correlator chip looks at hit patterns from both sides.





Background Variation with Strip Cut