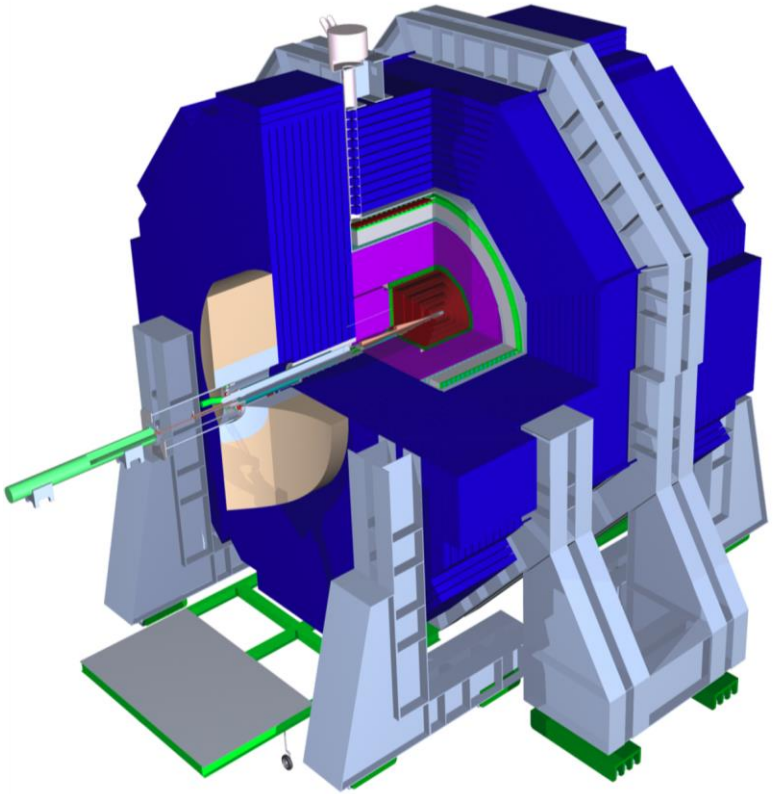
The SiD Detector

for the International Linear Collider



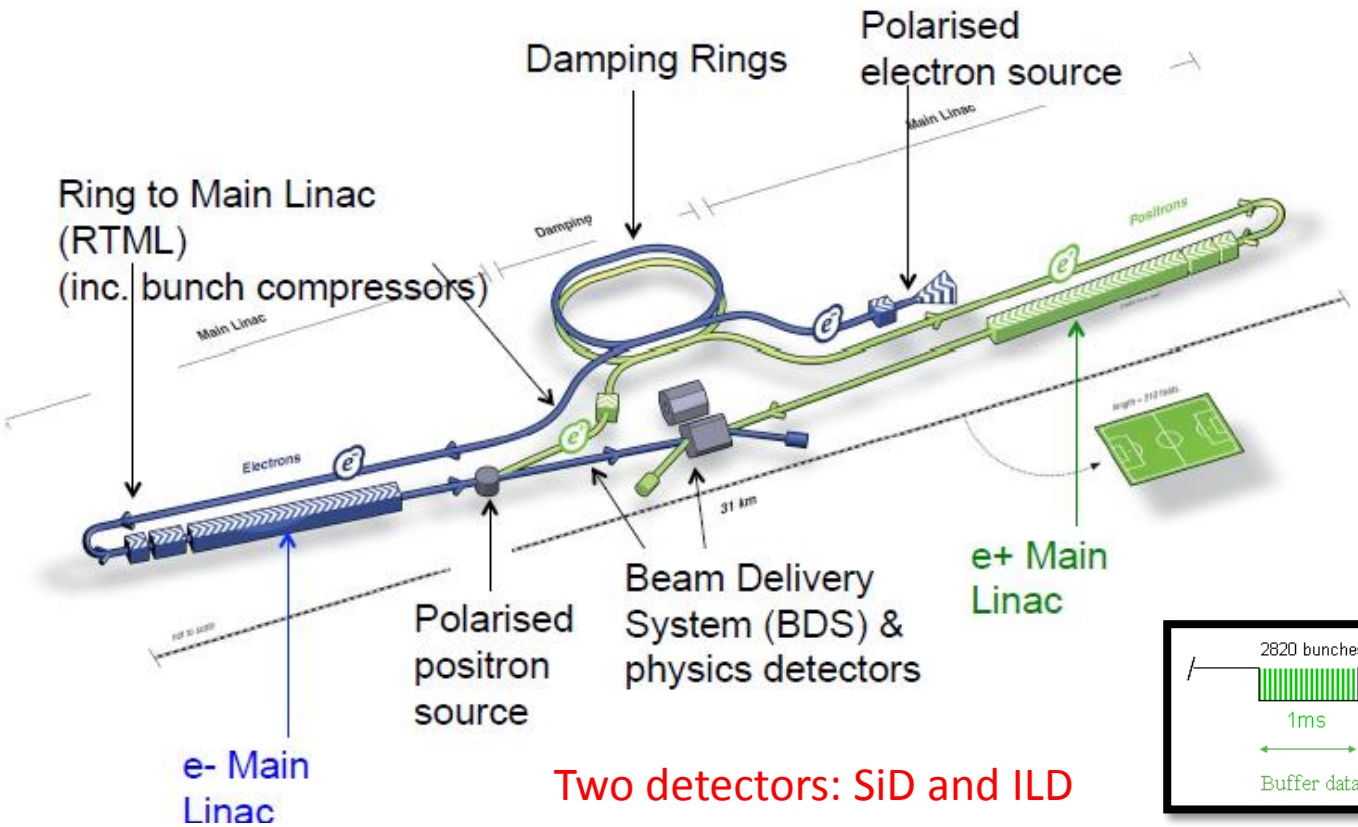
Andy White

UNIVERSITY OF TEXAS ARLINGTON

The SiD Detector for the International Linear Collider

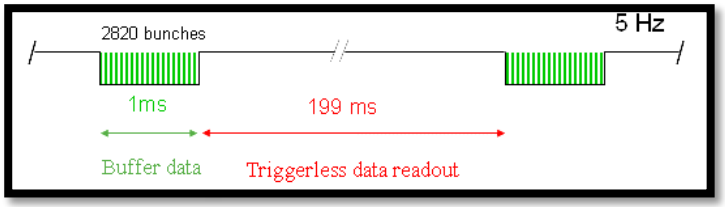
- The ILC
- ILC Physics Program
- SiD Detector design
- SiD Detector components
- Recent R&D, ongoing work, opportunities for participation

ILC Schematic

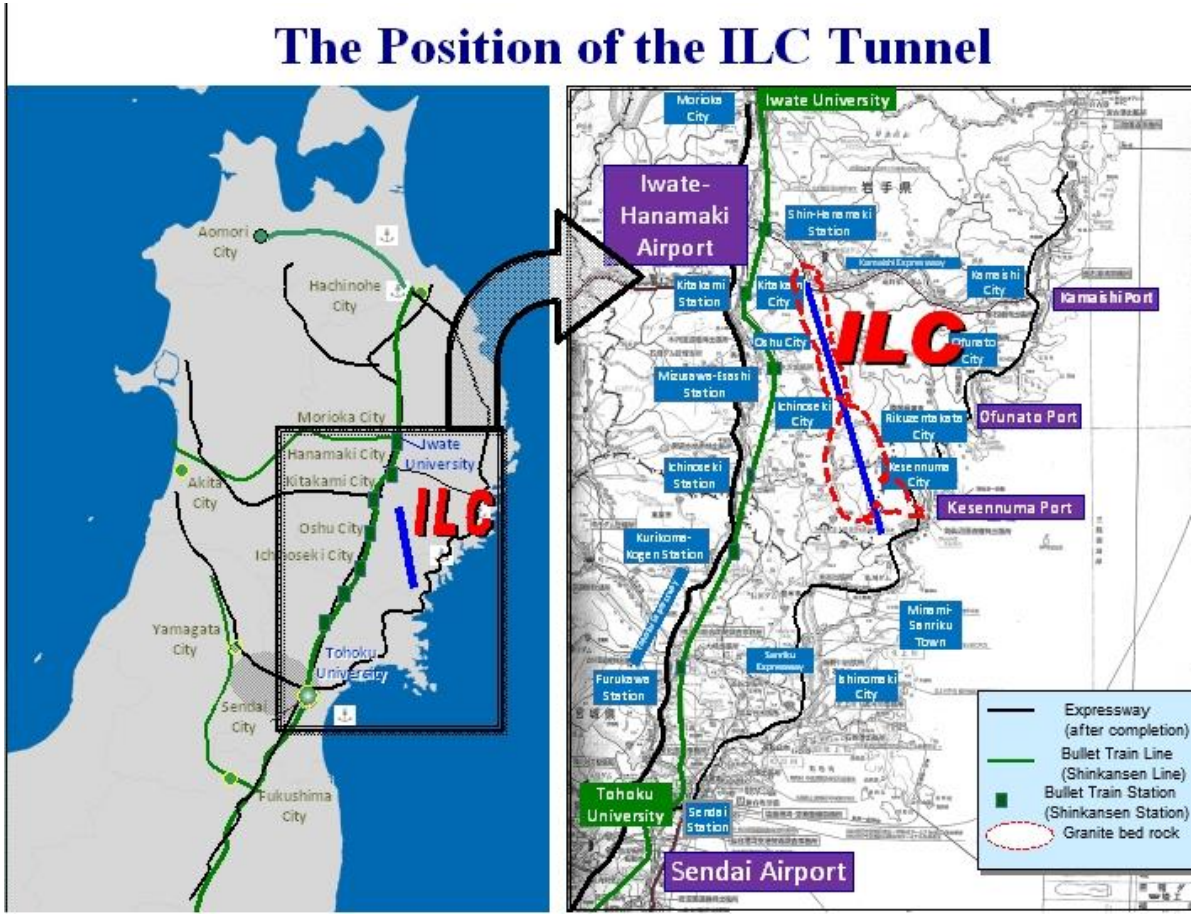


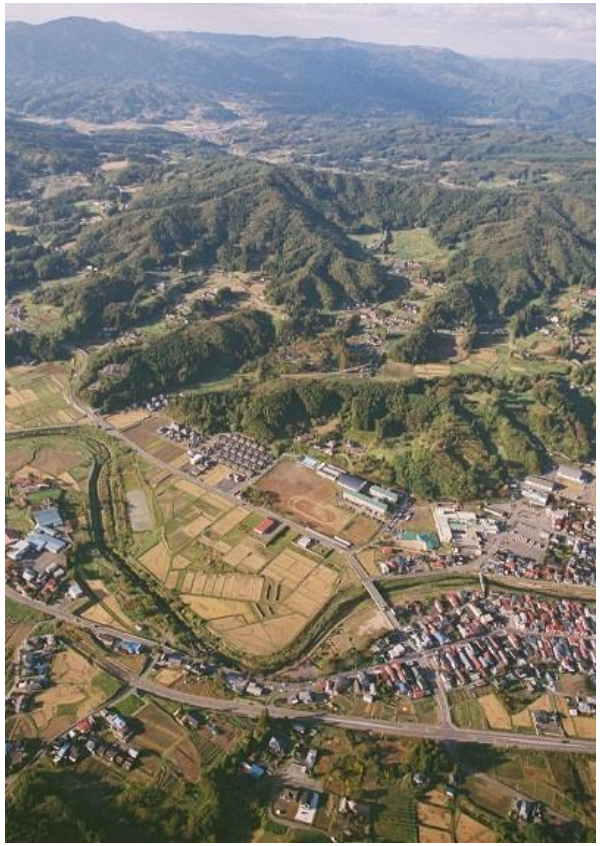
Two detectors: SiD and ILD

- 500 GeV Linear collider
- Upgrade to 1 TeV
  - 31 km long
- Acceleration
  - 7400 superconducting Cavities in 850 Cryo-Modules
  - Gradient 31.5 MV/m (Achieved!)



ILC Site: Kitakami Mountains

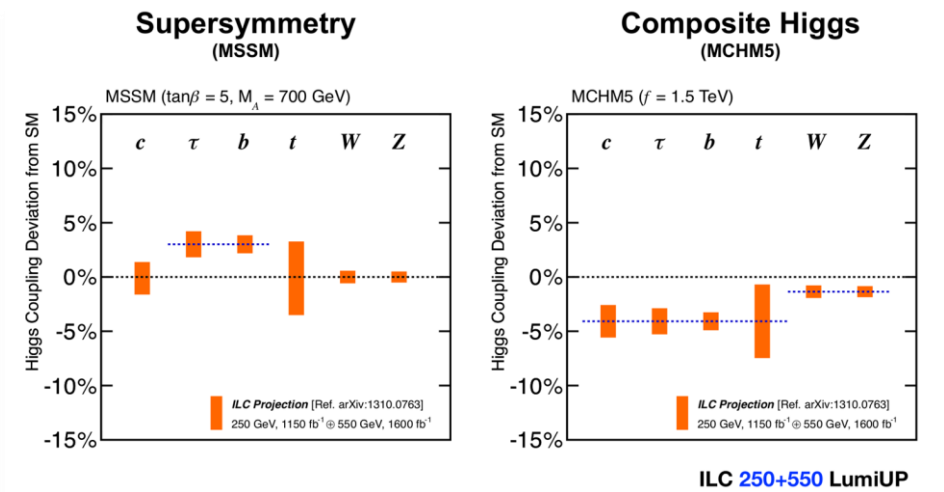


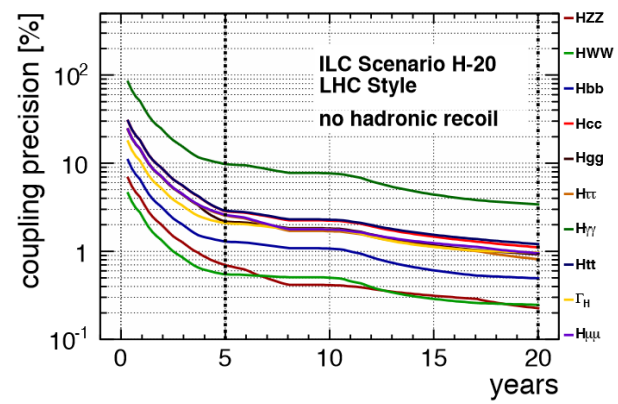


The International Linear Collider

Physics Program

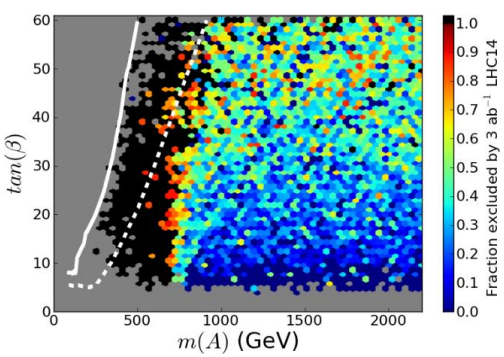
Higgs couplings

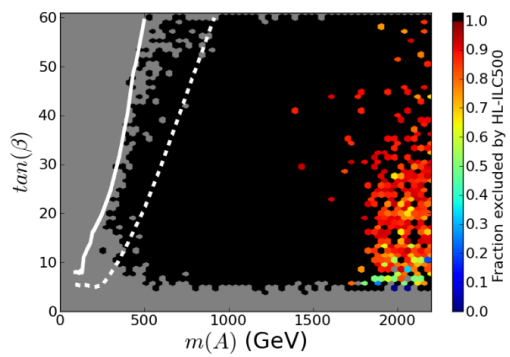




See Jim Brau's talk – this meeting

SUSY





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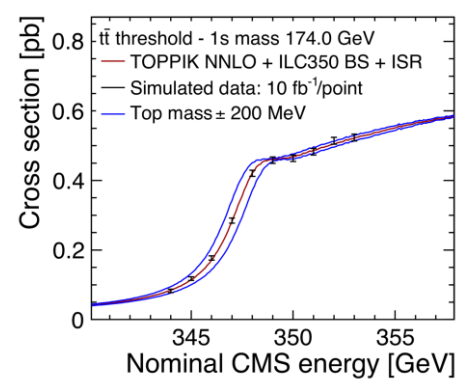


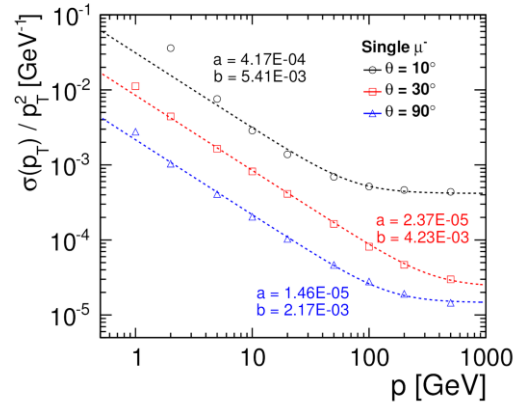
Detector Requirements for the ILC Physics Program

Physics Process	Measured Quantity	Critical System	Physical Magnitude	Required Performance
Zhh $Zh \to q\bar{q}b\bar{b}$ $Zh \to ZWW^*$ $\nu\bar{\nu}W^+W^-$	Triple Higgs coupling Higgs mass $B(h \to WW^*)$ $\sigma(e^+e^- \to \nu\bar{\nu}W^+W^-)$	Tracker and Calorimeter	Jet Energy Resolution $\Delta E/E$	3% to 4%
$Zh \to \ell^+\ell^- X$ $\mu^+\mu^-(\gamma)$ $Zh + h\nu\bar{\nu} \to \mu^+\mu^- X$	Higgs recoil mass Luminosity weighted E_{cm} BR$(h \to \mu^+\mu^-)$	μ detector Tracker	Charged particle Momentum Resolution $\Delta p_t/p_t^2$	$5 \times 10^{-5}(GeV/c)^{-1}$
$Zh, h \to b\bar{b}, c\bar{c}, b\bar{b}, gg$	Higgs branching fractions b-quark charge asymmetry	Vertex	Impact parameter	$5\mu m \oplus$ $10\mu m/p(\mathrm{GeV/c})\sin^{3/2}\theta$
SUSY, eg. $\tilde{\mu}$ decay	$\tilde{\mu}$ mass	Tracker Calorimeter μ detector	Momentum Resolution Hermeticity	

The International Linear Collider, Technical Design Report: Volume 4, Detectors

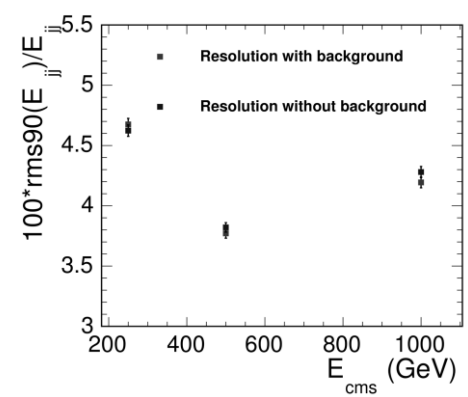
SiD simulation

Momentum resolution

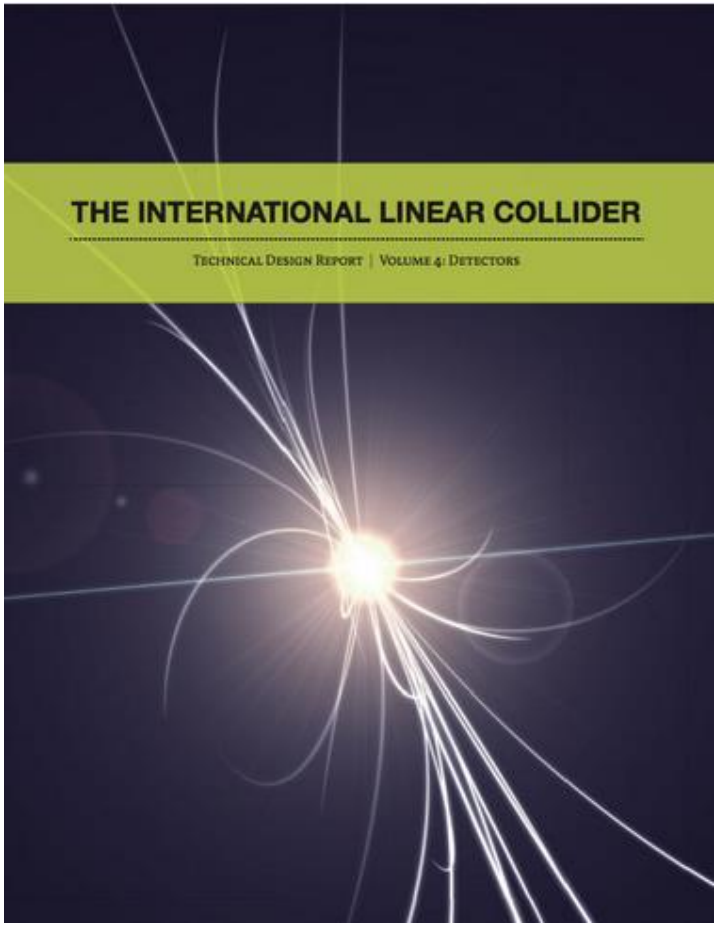


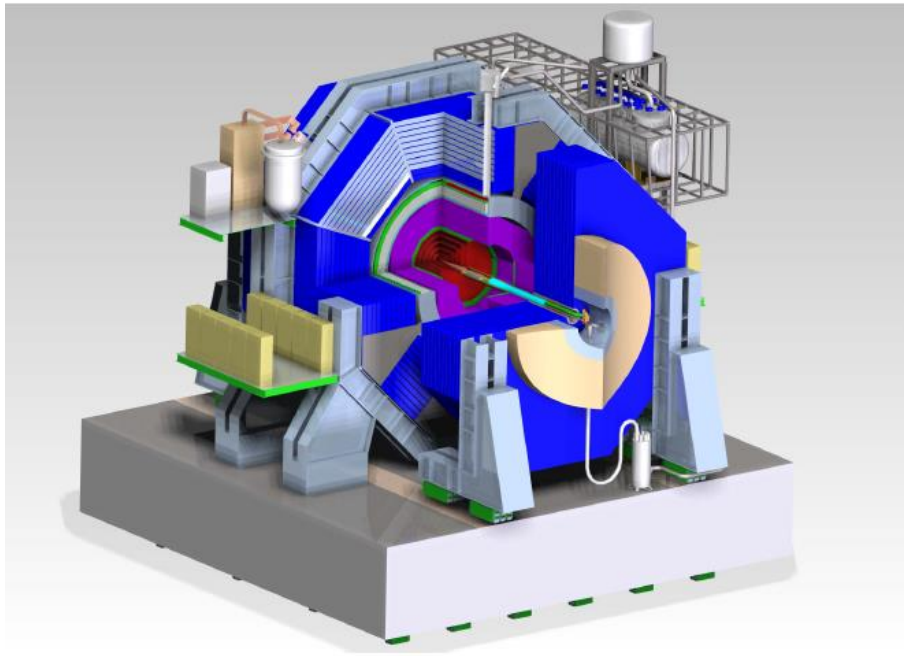
$$\sigma(p_T)/p_T^2 = a \oplus b/p\sin\theta$$

Energy resolution

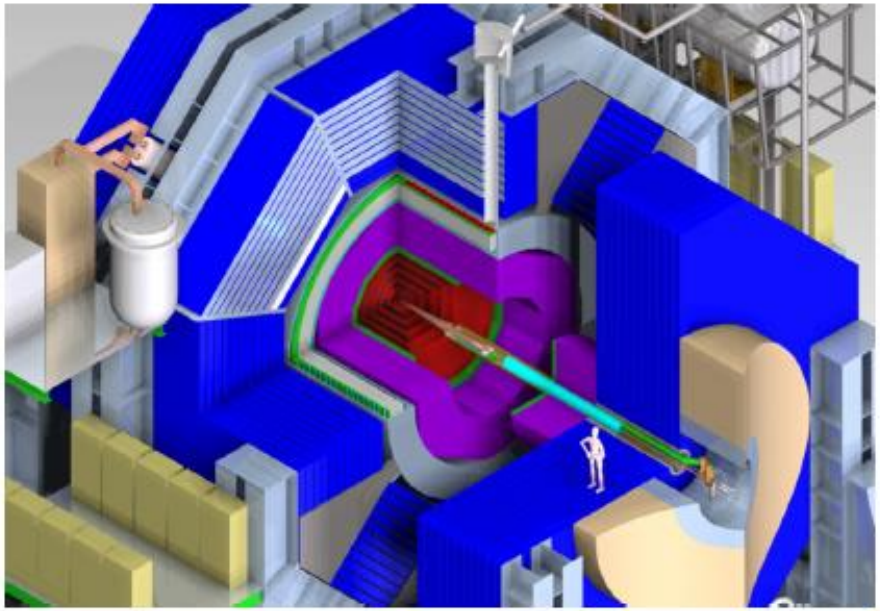


SiD Detector
Detailed Baseline Design

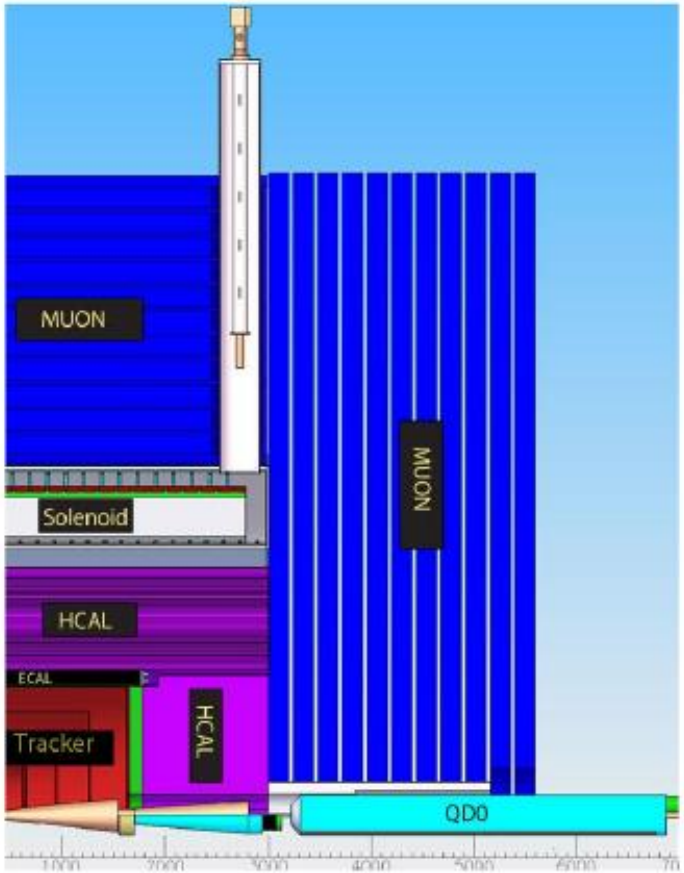




SiD Detector Rationale



A compact, cost-constrained detector designed to make precision measurements and be sensitive to a wide range of new phenomena



The SiD Design

A compact, cost-constrained detector designed to make precision measurements and be sensitive to a wide range of new phenomena.

-> Compact design with 5T field.

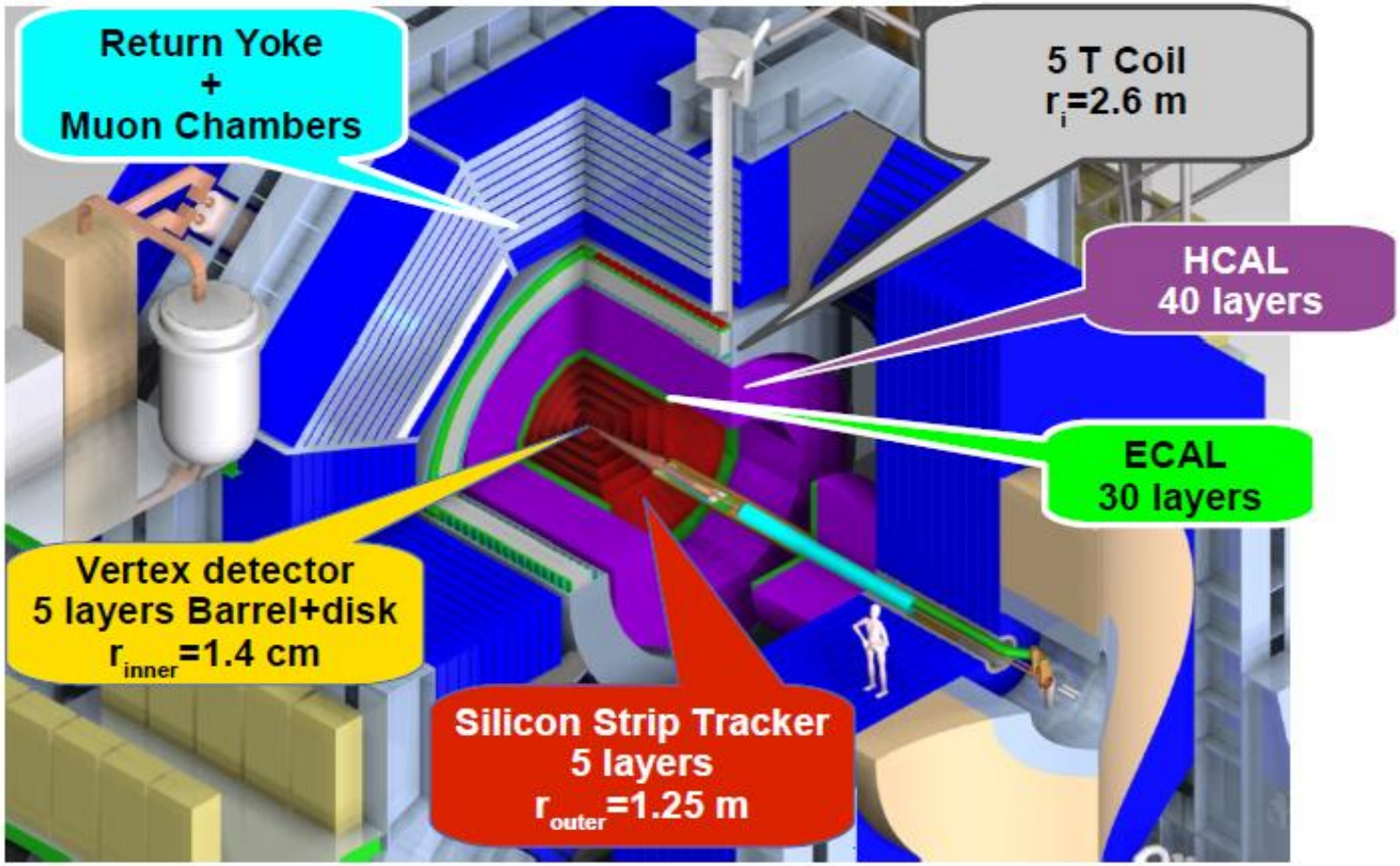
-> Robust silicon vertexing and tracking system – excellent momentum resolution, live for single bunch crossings.

-> Calorimetry optimized for jet energy resolution, based on a Particle Flow approach, “tracking calorimeters”, compact showers in ECal, highly segmented (longitudinally and transversely) ECal and HCal.

-> Iron flux return/muon identifier – component of SiD self-shielding.

-> Detector is designed for rapid push-pull operation.

SiD Detector Baseline



Overall dimensions (DBD)

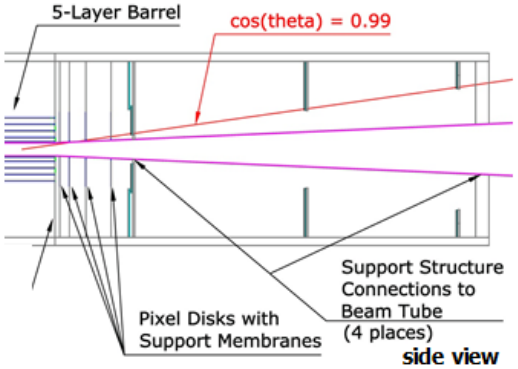
Table 1.1.1: Key parameters of the baseline SiD design. (All dimension are given in cm.)

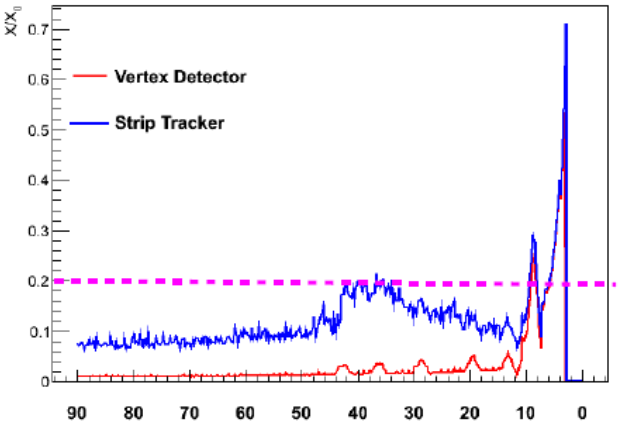
SiD BARREL	Technology	Inner radius	Outer radius	z max
Vertex detector	Silicon pixels	1.4	6.0	± 6.25
Tracker	Silicon strips	21.7	122.1	± 152.2
ECAL	Silicon pixels-W	126.5	140.9	± 176.5
HCAL	RPC-steel	141.7	249.3	± 301.8
Solenoid	5 Tesla	259.1	339.2	± 298.3
Flux return	Scintillator/steel	340.2	604.2	± 303.3

SiD ENDCAP	Technology	Inner z	Outer z	Outer radius
Vertex detector	Silicon pixels	7.3	83.4	16.6
Tracker	Silicon strips	77.0	164.3	125.5
ECAL	Silicon pixel-W	165.7	180.0	125.0
HCAL	RPC-steel	180.5	302.8	140.2
Flux return	Scintillator/steel	303.3	567.3	604.2
LumiCal	Silicon-W	155.7	170.0	20.0
BeamCal	Semiconductor-W	277.5	300.7	13.5

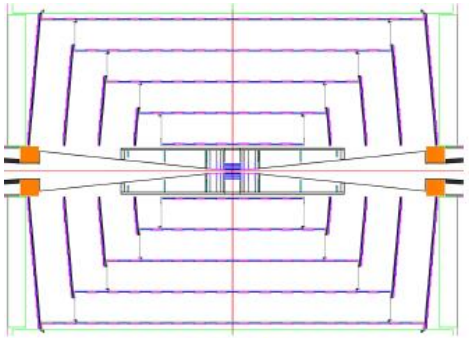
SiD Tracking

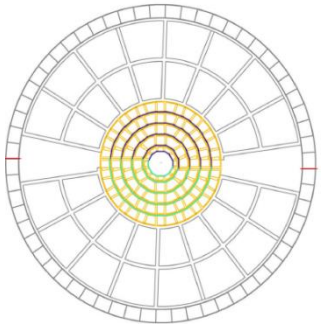
Vertex

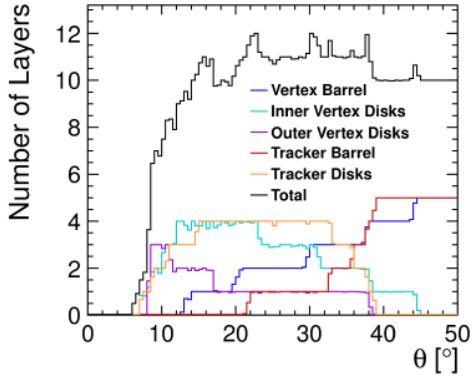


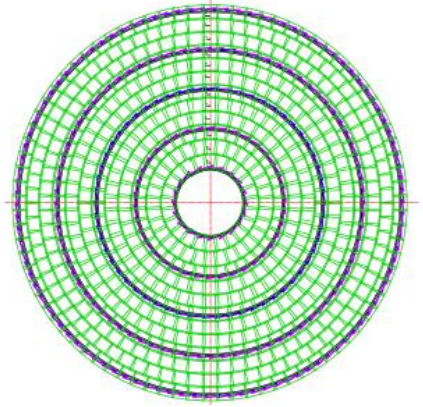


Tracker









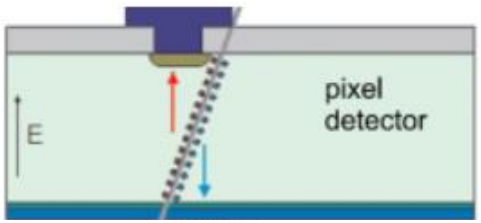
NO baseline selected – too early
R&D: Chronopix, 3-D,…

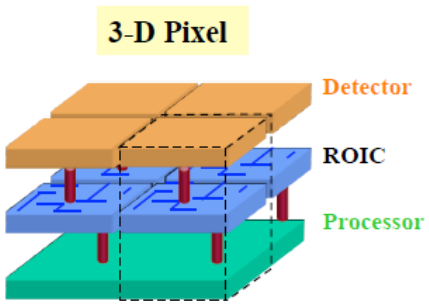
Si Strips + KPiX

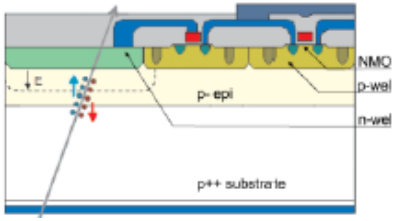
Vertex technologies

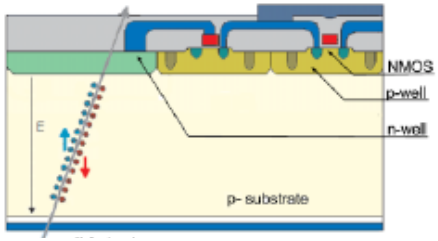
A number of sensor technologies being explored…

- Si diode pixels ("standard" technology)
- Monolithic designs (MAPS, Chronopix)
- Vertically Integrated ("3D") Approaches (VIP Chip)
- High Voltage CMOS (snappy timing)



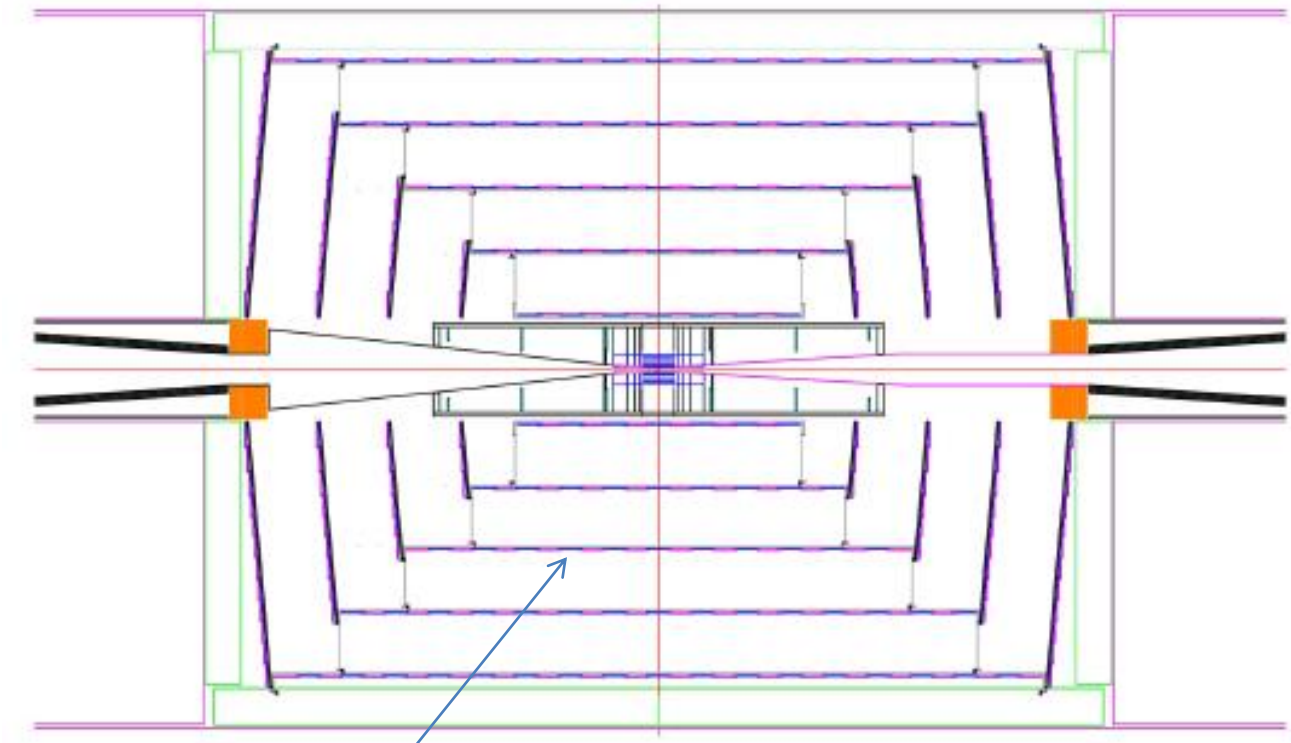


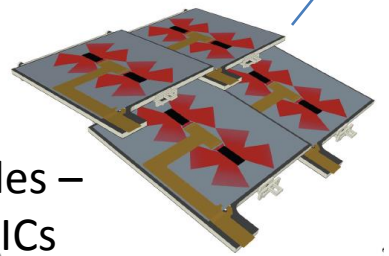




Final technology choice can be made late

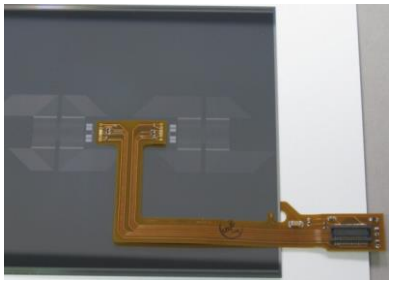
SiD Detector – Tracker





Silicon microstrip tiles – dual KPiX ASICs

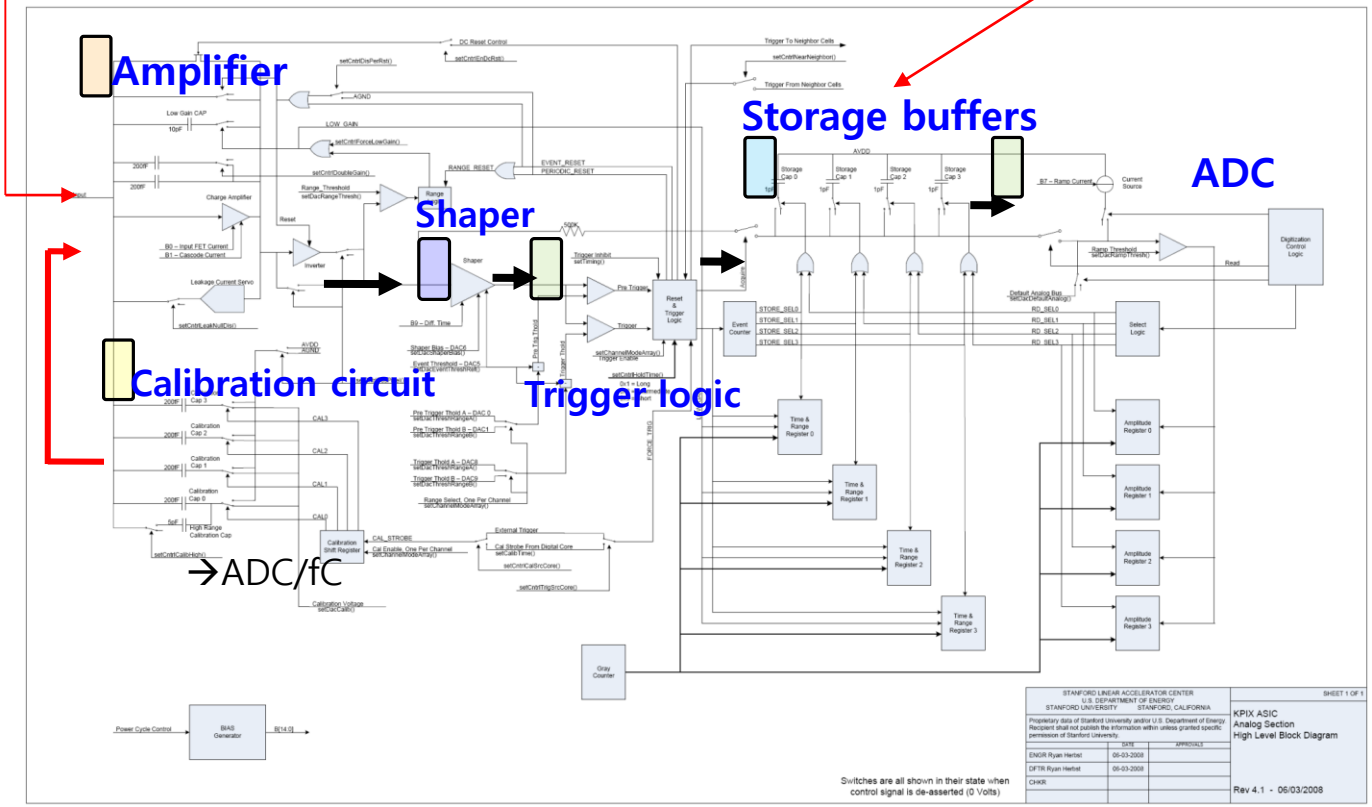
Pigtail cable



KPiX Readout scheme (SLAC)

Sensor element

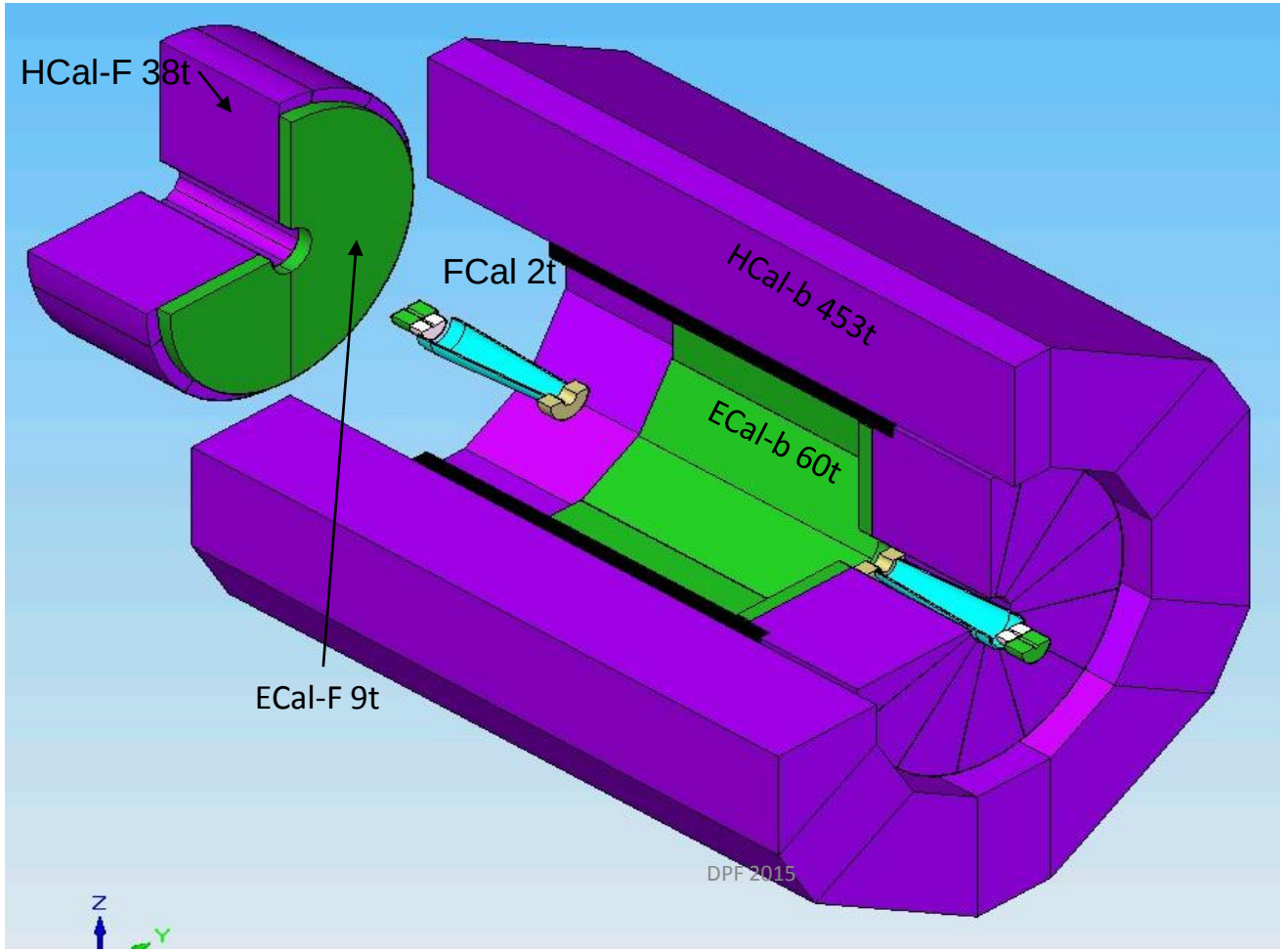
4-deep "pipeline"



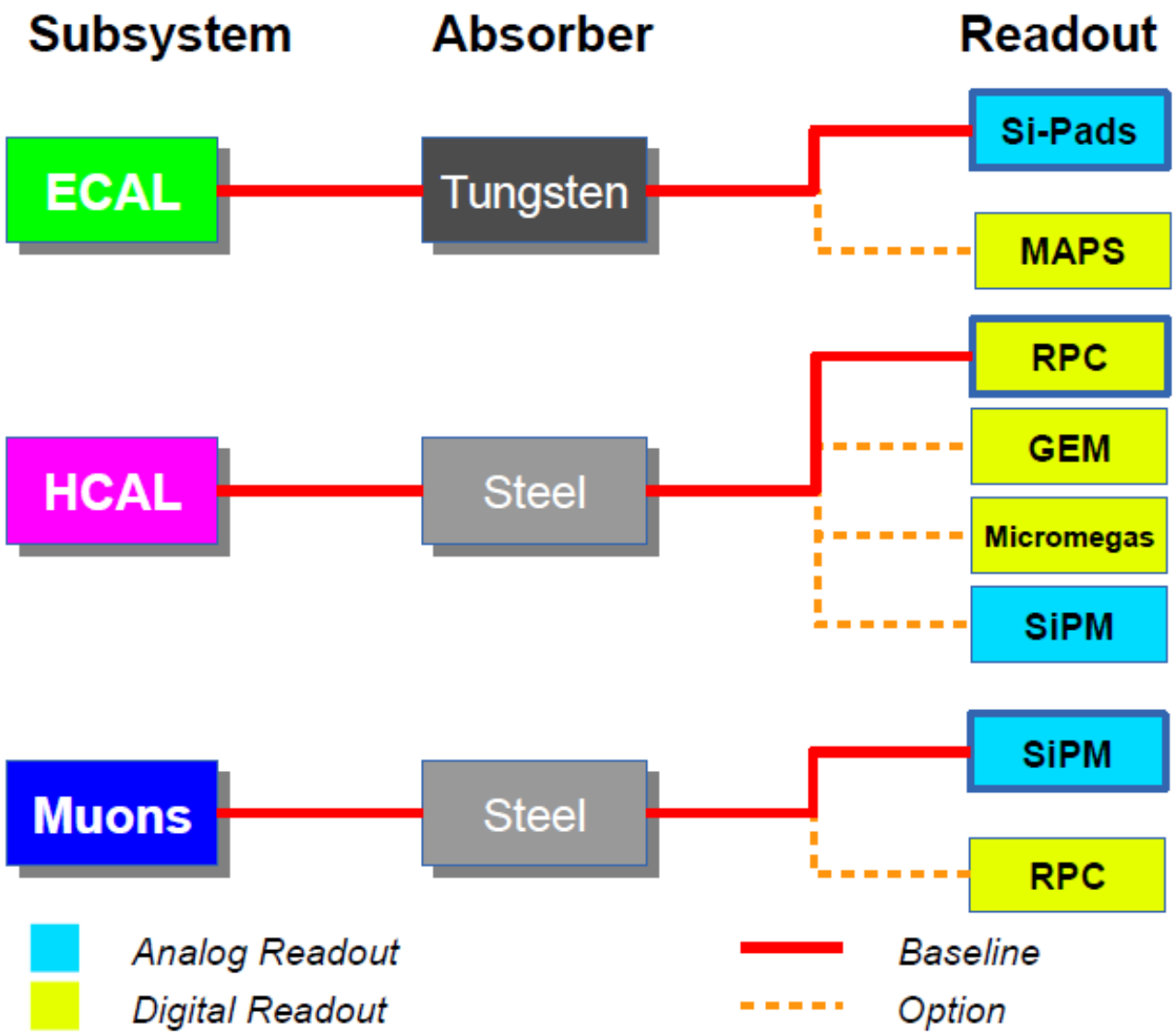
KPiX 1024 – channel chip

Intended as basic readout for all SiD detector elements except the vertex detector.

SiD Calorimetry



Calorimetry Tree

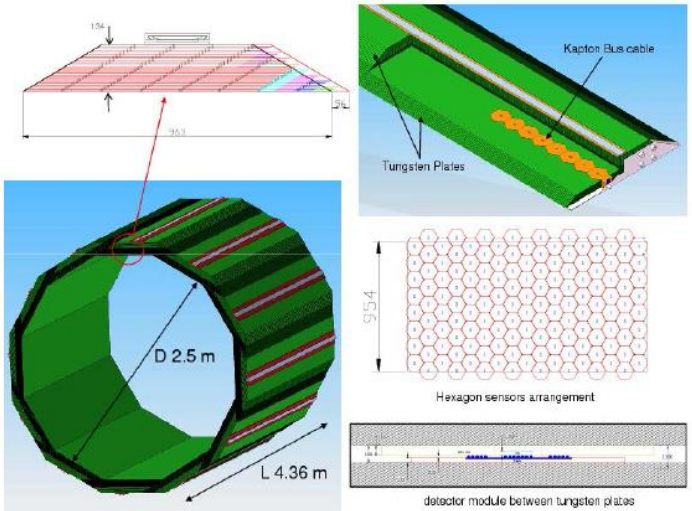


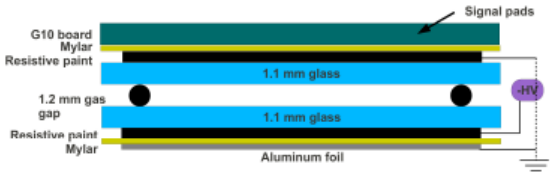
SiD Calorimetry

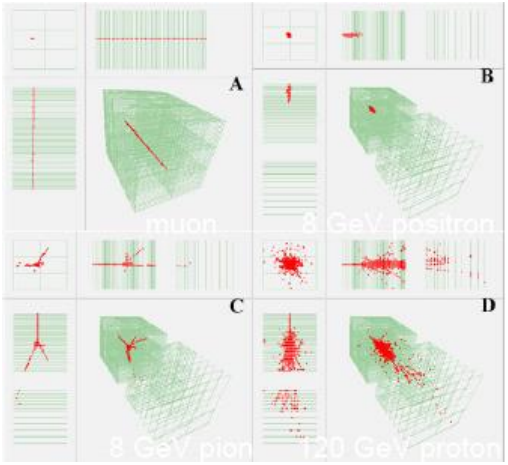
- SiD ECAL
  - Tungsten absorber
  - 20+10 layers
  - 20 x 0.64 + 10 x 1.30 X_0
- Baseline Readout using
  - 5x5 mm^2 silicon pads

- SiD HCAL
  - Steel Absorber
  - 40 layers
  - 4.5 Λ_i
- Baseline readout
  - 1x1 cm^2 RPCs

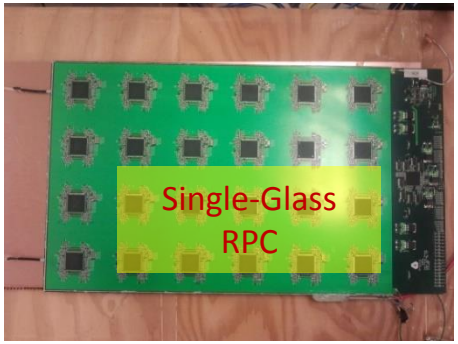
An imaging calorimeter: 30 layers tungsten interleaved with 30 layers pixellated silicon

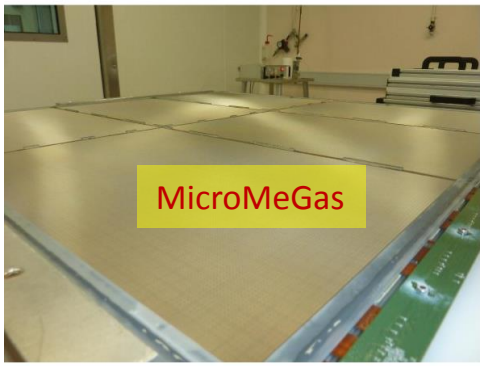


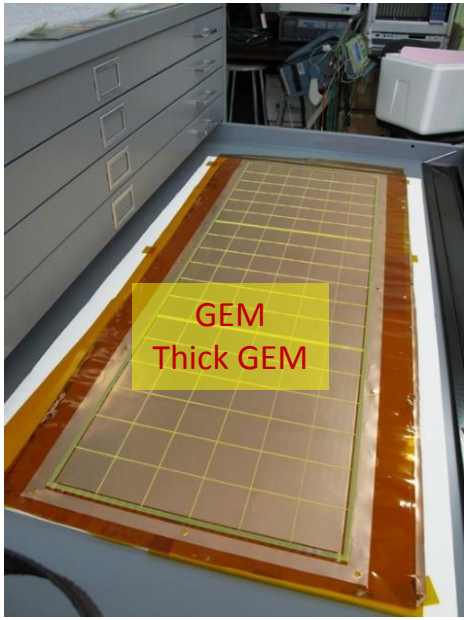


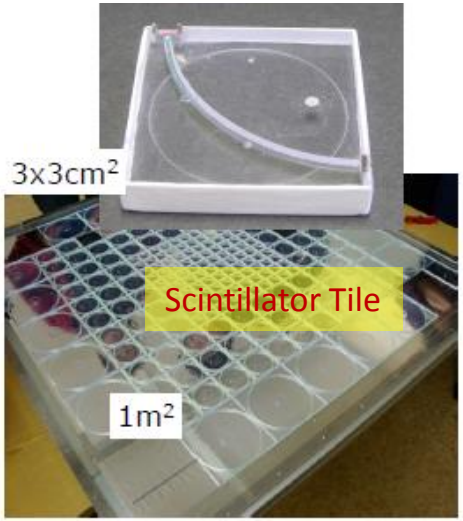


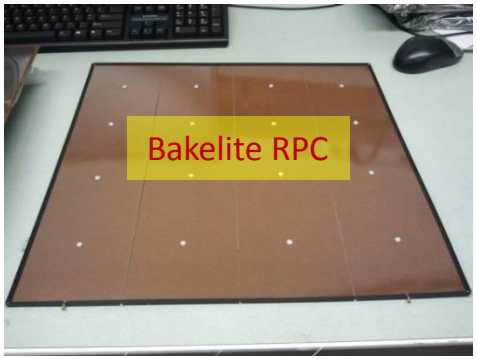
SiD Calorimetry - HCal





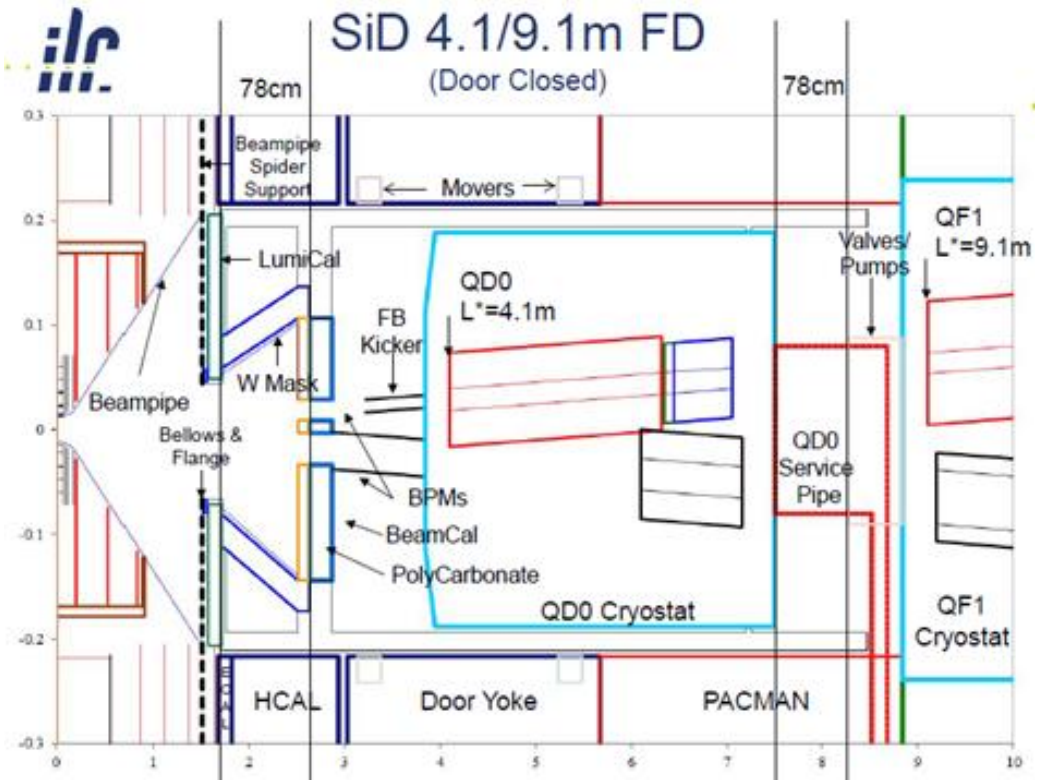






Many alternatives under exploration (largely under **CALICE** umbrella)

SiD Forward Calorimetry

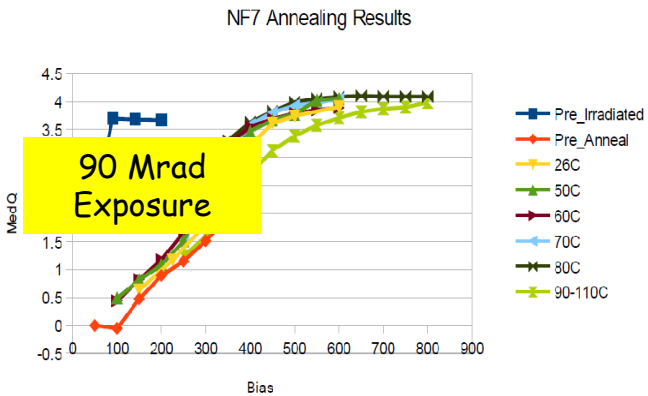


New (common) L* = 4.1m

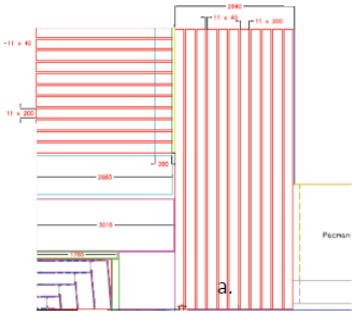
FCal

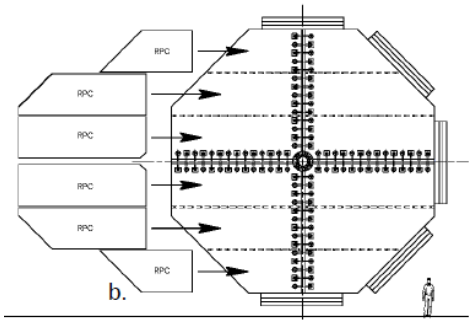
Ongoing electromagnetic radiation damage studies (Si diode, GaAs…) within FCAL Collaboration umbrella

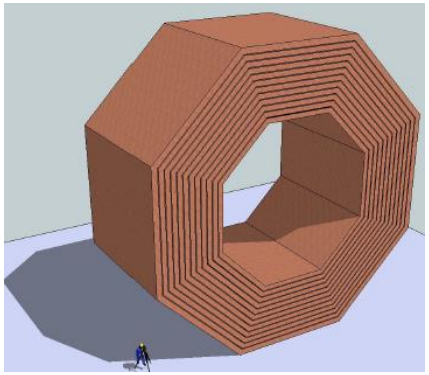
Annealing studies
90 Mrad exposure of N-type float-zone Si diode detector



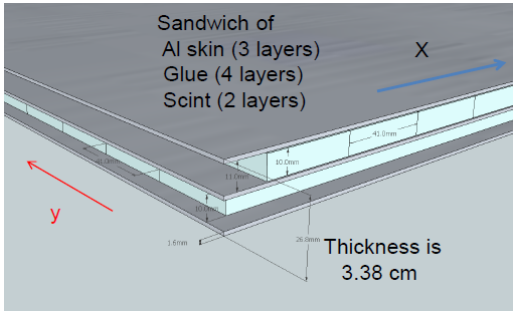
SiD Muon System/Tailcatcher

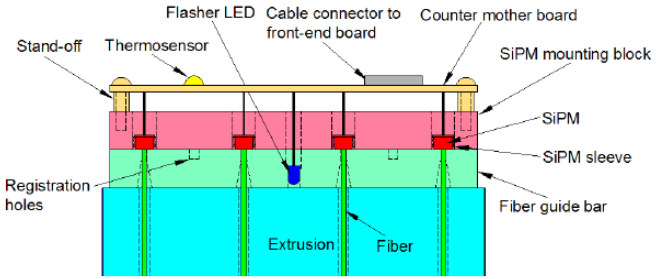






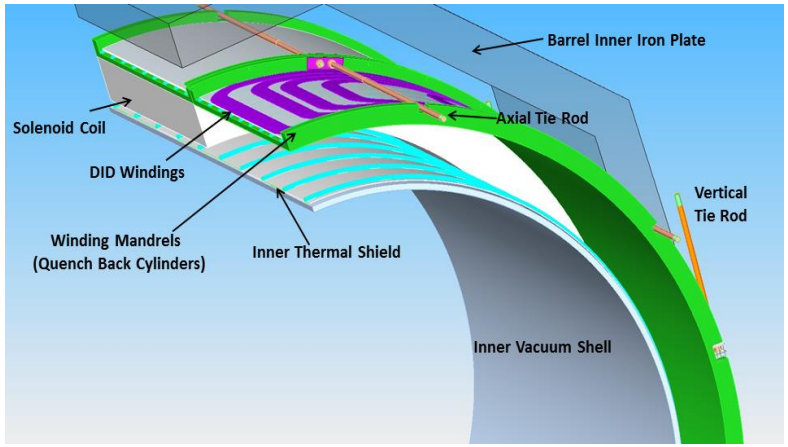
SiD Baseline – long scintillator strips with WLS and SiPM readout



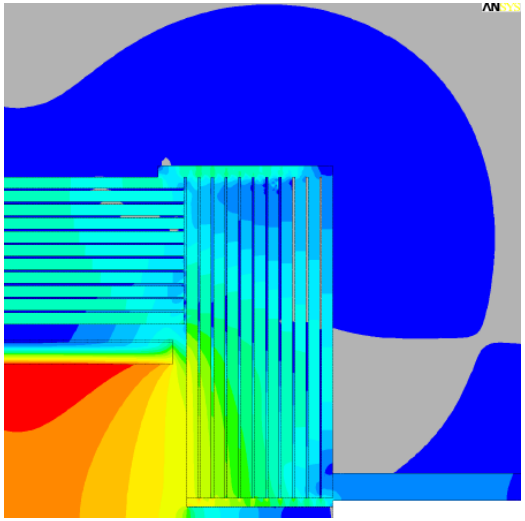


Alternative – RPC muon system – no recent development

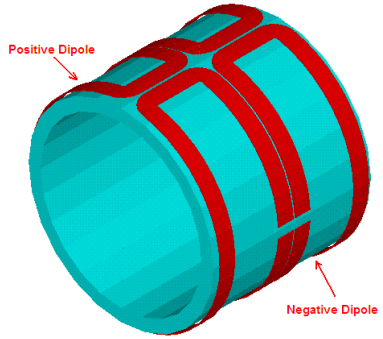
SiD Solenoid

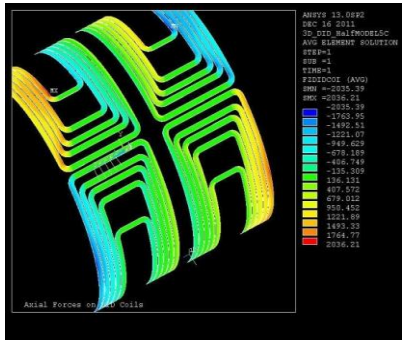


CMS style conductor – others/variation may be developed.

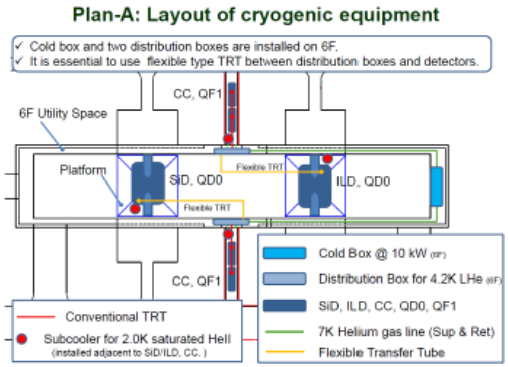


Field map – external (blue) 200 G



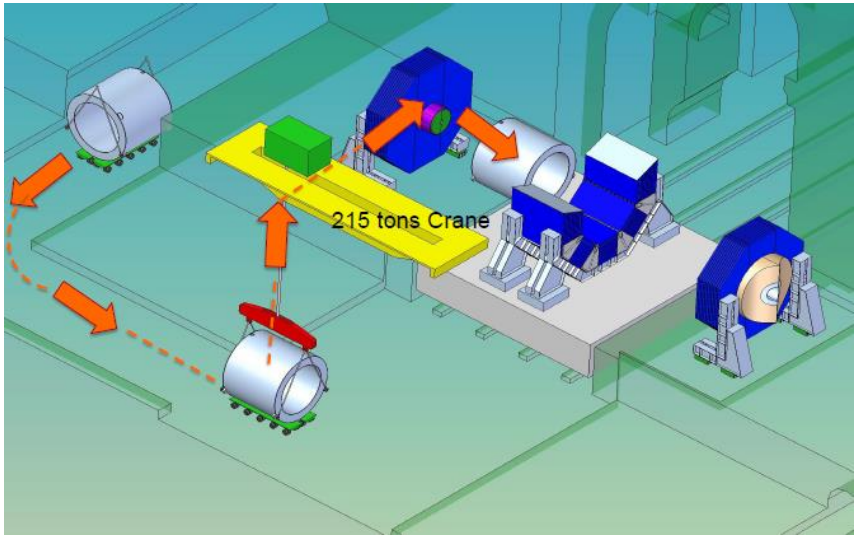


Detector Integrated Dipole



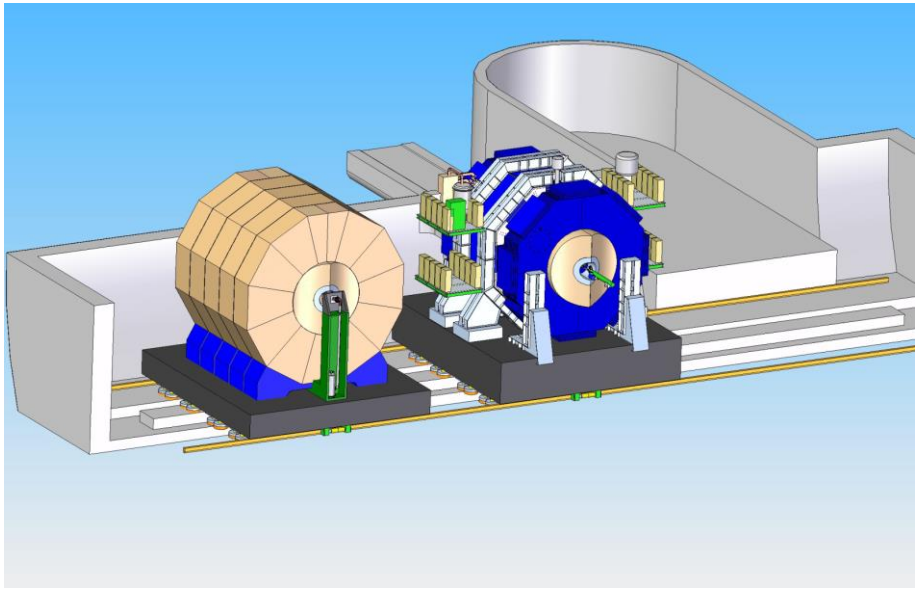
Recent update on iron/field design – see later slide

Detector Assembly and Push-Pull



Underground area assembly

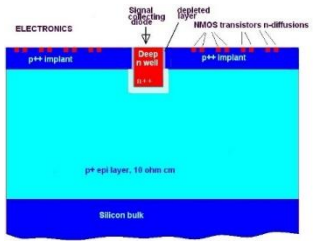
SiD and ILD – Push-Pull arrangement

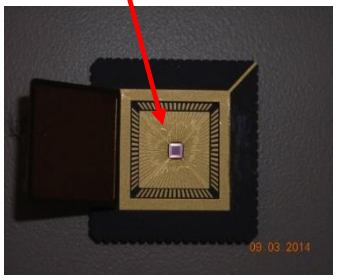


Recent/Ongoing SiD Detector Studies

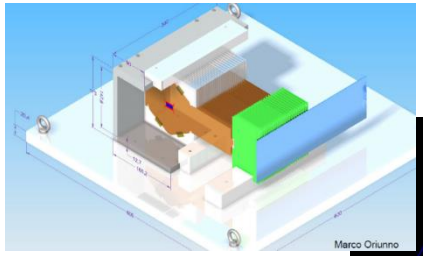
VTX – Chronopix

Noise issue solved in Prototype 3

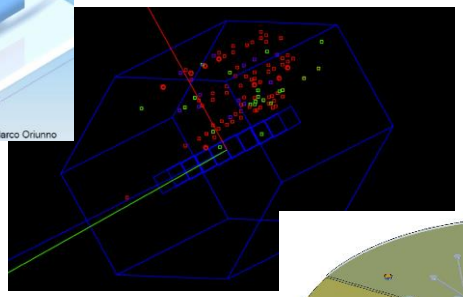




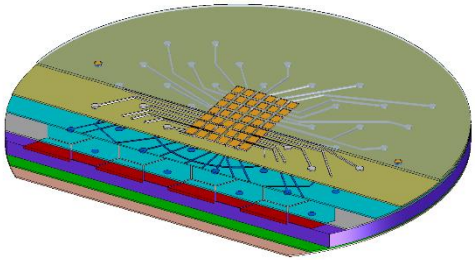
N. Sinev (U. Oregon)



ECal prototype



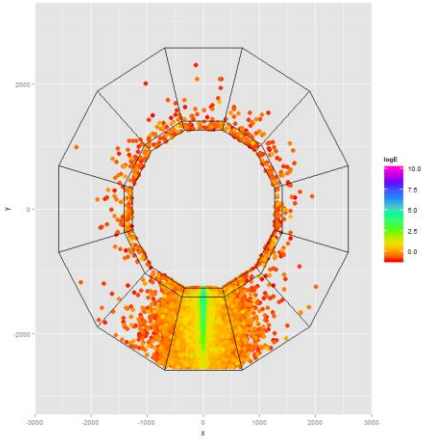
R. Frey (U. Oregon),
M. Breidenbach
(SLAC)

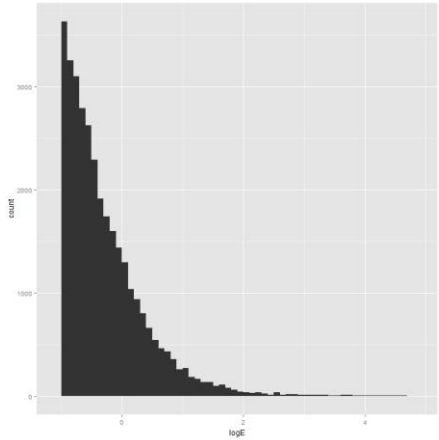


New version submitted with second metal shield layer

Single particle studies

R. Butner (PNNL)



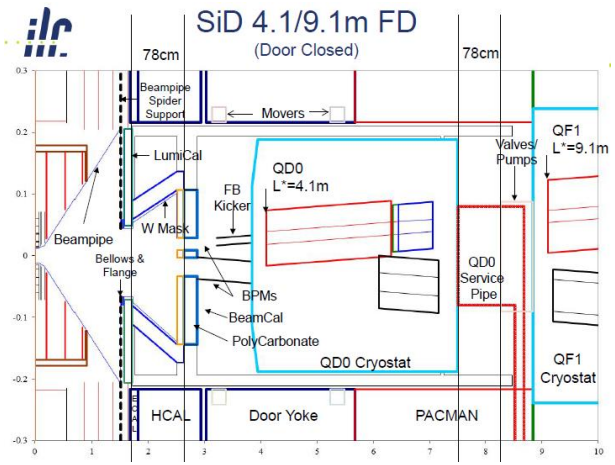


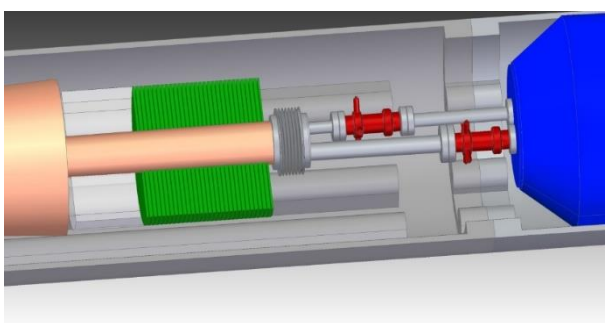
Future diagnostic tool for Particle Flow e.g. across sub-detector boundaries

Images courtesy of Pacific Northwest National Laboratory's Signature Discovery Initiative

Recent/Ongoing SiD Detector Studies

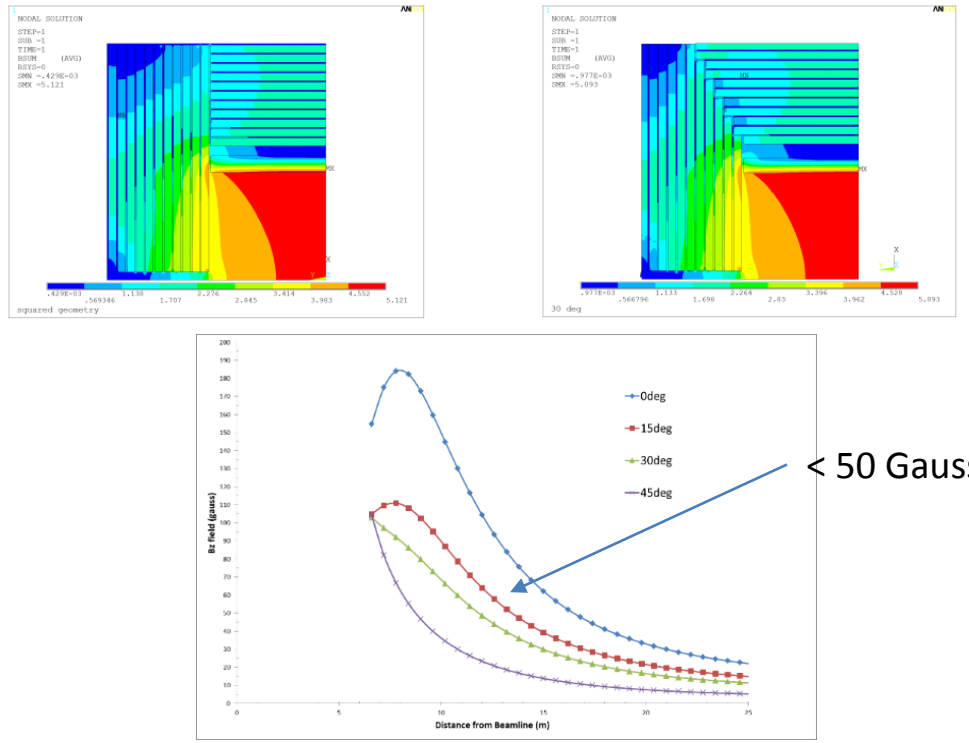
Forward region – new 4.1m L*





T. Markiewicz, M. Oriunno (SLAC)

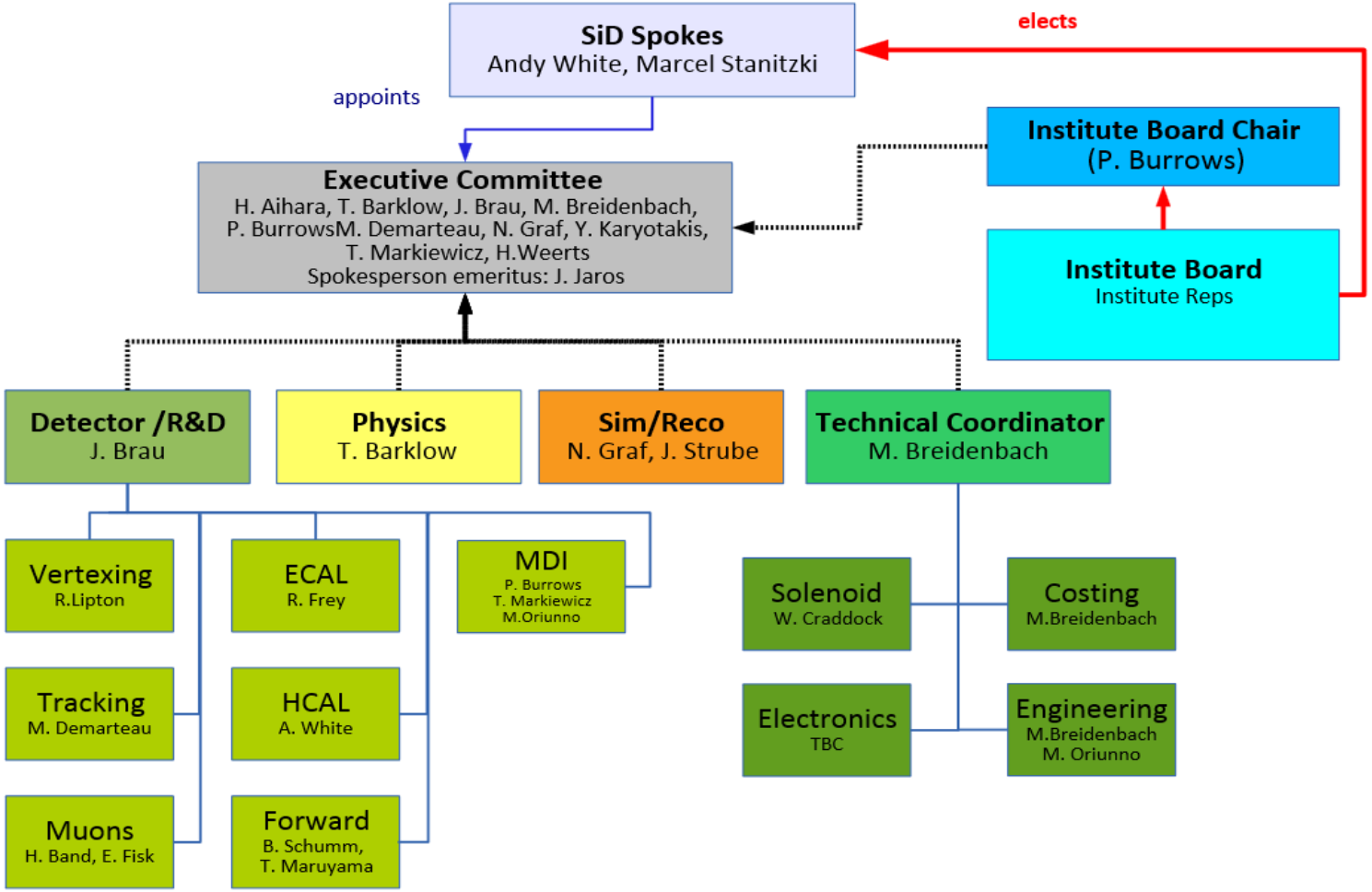
Magnet studies – fringe field reduction



< 50 Gauss at 15m

M. Oriunno (SLAC)

SiD Consortium



SiD Consortium

If you would like to contribute to the work of SiD please contact:

Marcel Stanitzki (DESY) (marcel.stanitzki@desy.de)

Andy White (U. Texas at Arlington) (awhite@uta.edu)

Phil Burrows (U. Oxford) (Philip.Burrows@physics.ox.ac.uk)

Extra

SiD Cost

	M&S Base (M US-$)	M&S Contingency (M US-$)	Engineering (MY)	Technical (MY)	Admin (MY)
Beamline Systems	3.7	1.4	4.0	10.0	
VXD	2.8	2.0	8.0	13.2	
Tracker	18.5	7.0	24.0	53.2	
ECAL	104.8	47.1	13.0	288.0	
HCAL	51.2	23.6	13.0	28.1	
Muon System	8.3	3.0	5.0	22.1	
Electronics	4.9	1.6	44.1	41.7	
Magnet	115.7	39.7	28.3	11.8	
Installation	4.1	1.1	4.5	46.0	
Management	0.9	0.2	42.0	18.0	30.0
	314.9	126.7	186.0	532.1	30.0