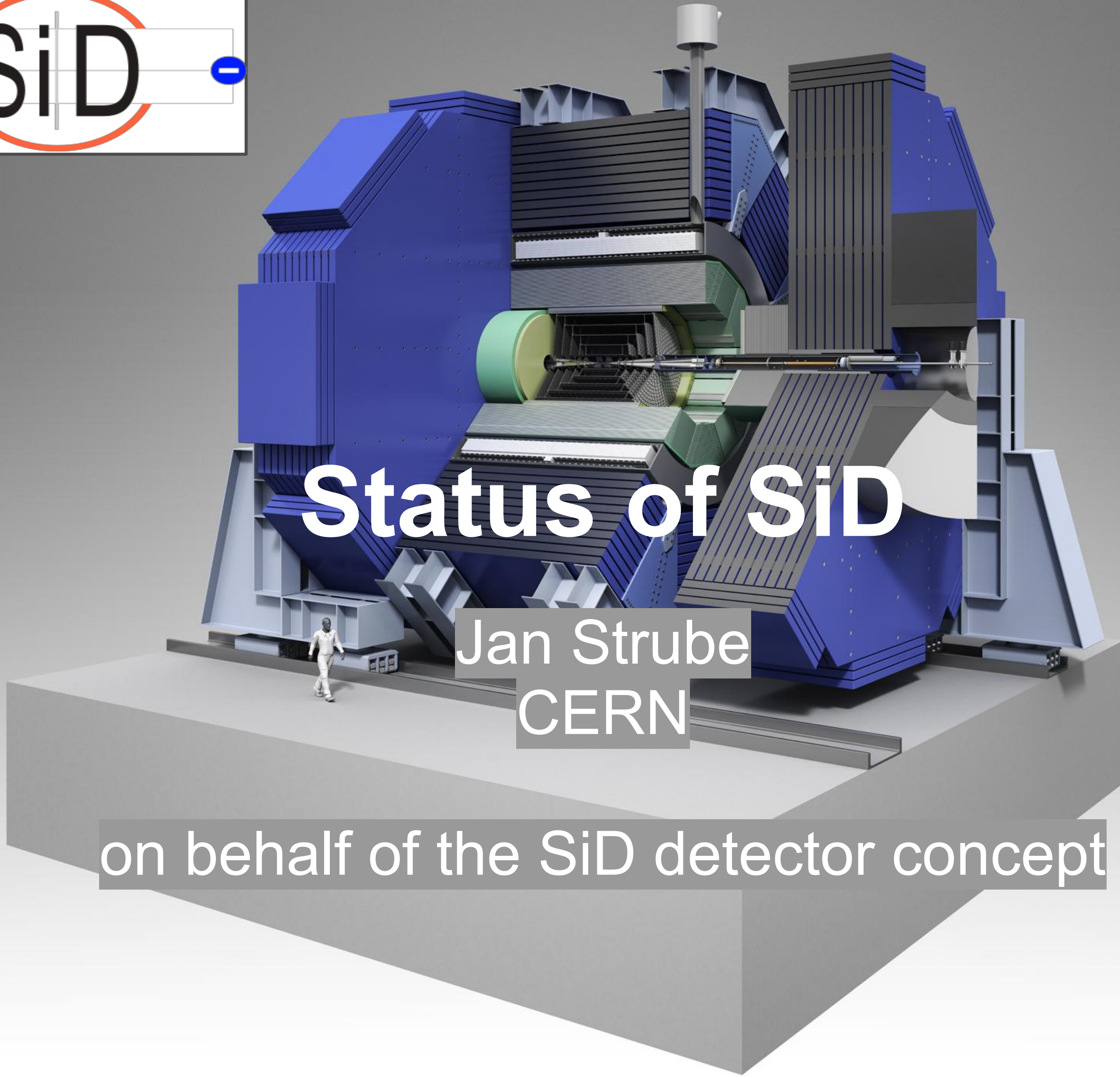


Status of SiD

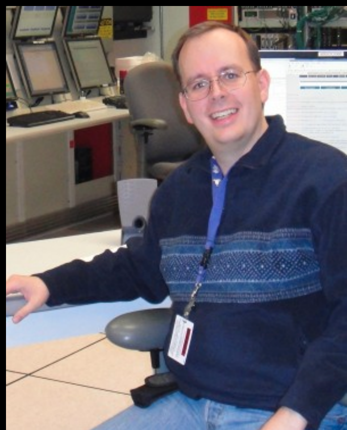
Jan Strube
CERN

on behalf of the SiD detector concept

Outline

- Introduction to SiD
    - People
    - The detector concept
- Highlights from the DBD
    - Detector baseline choices / options
    - Software
    - Selected physics analysis results
- Summary / Outlook

Introducing SiD

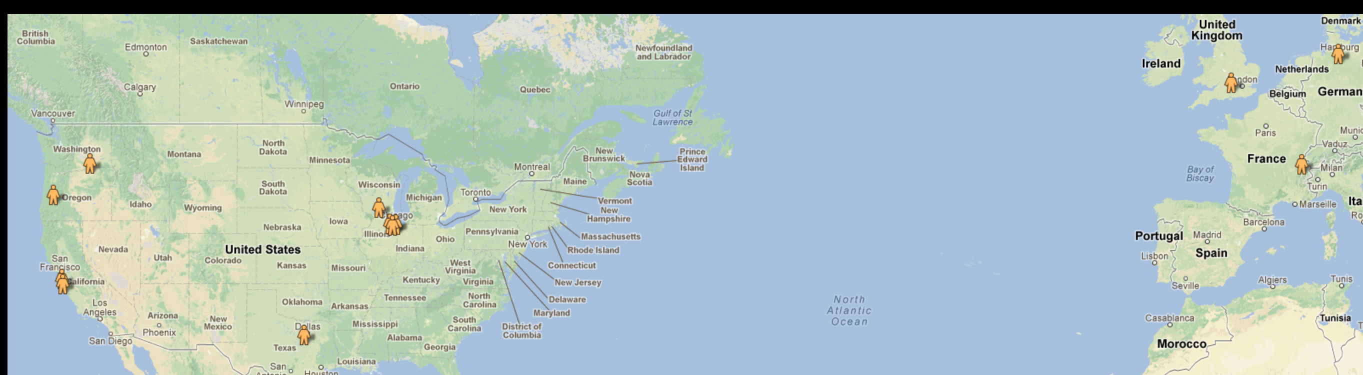


Co-spokesperson
M. Stanitzki
DESY

Co-spokesperson
A. White
UT Arlington

An international group studying a detector concept for LCs

SiD
Detailed
Baseline
Report
Editors

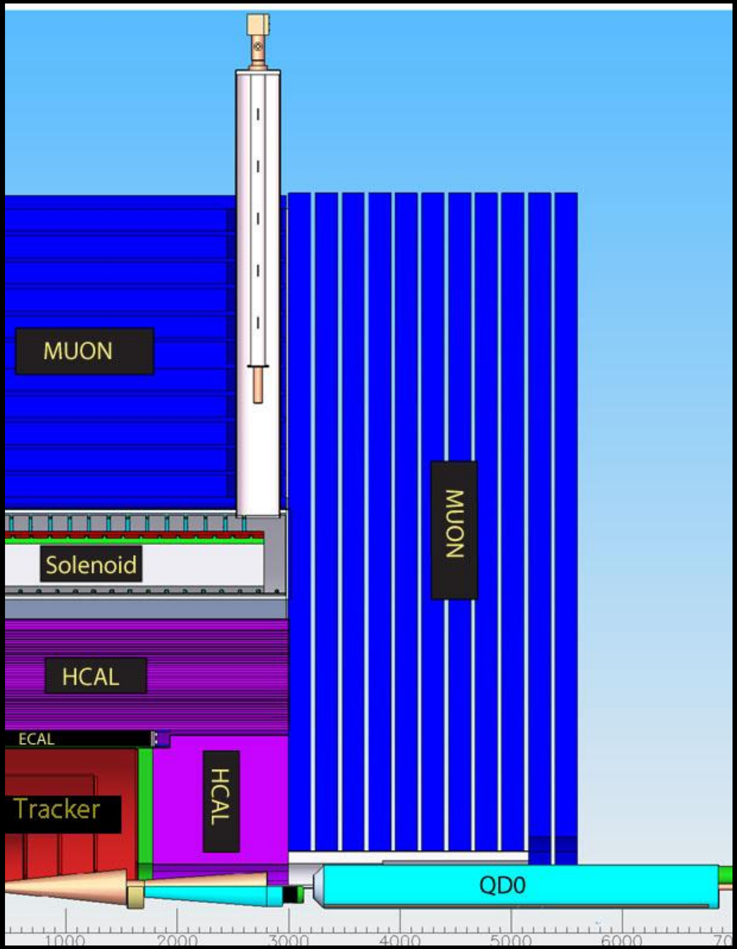


The SiD Detector Concept at the ILC

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

<u>Design Choices:</u>

- Compact Design in a 5 T field
- Robust all-Silicon tracking with excellent momentum resolution
- Time-stamping for single bunch crossings
- Highly granular calorimetry optimized for Particle Flow
- Integrated Design: All parts work in tandem
- Iron flux return / muon identifier is part of SiD self-shielding



Physics Requirements

Momentum resolution

Higgs Recoil

$\sigma(p_T)/p_T^2 \sim 2\text{-}5 \times 10^{-5}\ \mathrm{GeV}^{-1}$

Jet Energy Resolution

Separation of W/Z/H bosons:

Gauginos, Triple Gauge Coupling

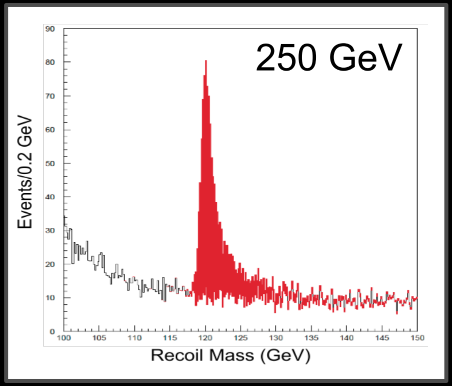
$\sigma(E)/E = 3.5\%\text{-}5\%$

Flavor Tagging

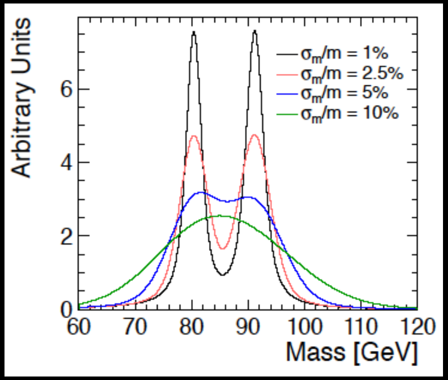
Higgs Branching ratios

$\sigma_{r\varphi} \approx 5\ \mu m \oplus 10\ \mu m / (p[\mathrm{GeV}] \sin^{3/2}\theta)$

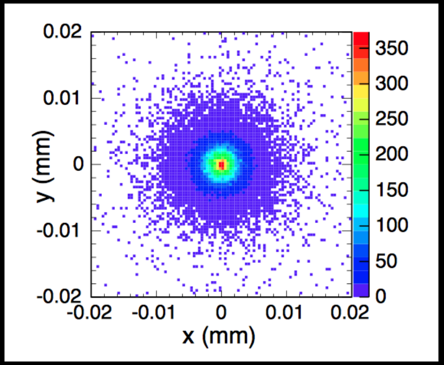
HZ → $\mu^+\mu^-$ + anything



W-Z separation



primary vertices in tth events



ILC
1 TeV

Milestones

Concept and its performance at various collision energies documented in several documents.
SiD was validated by IDAG in 2009.

The DBD

will
disks
event
momentum
SiD
pixel
track
polarisation
tracks
material
beamcal
different
sensors
solenoid
power
module
theta
integrated
reconstructed
support
benchmarking
tracker
events
hits
silicon
inner
jet
signal
particle
jets
readout
calorimeter
chip
backgrounds
requirements
disk
performance
physics
design
beam
noise
barrel
results
muon
system
calorimetry
magnet
energy
alignment
sensor
detector
luminosity
mass
tracking
resolution
layer
modules
size
high
background
detectors
layers
efficiency
full
strips
charge
particles
data
process
region
model
baseline
reconstruction
precision
endcap
ILC
single
prototype
active
Higgs
measured
measurement
vertex
time
cost

The DBD

The DBD describes the baseline choices for all sub-detectors (except the vertex detector)

Options have been kept

This baseline is fully costed

Options offer better performance and/or lower cost

Not as mature as baseline choices

The DBD is a waypoint on the road to the SiD TDR and beyond.

R&D continues.

Overview of Detector Baseline

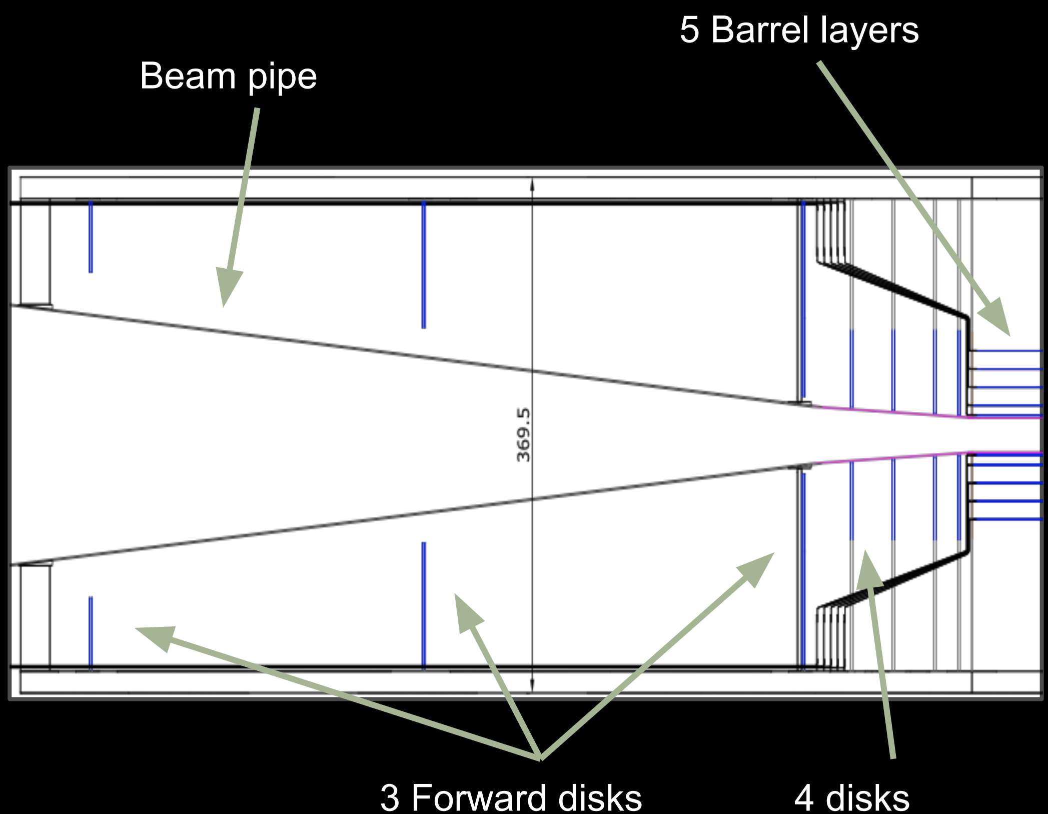
Vertex Tracker

Excellent impact parameter resolution for reconstruction of secondary and tertiary vertices

Several technologies potentially meet the requirements: 3D, SOI, MAPS, hybrid pixels, DEPFET

5 pixel layers in barrel
  Innermost layer at 14 mm
4 disks
~ 20x20 μm^2 pixels

3 forward disks
~ 50x50 μm^2 pixels



R&D for extremely low-mass support structures: All-silicon assembly, foam-based ladders (PLUME collaboration), carbon fibre supports

SiD is designed to make insertion and removal of the Vertex Detector straightforward.
Allows to take advantage of the best possible technology.

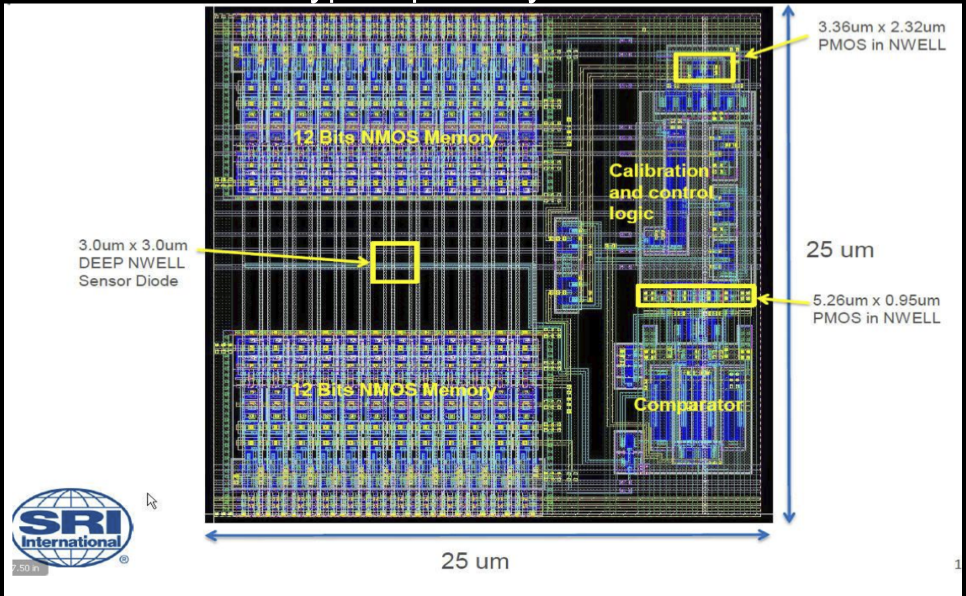
Pixel Technology Examples

Chronopix: Monolithic CMOS chip with time stamp memory for a whole bunch train.
25x25 μm^2 pixels currently, 90 nm technology.

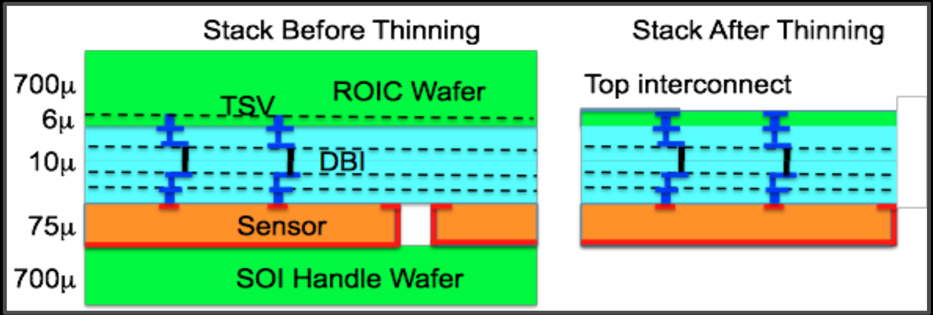
Full prototype to have 10x10 μm^2 or 15x15 μm^2, will go to 45 nm technology.

See N. Sinev's talk on Tuesday morning

Prototype 2 pixel layout



3D technology:
Top interconnect can be done in final topside aluminum patterning with low mass.
Cables bump-bonded to end of ladders. Allows for all-silicon design.



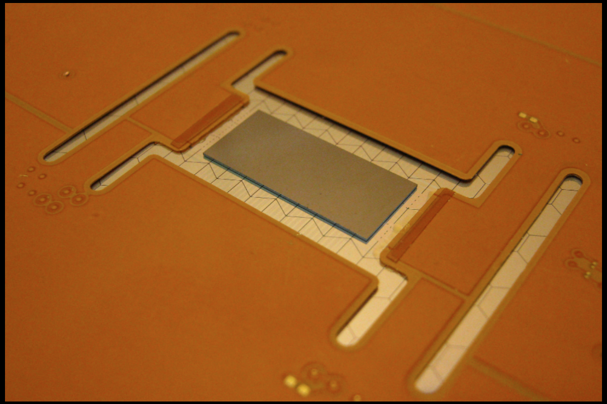
KPiX - System on a chip

1024 channels prototype under test
optimized for ILC
(1 ms train, 5 Hz train repetition rate)

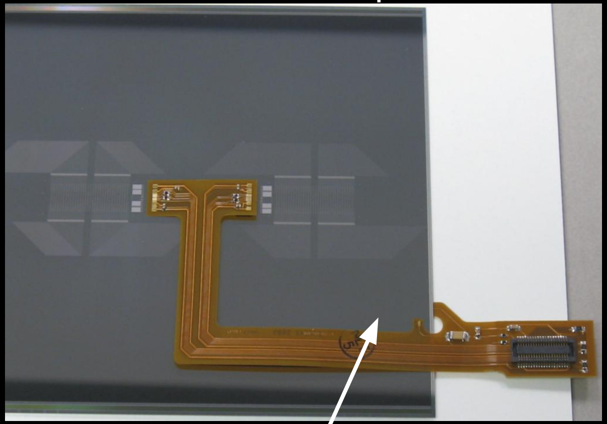
- Low noise dual range charge amplifier with; 17 bit dynamic range
- Low noise floor 0.15 fC (1000 e^-)
- Designed for power modulation, average power < 20 μW / channel
- Internal calibration system
- Up to four measurements per channel per train
- Versatile

Baseline for Tracker and ECAL.

KPiX as a Calorimeter chip



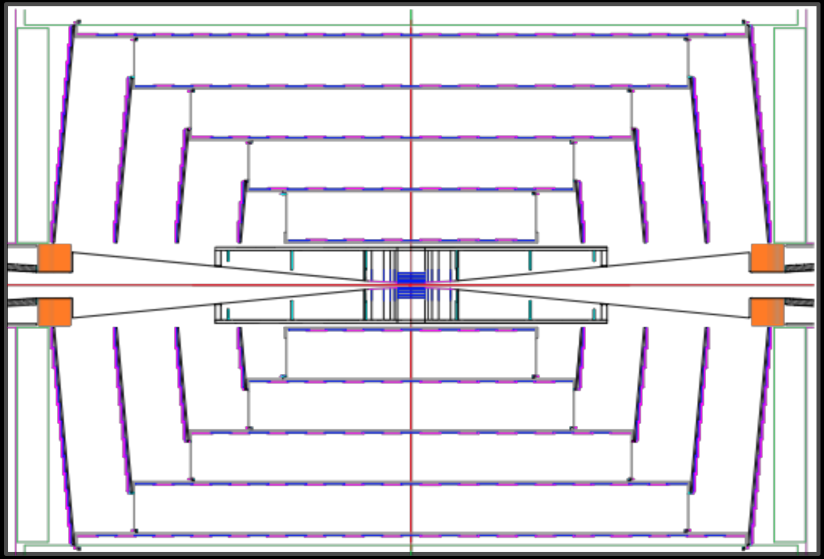
KPiX as a Tracker chip



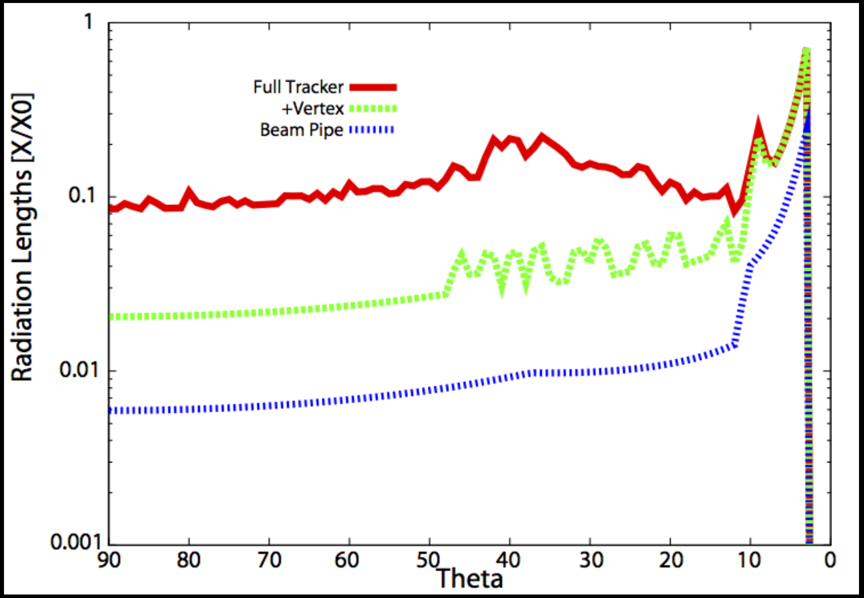
First revision of pigtail cable has been tested.
Second revision has been ordered.

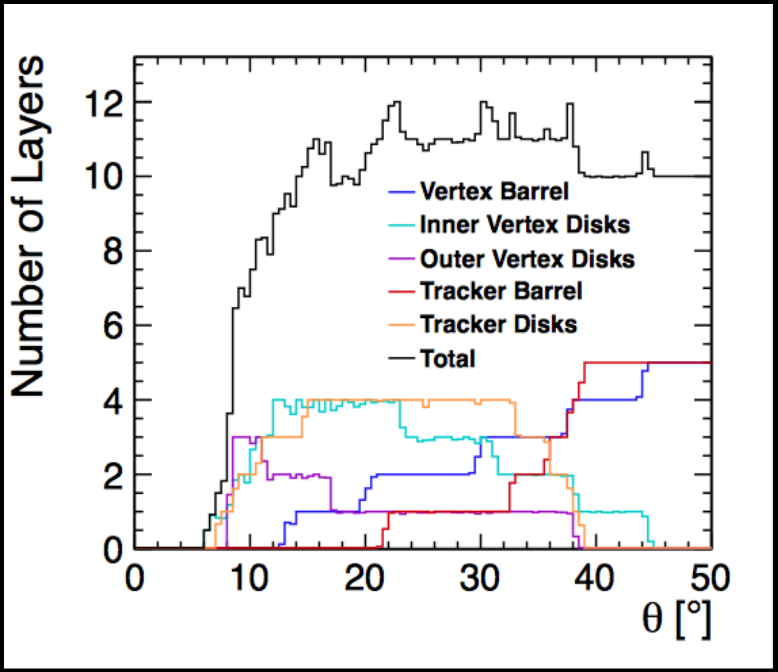
Outer Tracker

Low material budget ↔ excellent momentum resolution
In an all-silicon tracker, this means:
1. thin sensors
2. advanced integrated electronics
3. low-mass suport
4. low power ↔ low-mass cooling



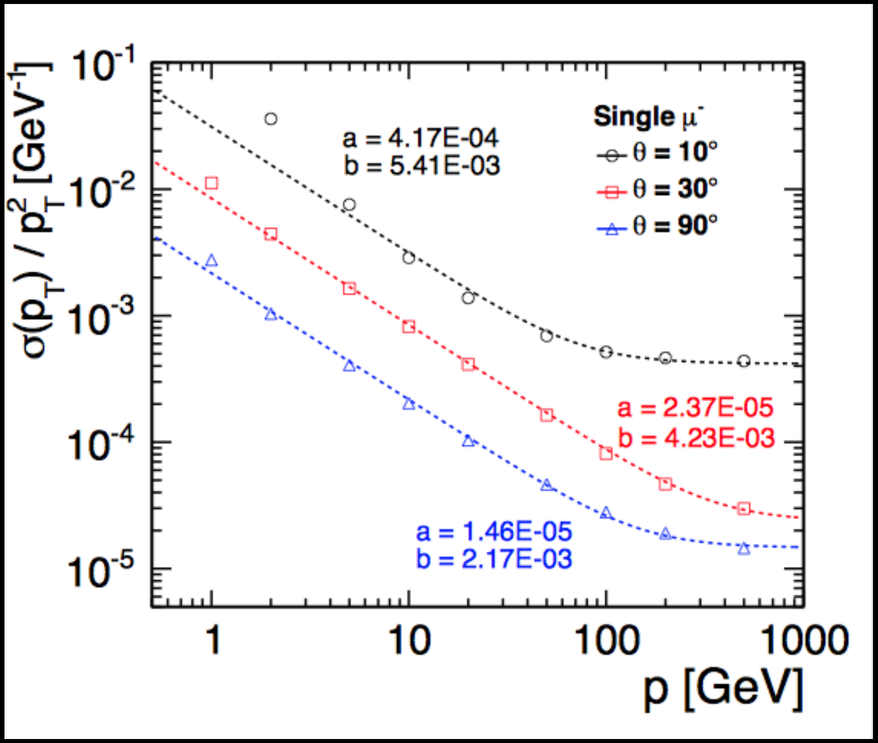
Hermetic coverage

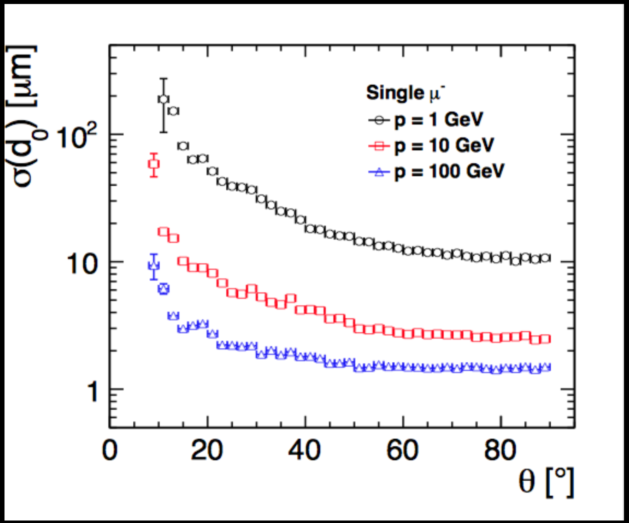


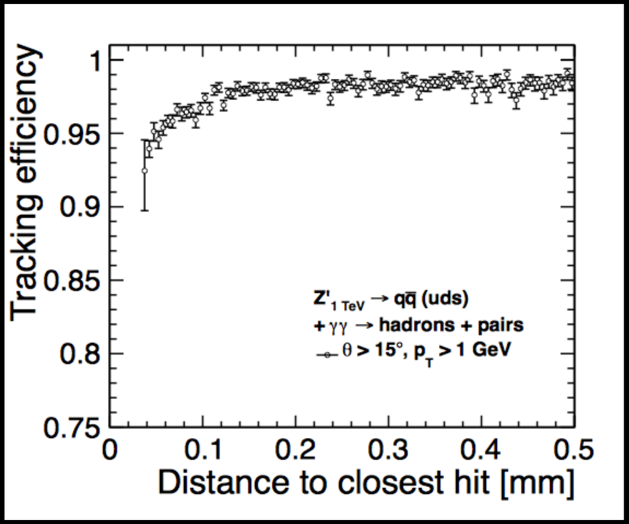


Tracking Performance

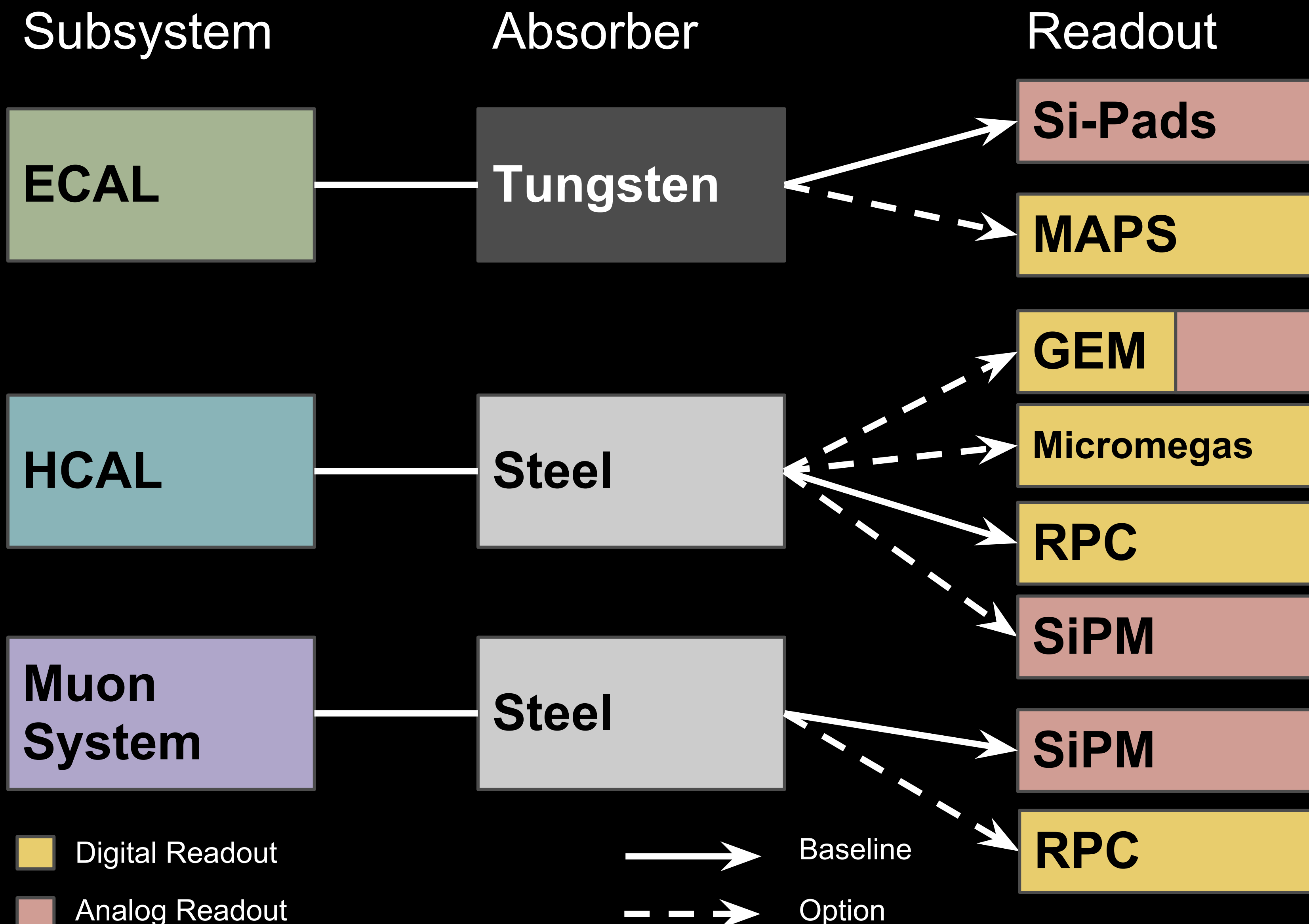
Excellent momentum resolution, impact parameter resolution and track finding efficiency even in high-energy jets



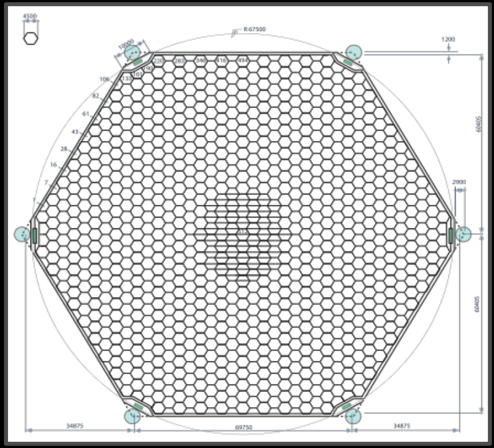




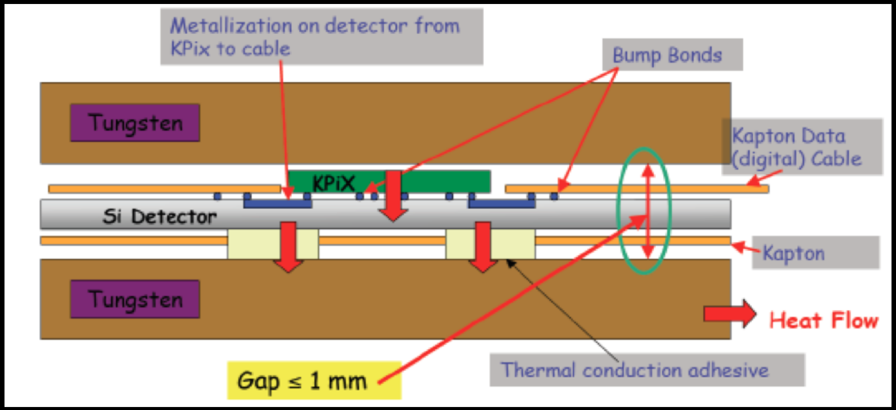
Calorimetry Tree



Si-W ECAL

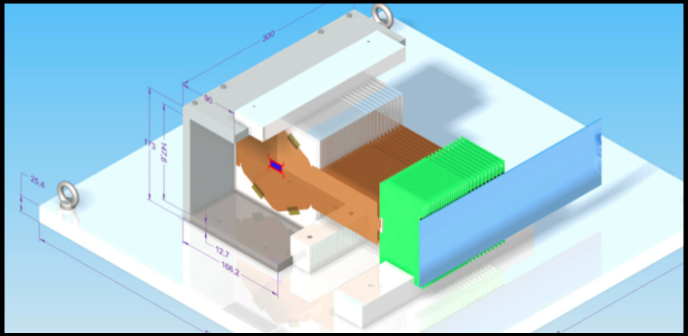


Highly segmented in lateral and transverse directions
Hexagonal shapes
Readout with KPiX chip



20 layers 2.5 mm W (5/7 X_0),
10 layers 5 mm W (10/7 X_0)
1.25 mm gaps → 29 X_0, 1 λ
$\Delta E / E \approx 17\% / \sqrt{E}$

Scheduled for SLAC ESA beamline in July 2013, <15 of the full 30 layers;
All layers for later running in 2013-14



The R&D provides the required baseline ECal components (except large-scale mechanics) – now nearly completed

See Jim Brau's talk on Tuesday afternoon.

HCAL

Highly granular calorimeter - 1x1 cm^2 readout pads. World record for number of channels in hadron calorimetry already in test stack.

Baseline: Glass RPC, digital readout

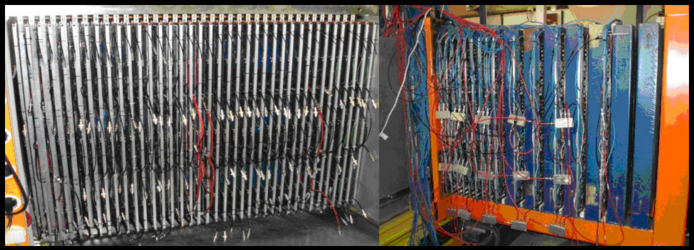
Technology successfully tested in beam tests in steel absorber stack at FNAL and in tungsten absorber stack at CERN

Data analysis is underway

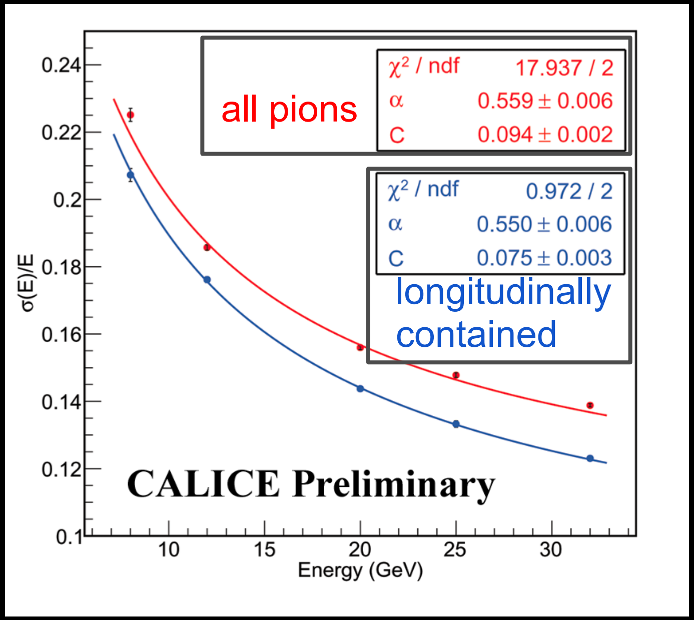
Operational experience drives further R&D: Single-glass RPC, low-resistivity glass for lower multiplicity, higher rate

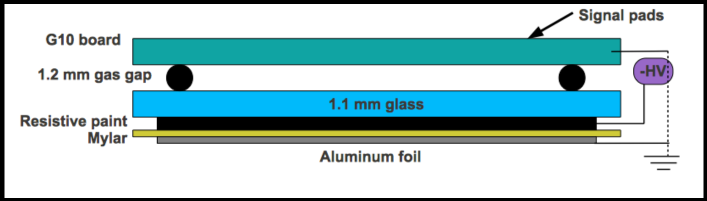
See B. Bilki's talk on Wednesday afternoon
and A. White's talk on GEMs on Thursday morning

HCAL in the Steel absorber stack at FNAL

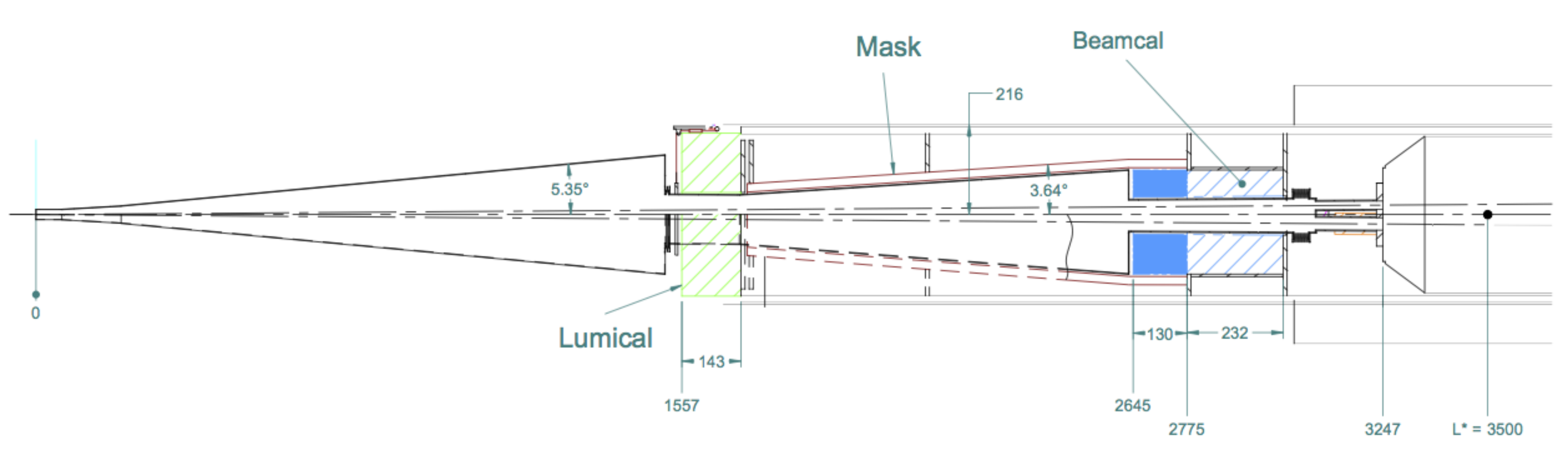


Energy resolution of pions





Forward Systems

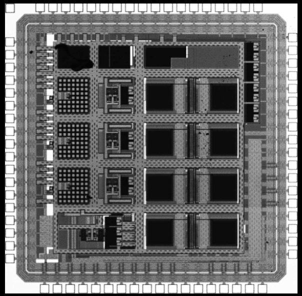


LumiCal: 40 mrad < θ < 90 mrad

- to measure integrated luminosity to better than 10^{-3}
- read out by Bean, KPiX

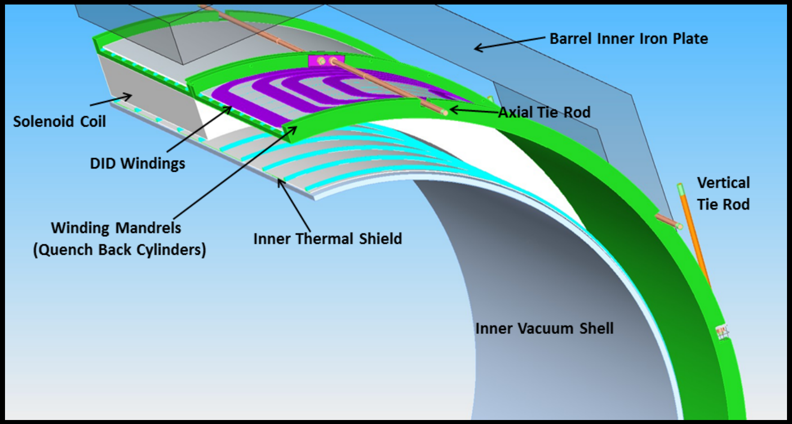
BeamCal: 3 mrad < θ < 40 mrad

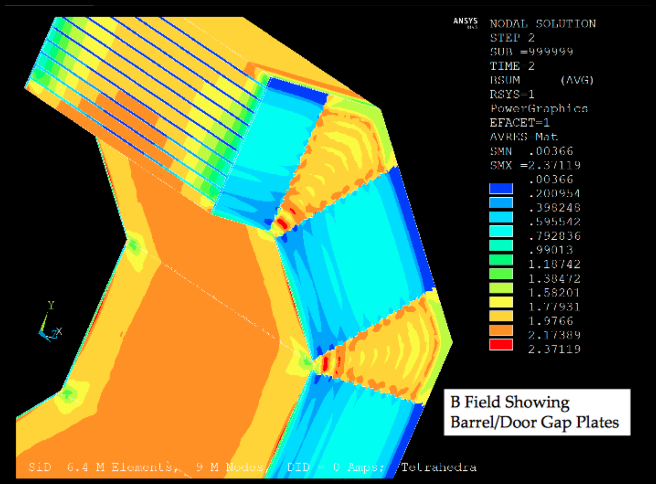
- to measure instantaneous luminosity using pairs
- read out by Bean chip



Bean Chip developed for higher radiation dose, high occupancy in far forward region
180 nm CMOS

Solenoid

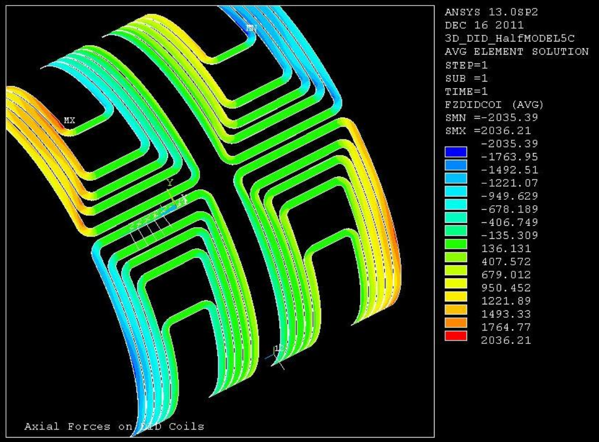




Wes Craddock, SLAC, SiD Workshop, Jan. 2013

5 T coil with Detector Integrated Dipole (DID)
Coil Design builds on CMS experience.
Advances in computation give a significant advantage to the SiD design as compared to prior CMS design work
- Magnetic field calculations in 3D ANSYS model
- Conservative choice of material. Feasibility demonstrated.
- Further conductor R&D could lead to cost savings.

More details in talk by W. Craddock on Tuesday afternoon (via webex)



Muon

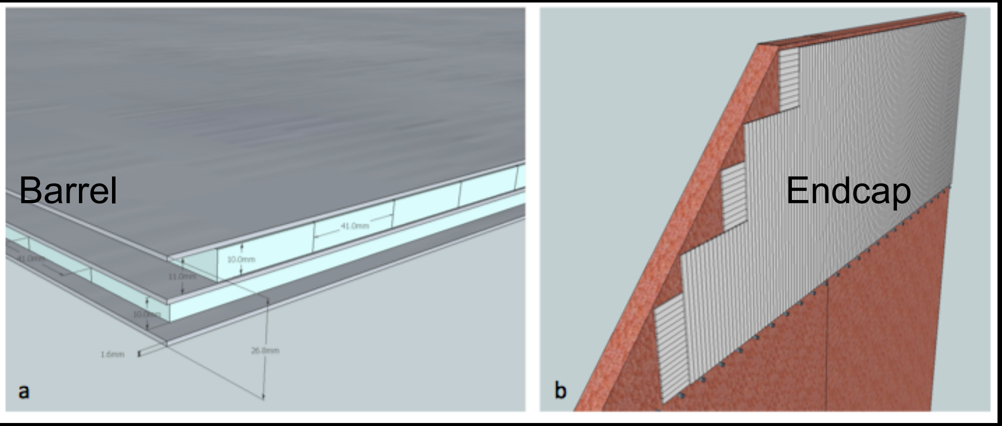
Instrumented Flux Return. Main purpose:
- Identification of muons
- Rejection of hadrons

10 layers in barrel,
 9 in each endcap

Major change since LOI:

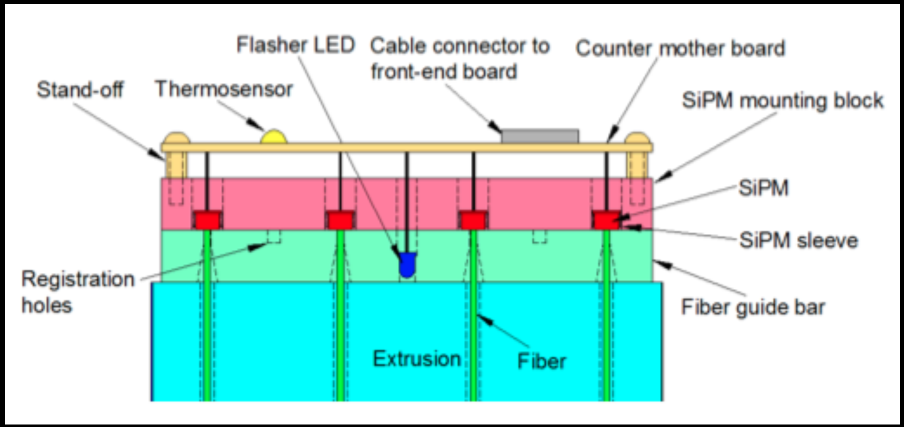
RPC → Extruded Scintillator bars, SiPM readout

Technology successfully tested in FNAL beam.

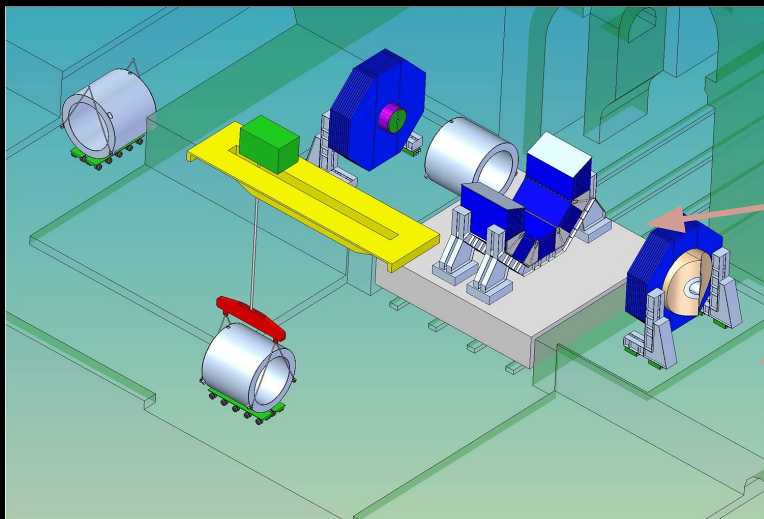


Barrel: Double layers of orthogonal strips, glued together with aluminum sheets
Endcap: Strip size adjusted to fit between spacers

Wavelength-shifting fibers read out by SiPM in a mounting block



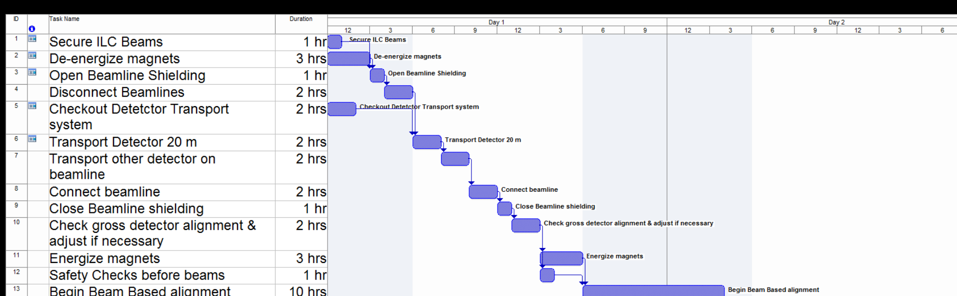
Engineering and Push-Pull



Horizontal access site

SiD barrel fixed on 3.8 m concrete platform for push-pull

Endcaps can be routinely opened for service



ID	Task Name	Duration
1	Secure ILC Beams	1 hr
2	De-energize magnets	3 hrs
3	Open Beamline Shielding	1 hr
4	Disconnect Beamlines	2 hrs
5	Checkout Detetctor Transport system	2 hrs
6	Transport Detector 20 m	2 hrs
7	Transport other detector on beamline	2 hrs
8	Connect beamline	2 hrs
9	Close Beamline shielding	1 hr
10	Check gross detector alignment & adjust if necessary	2 hrs
11	Energize magnets	3 hrs
12	Safety Checks before beams	1 hr
13	Begin Beam Based alignment	10 hrs

Specific push-pull planning depends on IR layout

"Fastest turnaround that is safely achievable": estimated 32 hrs

Costing

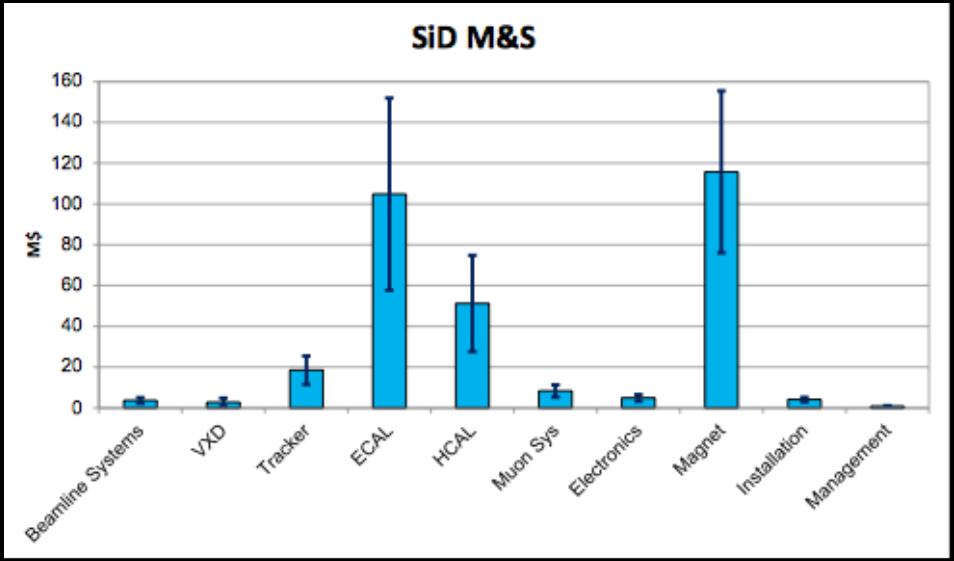
Costing units agreed between SiD, ILD, CLIC: 2008 USD
SiD uses central values of agreed costs
Cost of baseline:

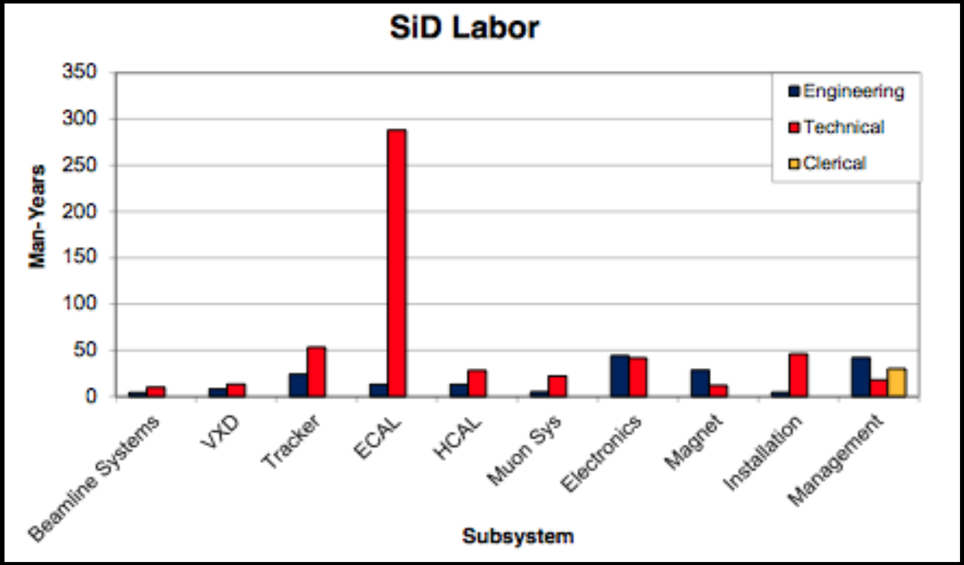
- M&S: 315 MCU
- Contingency: 127 MCU
- Effort: 748 person-years

Parametric detector costing
→ cost sensitivity analysis

Baseline: 6 CU / cm^2 Si
Coil costed as being made by industry

3 CU / cm^2 Si, coil made in-house, 6000 CU / m^2 HCAL:
M&S: 315 MCU → 222 MCU



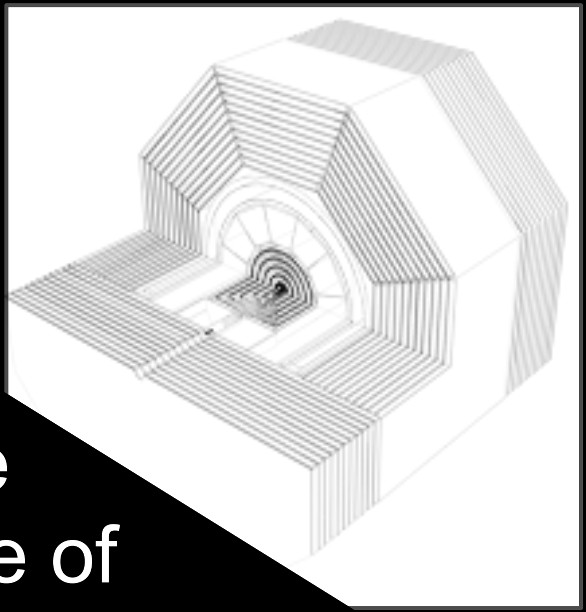


Detector Baseline Summary

- SiD is designed for precision physics
  - Designed to perform well in worse environment than planned
- Technological feasibility has been shown
  - Detailed studies ongoing
- SiD is fully costed
  - Solid foundation for a TDR
- All the cornerstones are in place
  - We're ready to start a TDR process

SiD's
Physics Performance

Simulation



SLIC - developed at SLAC

- Geometry definable at runtime
- XML file allows easy exchange of geometries between collaborators
- Now integrated in ILCSOFT

Centerpiece for the DD4HEP project to unify detector description for simulation and reconstruction

See C. Grefe's talk on Tuesday morning

Reconstruction

Major change since LOI:
Moving to common tools

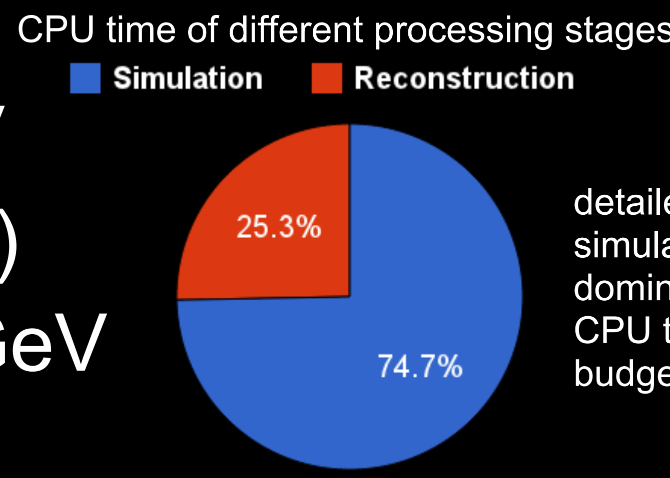
- PandoraPFA: Calorimeter reconstruction and sophisticated Particle Flow Algorithms
- LCFIPlus: Vertex reconstruction and flavor tagging
- MarlinReco: Collection of analysis tools, e.g. isolated lepton identification
- New OverlayDriver to mix in two kinds of background

Seamless transition enabled by the common LCIO format

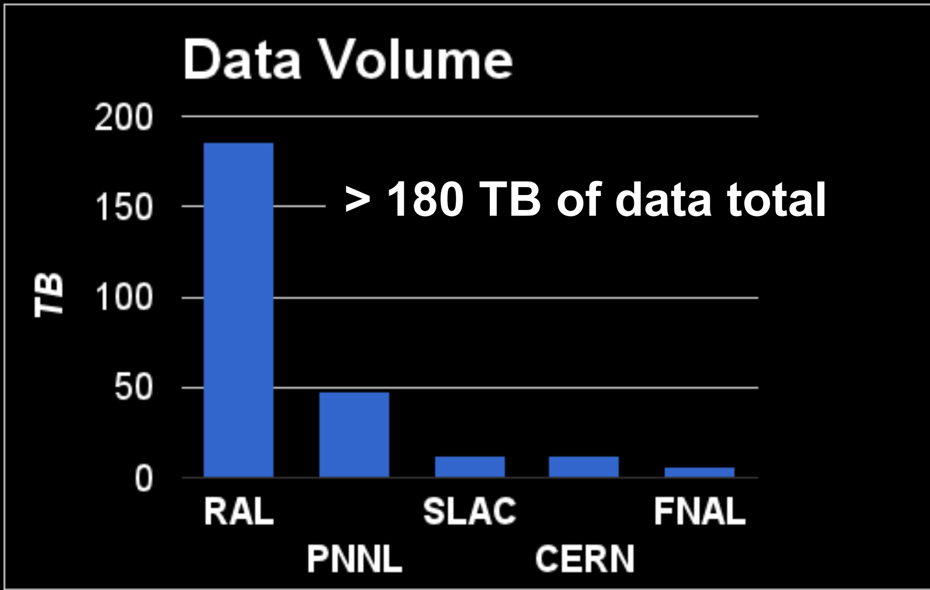
DBD Production in Numbers

Production summary on SLAC confluence

50.7 million events at 1 TeV
(+ 4.7 million gghadrons)
6.55 million events at 500 GeV
(+ 4.4 million gghadrons)



detailed simulation dominates CPU time budget



Country	Total CPU Time (years)
UK	100.2
CH	68.2
FR	15.0
US	28.2
TOTAL	211.6

SiD on the Grid

Open Science Grid (OSG) resources are new addition to the SiD resource pool

dedicated resources: PNNL, SLAC, CERN
temporary quota increase: FNAL, RAL Tier 1
opportunistic use: all others

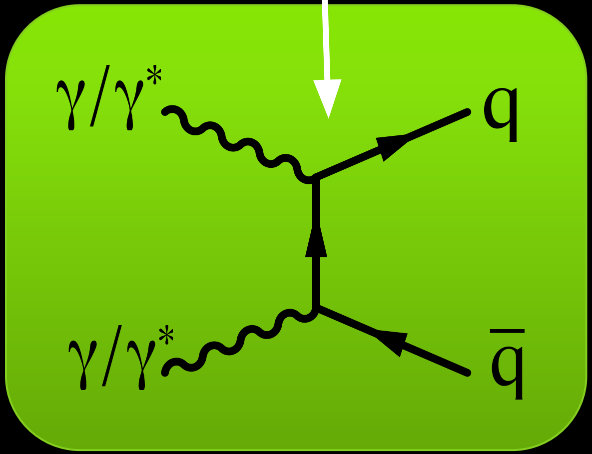
Worldwide LHC Computing Grid (WLCG) resources have been established during LOI and CLIC CDR efforts

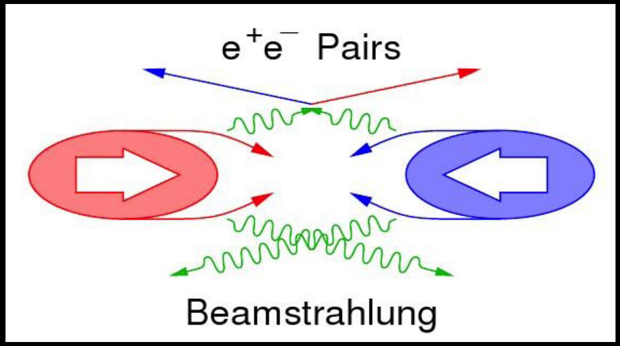
SiD takes advantage of the international computing grid infrastructure

DBD Benchmarking Analyses

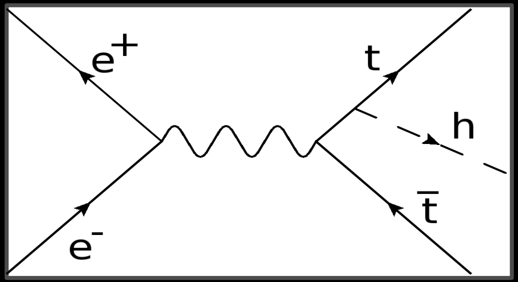
All analyses with detailed detector simulation

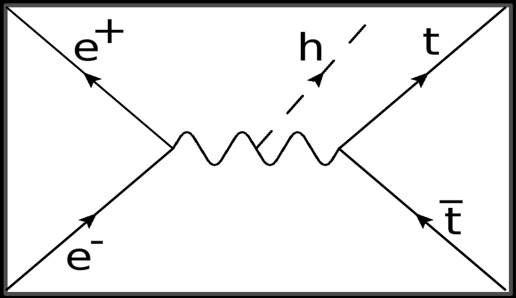
- SLIC with realistic (conservative) z distribution of events across luminous region
- Taking into account background from
- γγ interactions and incoherent pairs





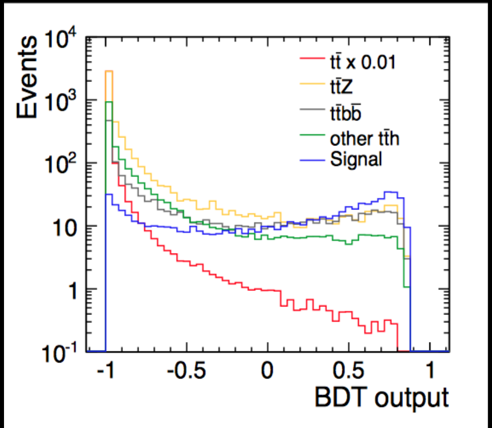
Top Yukawa Coupling





Dominant tth production diagrams

Direct measurement of the top Yukawa coupling by measuring the tth cross section at 1 TeV

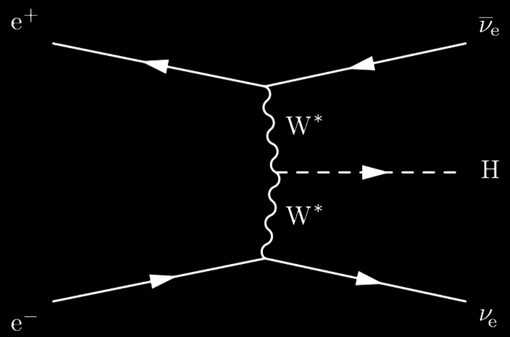


analysis in 6-jet + 1 lepton and in 8-jet channel;
candidates formed from jets by minimizing χ^2

DBD Result:
13.2% cross section uncertainty in 6-jet channel
11.5% cross section uncertainty in 8-jet channel
combined uncertainty on the top Yukawa coupling (1 ab^{-1}): 4.5%
with only P_{e-}, P_{e+} = -80%, +20%: uncertainty about 4%

see also Philipp Roloff's talk in the Higgs parallel session for details

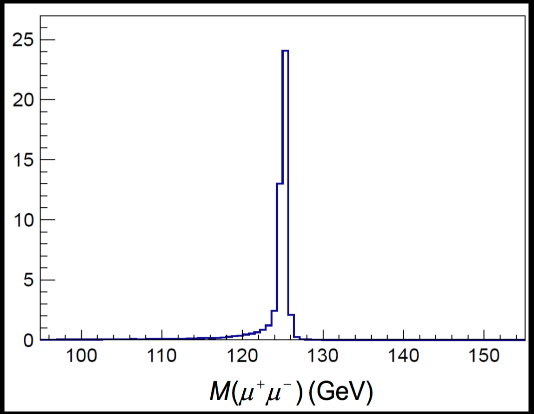
Higgs Branching Ratios



Measurement of the Higgs branching ratios to b, c, g, W, μ pairs (3 separate analyses) in direct production at 1 TeV

Relative uncertainties on the cross section times Higgs BR

Energy	1 TeV		
Luminosity	$\mathscr{L}$ = 500 fb^{-1}		$\mathscr{L}$ = 1000 fb^{-1}
P(e$^-$) P(e$^+$)	− 80% + 20%	+ 80% − 20%	− 80% + 20%
h → bb	0.0065	0.026	0.0046
h → cc	0.100	0.733	0.071
h → gg	0.040	0.234	0.028
h → WW	0.042	0.260	0.030
h → μμ			0.32



Results do not take into account results from stages below 1 TeV.

For example, h → cc at 250 GeV, 250 fb^{-1} ≈ 6 %

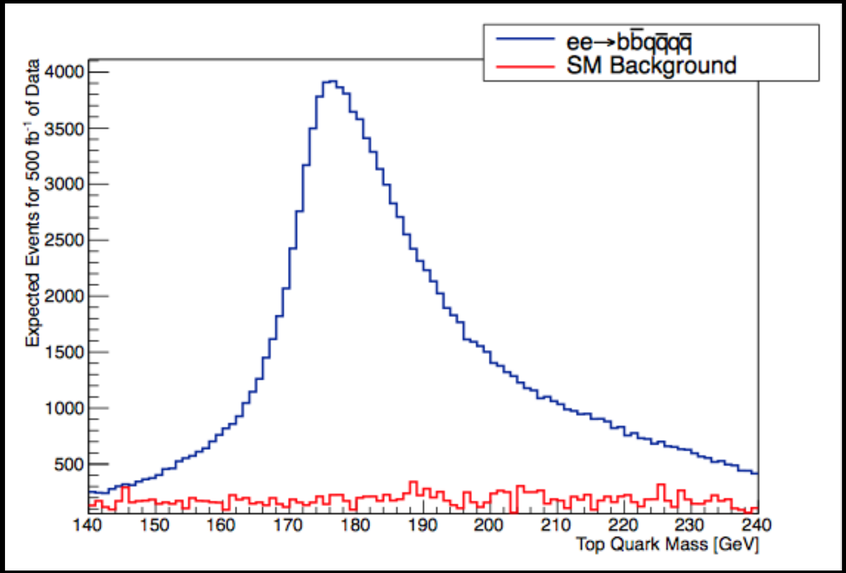
some analyses still being updated

quoted uncertainties statistical only

Top Pair Production at 500 GeV ILC

Repetition of a LOI background with updated detector description:

Measurement of top mass and forward-backward asymmetry in top pair production at 500 GeV.



Reconstructed top mass in the fully hadronic channel.

Result with 500 fb^{-1}, P_{e-}, P_{e+} = +80%, -30%:

statistical uncertainty only

- top production cross section: < 1%
- measurement of forward-backward asymmetry: ± 2%

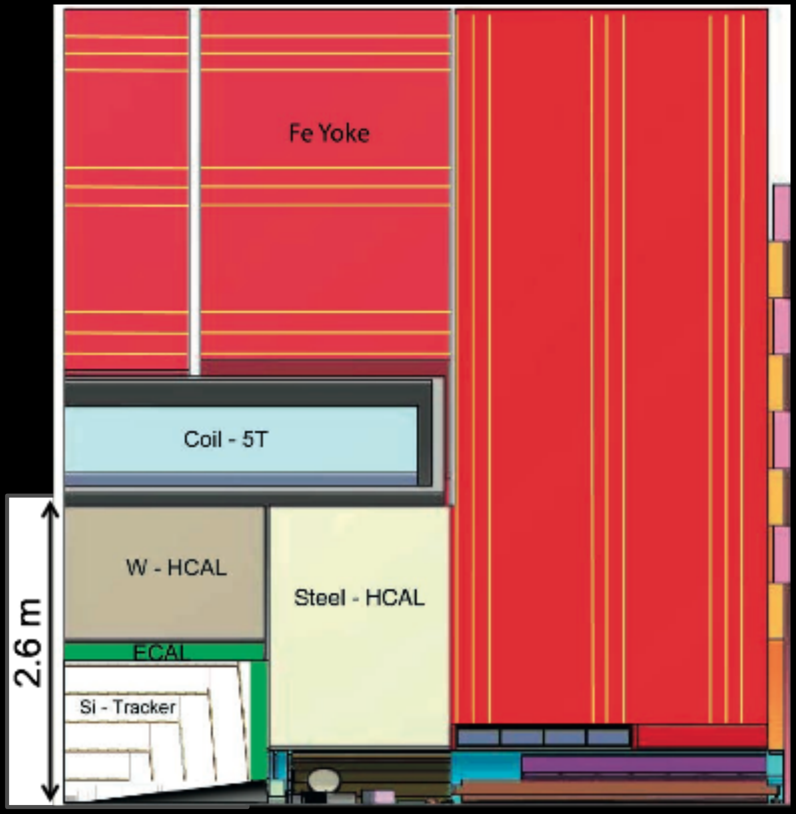
Summary of Physics Performance

- SiD baseline performance has been demonstrated in realistic simulation studies of precision measurements.
- Excellent b- and c-tagging as well as momentum and jet energy resolution allow to measure the Higgs couplings also to second generation fermions.
- Physics Performance with baseline has been studied up to 1 TeV.

The SiD Detector Concept at CLIC

Main differences wrt. ILC:
- Larger r_{inner} of the vertex detector
- Tungsten absorber in HCAL
- RPC-based muon system
- More complex forward region
- More precise time stamping in the active layers
- Faster power cycling: 50 Hz

more details in talk by C. Grefe



Summary

- The SiD concept is a compelling option for a detector at a linear collider.
- The SiD concept (with appropriate adjustments of technology) has been successfully used for physics analyses in extensive simulation studies 250 GeV up to 3 TeV.
- The DBD is a snapshot of the SiD road to a TDR.

- **R&D continues, analyses being updated / added for the US "Snowmass Process".**
- **Now is an ideal time to contribute. You are welcome to join the SiD study group meeting on Thursday at 14.00 in Seminar Room 2.**

Outlook

N. Graf, SLAC

We do not have the ilc, yet, but we will continue to work hard to make sure that the ILC got SiD.

Thank you, John & Harry

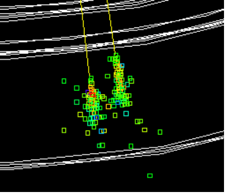
<u>For</u>

- leading us for nine years and through almost as many reports from DOD to DBD
- your scientific guidance and insight
- keeping SiD together and driving us forward even when times were difficult

Remember “Hotel California”: You can check-out any time you like, But you can never leave!

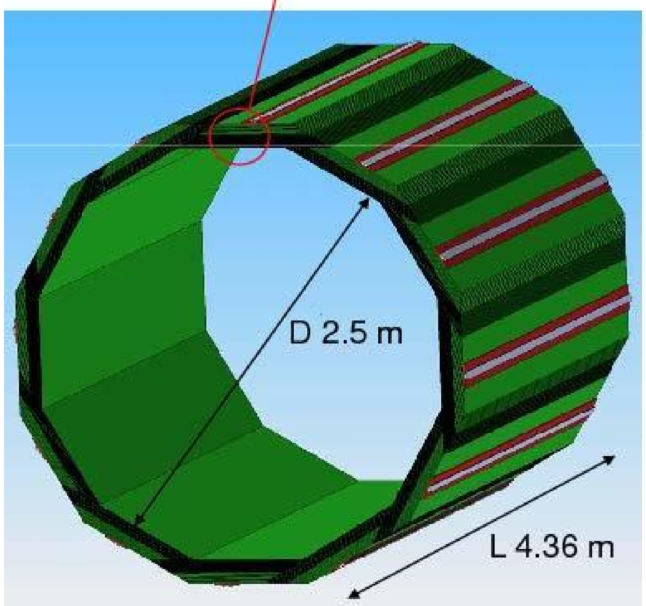
Thank you for your attention

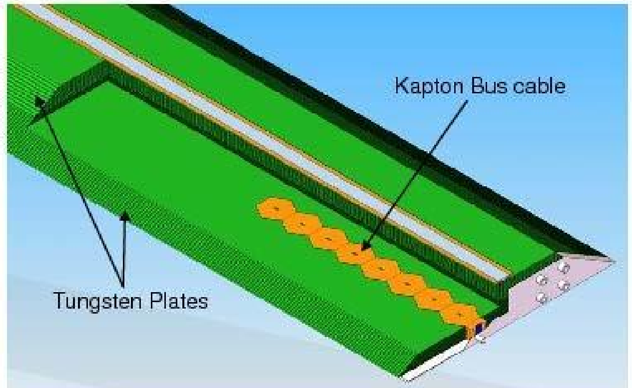
Backup

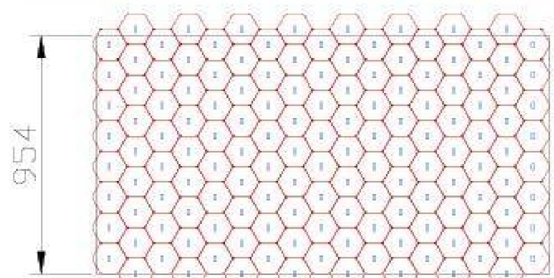


The SiD ECal Baseline

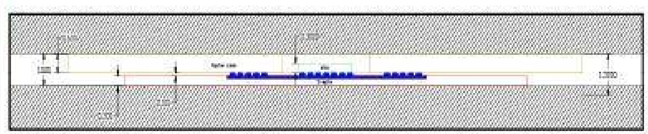
An imaging calorimeter: 30 layers tungsten interleaved with 30 layers pixellated silicon







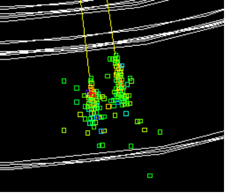
Hexagon sensors arrangement



detector module between tungsten plates

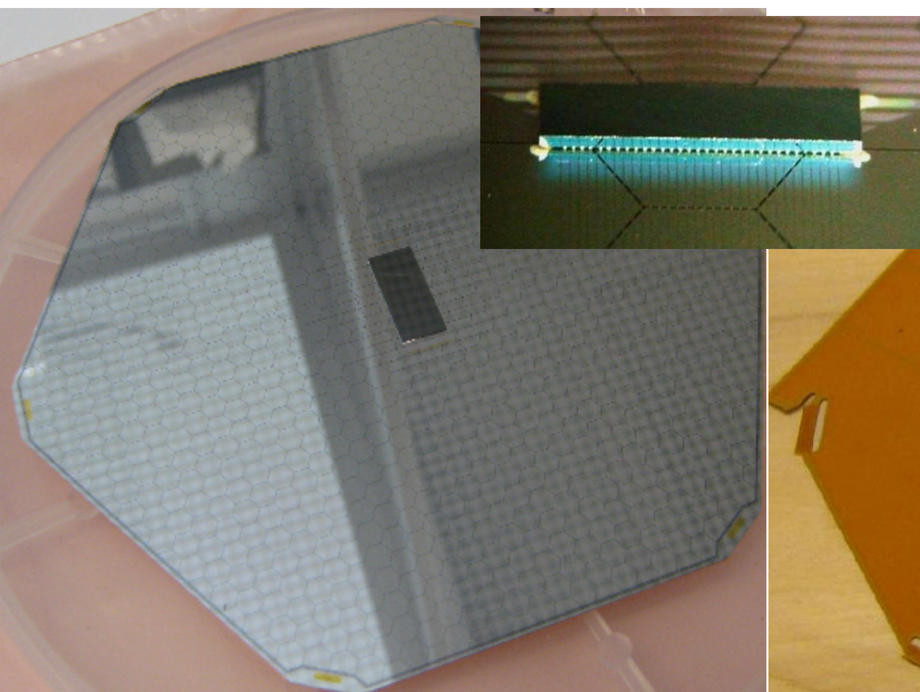
<u>Baseline configuration:</u>

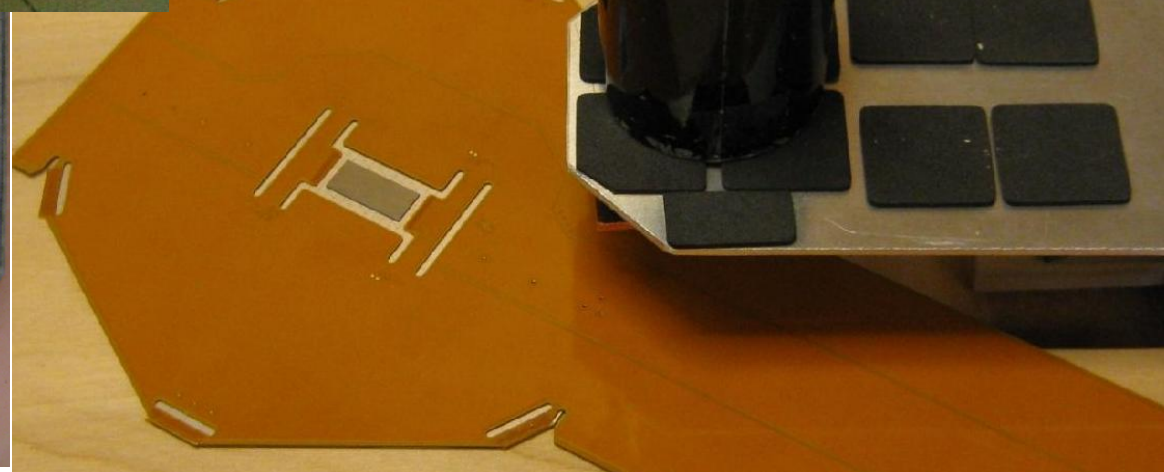
- transverse: 12 mm^2 pixels
- longitudinal: $(20 \times 5/7\ X_0)$ + $(10 \times 10/7\ X_0)$ $\Rightarrow$ 17%/sqrt(E)
- 1 mm readout gaps $\Rightarrow$ 13 mm effective Moliere radius

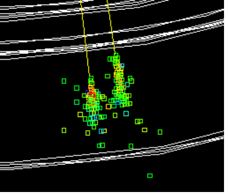


The R&D program

- Physics: A highly-segmented *imaging* ECal with small Moliere radius which can image MIPs to 500 GeV EM showers without melting
- The key element: a highly integrated electronic readout
  - ~1024 pixel sensors readout and digitized by single chip (KPiX) with power pulsing which is bump-bonded to the sensor
- The R&D provides the required baseline ECal components (except large-scale mechanics) – now nearly completed

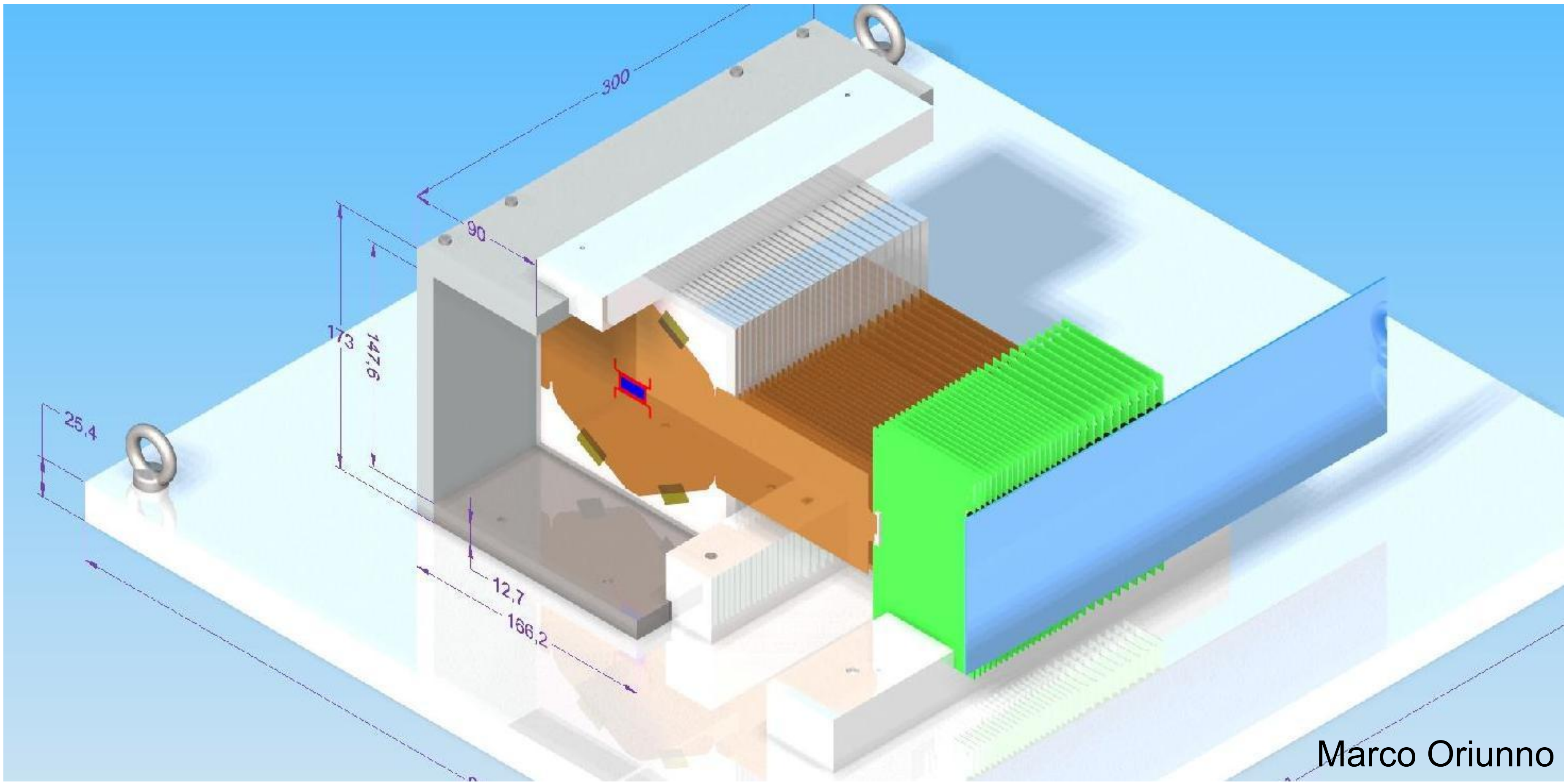


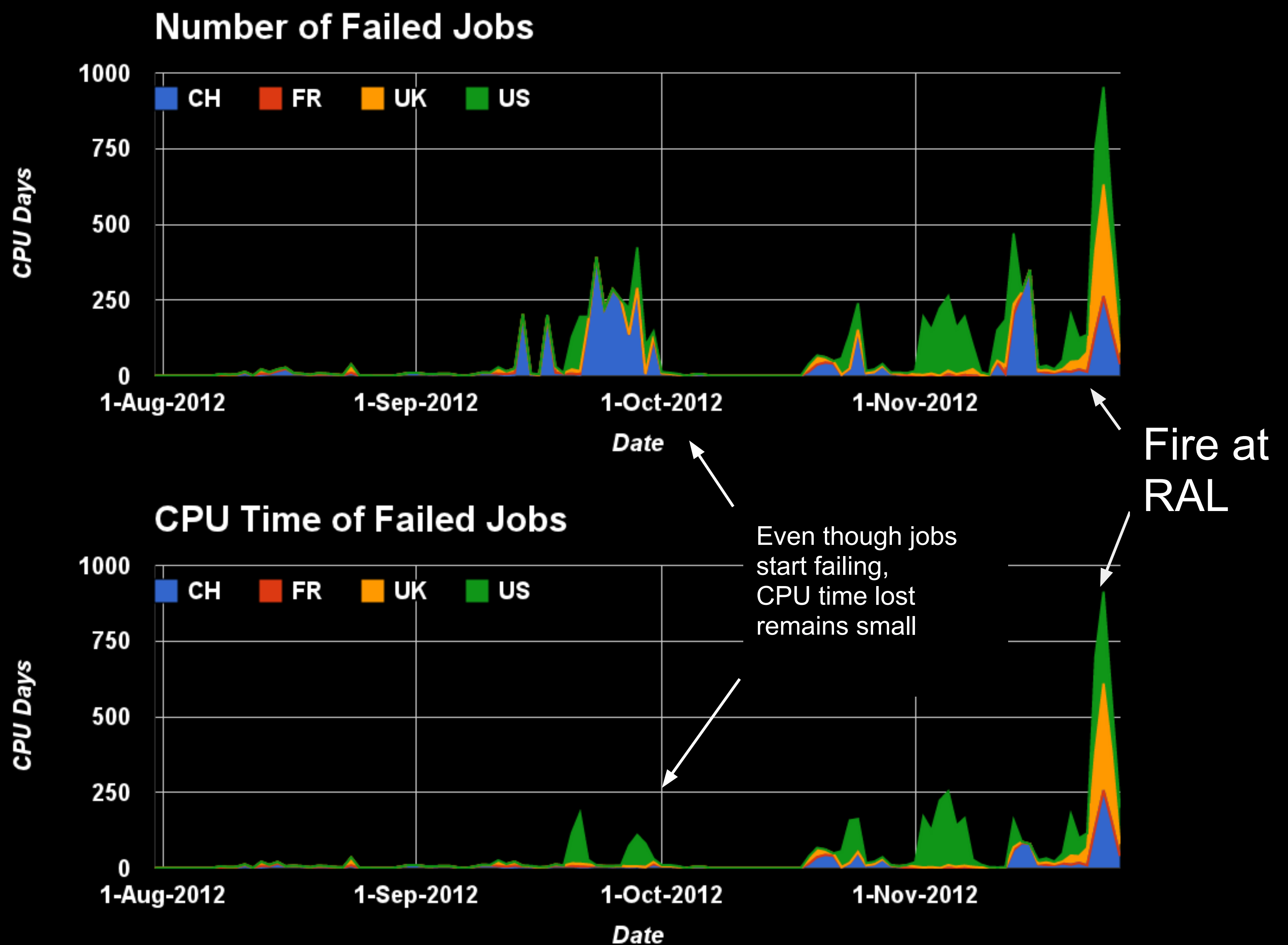




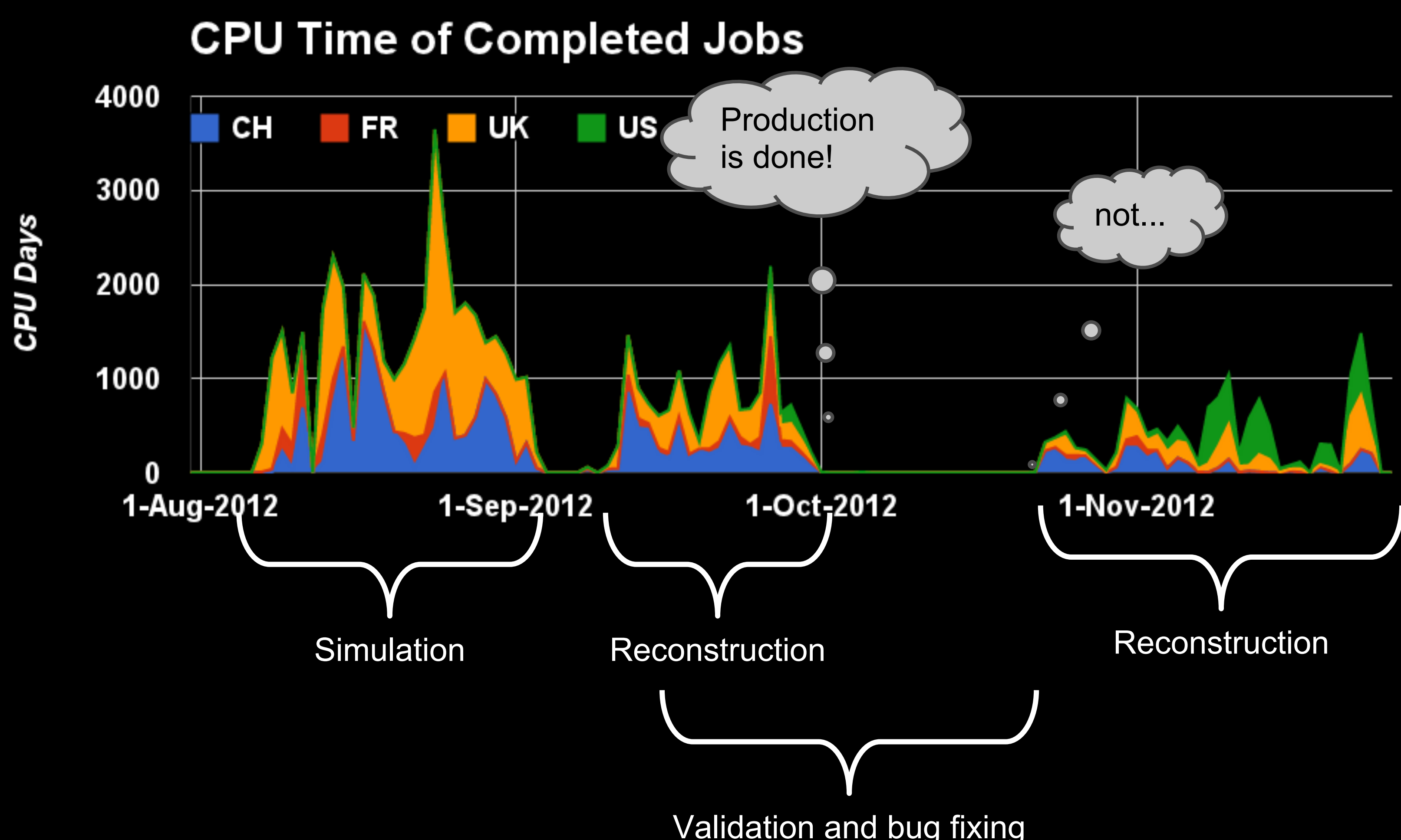
On to the test beam…

- Scheduled for revived SLAC ESA beamline starting July 2013
- <15 of the full 30 layers; All layers for later running in 2013-14

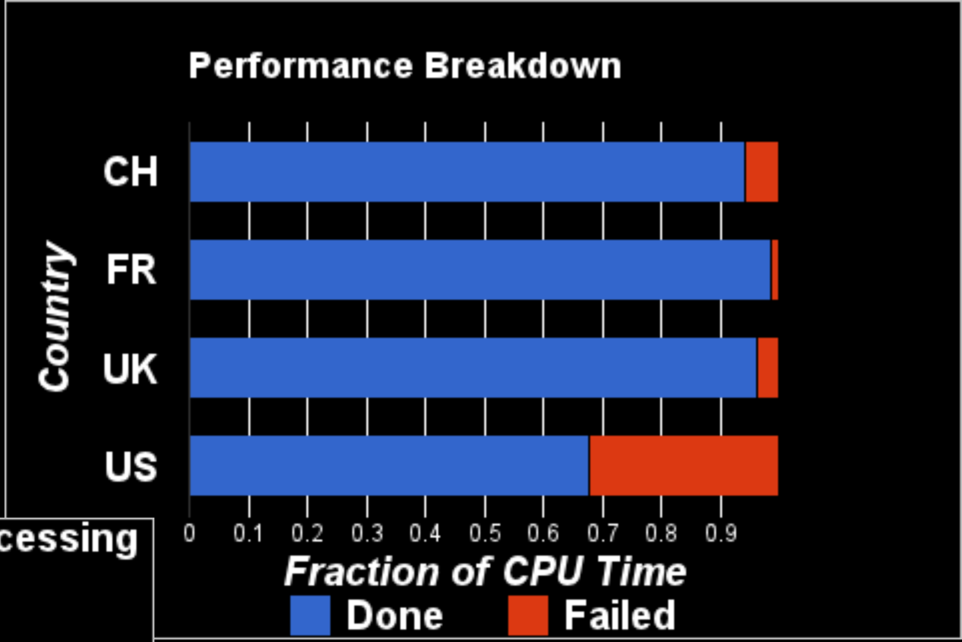



Number of Failed Jobs
CH
FR
UK
US
1000
750
500
250
0
CPU Days
1-Aug-2012
1-Sep-2012
1-Oct-2012
1-Nov-2012
Date
CPU Time of Failed Jobs
CH
FR
UK
US
1000
750
500
250
0
CPU Days
1-Aug-2012
1-Sep-2012
1-Oct-2012
1-Nov-2012
Date
Fire at RAL
Even though jobs start failing, CPU time lost remains small

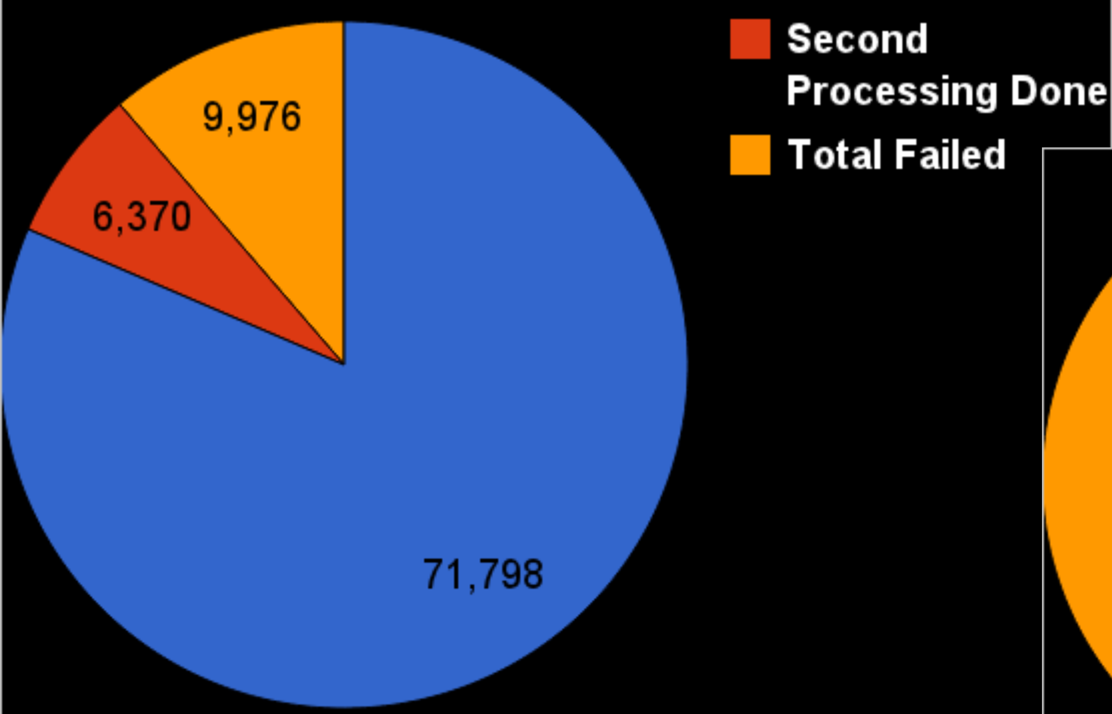
Production Timeline



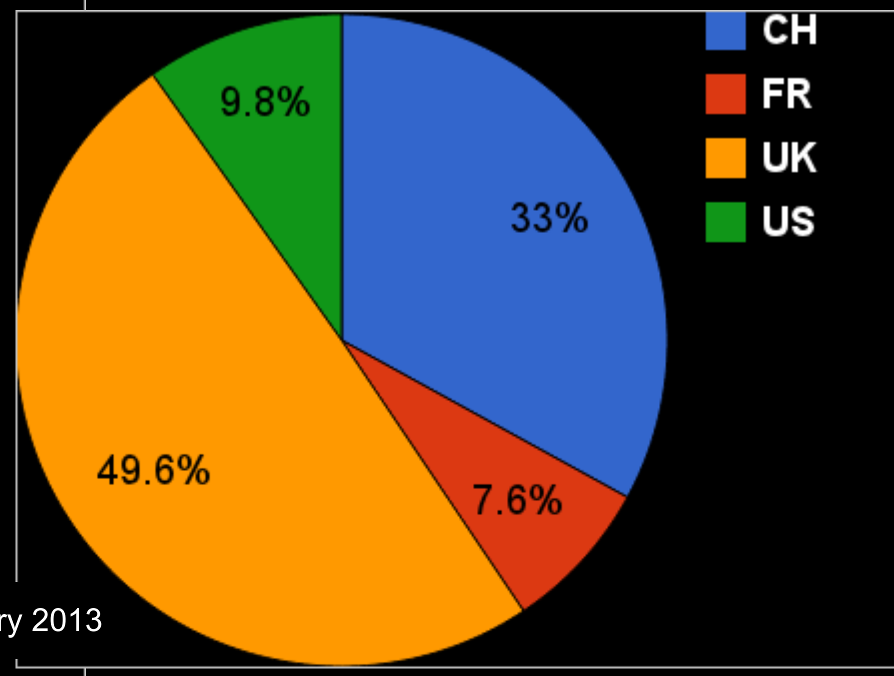
Performance Summary



Number of Jobs

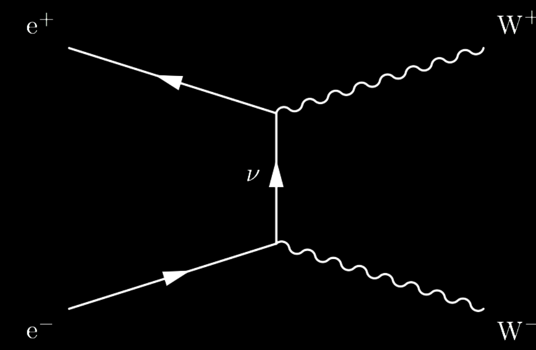


CPU Time



Measurement of Beam Polarization

$e^+e^- \rightarrow W^+W^-$ production in the forward region
Sensitive to polarization,
insensitive to new physics.



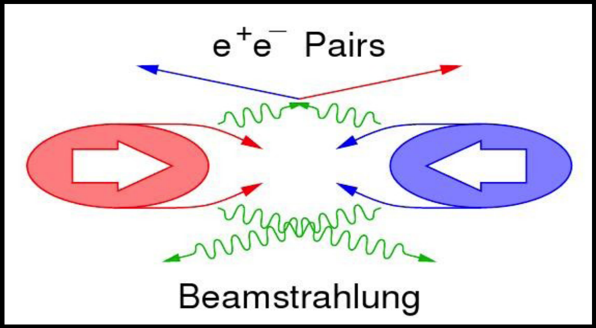
Four jet topology: $0.8 < \cos(\theta) < 1$
Two jets + lepton: $0.8 < \cos(\theta) < 1$ and
$-1 < \cos(\theta) < 1$

<u>Result</u>:

assuming 500 fb^{-1} in each polarization state	Pol.	$\Delta\lvert P_{e-}\rvert$	$\Delta\lvert P_{e+}\rvert$
$0.8 < \cos(\theta) < 1$	−80%,+20%	0.12	0.077
$0.8 < \cos(\theta) < 1$	+80%,−20%	0.0046	0.023
$-1 < \cos(\theta) < 1$	sum	0.0020	0.0029

assuming SM production of W^+W^-

Beam-Induced Background

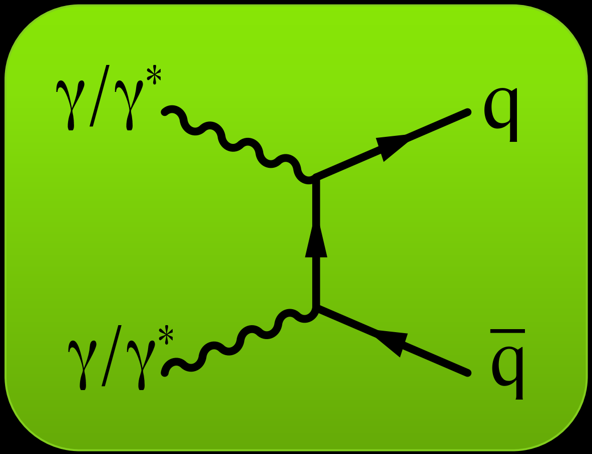


Pair background
1 event per BX
450k particles

Generated by GuineaPig
ascii → hepevt → stdhep

Merged with each "physics" event

MCParticles that don't make hits are dropped



γγ interactions
4.1 events per BX @ 1 TeV
1.7 events per BX at 500 GeV

Generated by Whizard

Baseline	M&S Base (M$)	M&S Contingency (M$)	Engineering (MY)	Technical (MY)	Administrative (MY)
Beamline Systems	3.7	1.4	4.0	10.0	0.0
VXD	2.8	2.0	8.0	17.7	0.0
Tracker	17.7	6.9	24.0	53.2	0.0
EMCal	99.9	40.0	13.0	298.9	0.0
Hcal	51.6	20.1	13.0	28.0	0.0
Muon Sys	8.3	2.9	5.0	14.6	0.0
Electronics	4.9	1.6	44.1	41.7	0.0
Magnet	114.8	39.5	29.2	25.0	0.0
Installation	4.1	1.1	4.5	46.0	0.0
Management	0.9	0.2	42.0	18.0	30.0
	308.8	115.7	186.8	553.1	30.0

Modified Costing	M&S Base (M$)	M&S Contingency (M$)	Engineering (MY)	Technical (MY)	Administrative (MY)
Beamline Systems	3.7	1.4	4.0	10.0	0.0
VXD	2.8	2.0	8.0	17.7	0.0
Tracker	14.4	5.7	24.0	53.2	0.0
EMCal	63.5	25.4	13.0	298.9	0.0
Hcal	30.6	11.7	13.0	28.0	0.0
Muon Sys	8.3	2.9	5.0	14.6	0.0
Electronics	4.9	1.6	44.1	41.7	0.0
Magnet	88.9	30.4	29.2	25.0	0.0
Installation	4.1	1.1	4.5	46.0	0.0
Management	0.9	0.2	42.0	18.0	30.0
	222.1	82.4	186.8	553.1	30.0