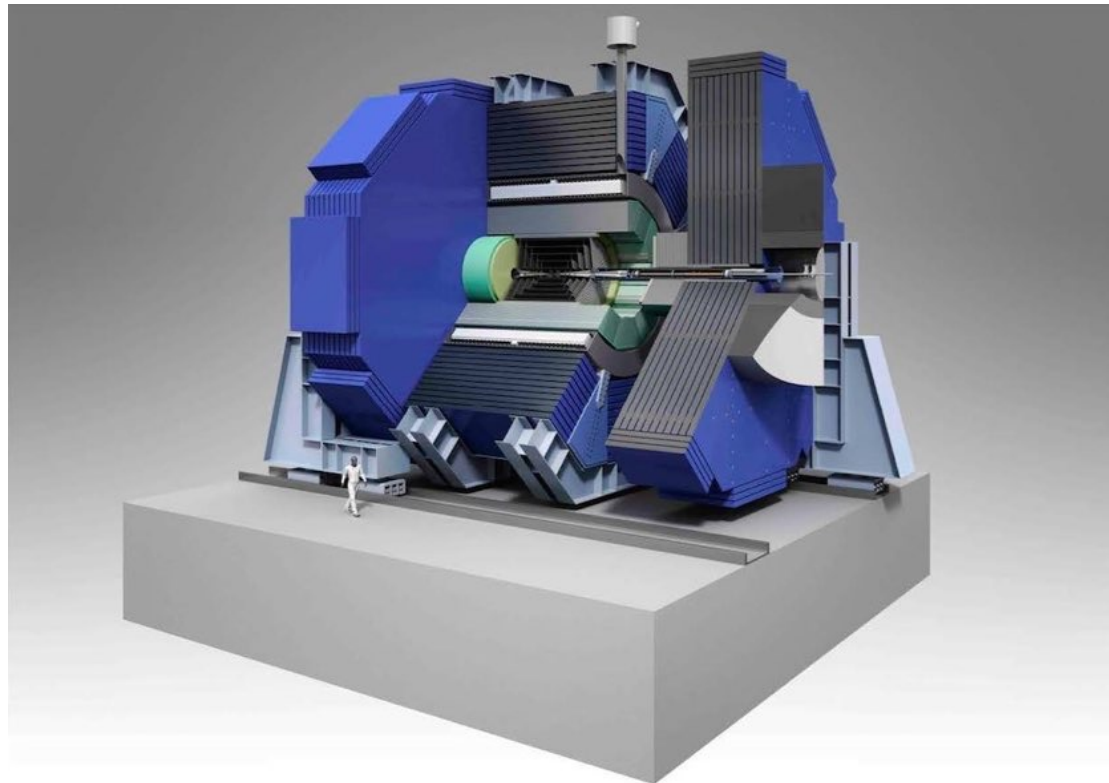


SiD detector design - a critic's view

Felix Sefkow
DESY

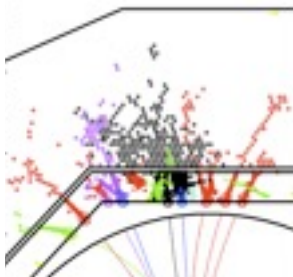


SiD workshop, SLAC, January 12-14, 2015



Outline

- SiD concept
- Vertex detector and tracking system
- ECAL and HCAL
- Structure and community



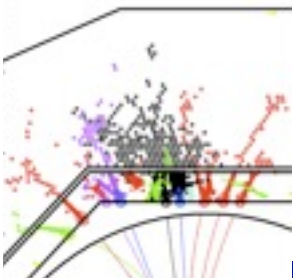
Disclaimer

- In preparation, I consulted people in ILD, SiD, CLICdp
 - Mostly ILD - open discussions in SiD anyway
- All mistakes or superficial remarks are my responsibility.
- I am not a silicon detector expert at all.



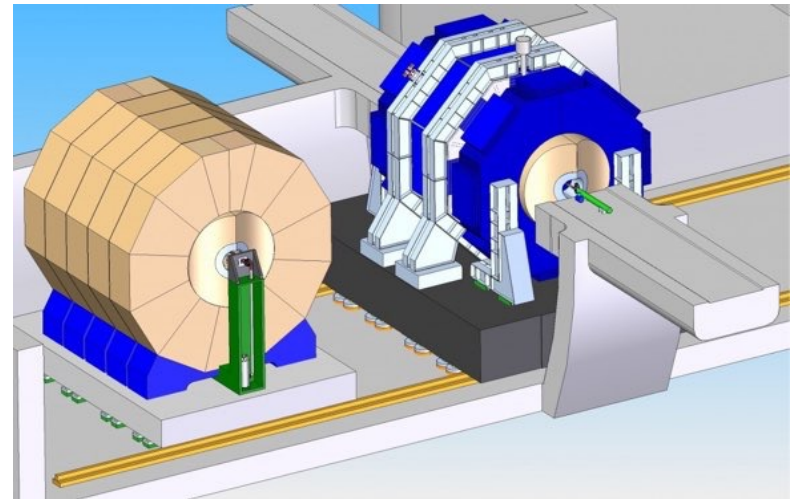
Not me, I hope !!

SiD concept

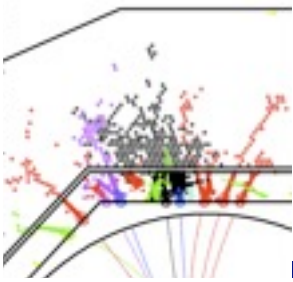


Two detectors - or one?

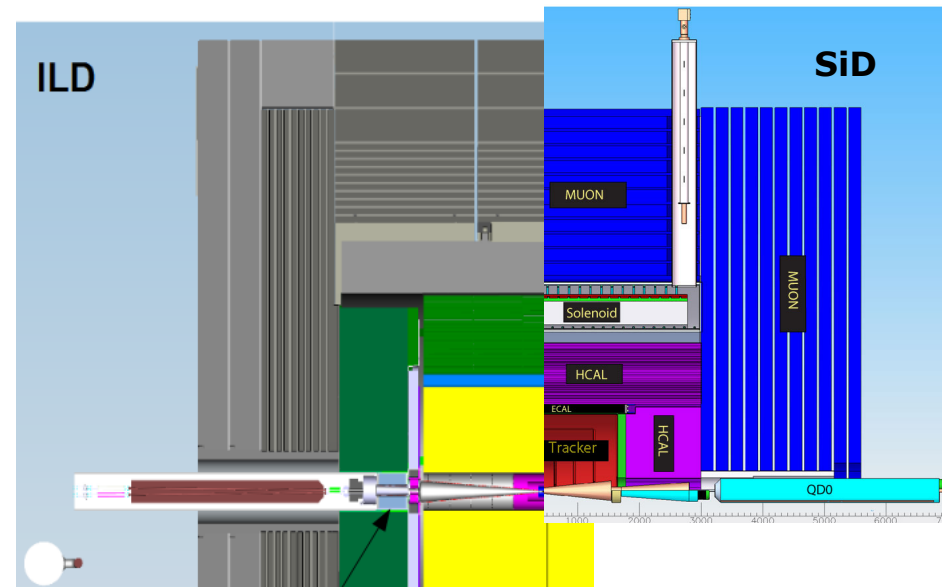
- Current baseline: 2 detectors
- But presently there is *no premium* for being *different*
- No guidance for, e.g.
 - cheap vs expensive
 - simple vs complex
 - aggressive vs conservative
 - low E_{CM} vs high E_{CM}
 - gaseous vs still
- Convergence not unlikely
- Consider myself as friend of and contributor to SiD and help to make it the best possible detector, *regardless of others*



ILD and SiD

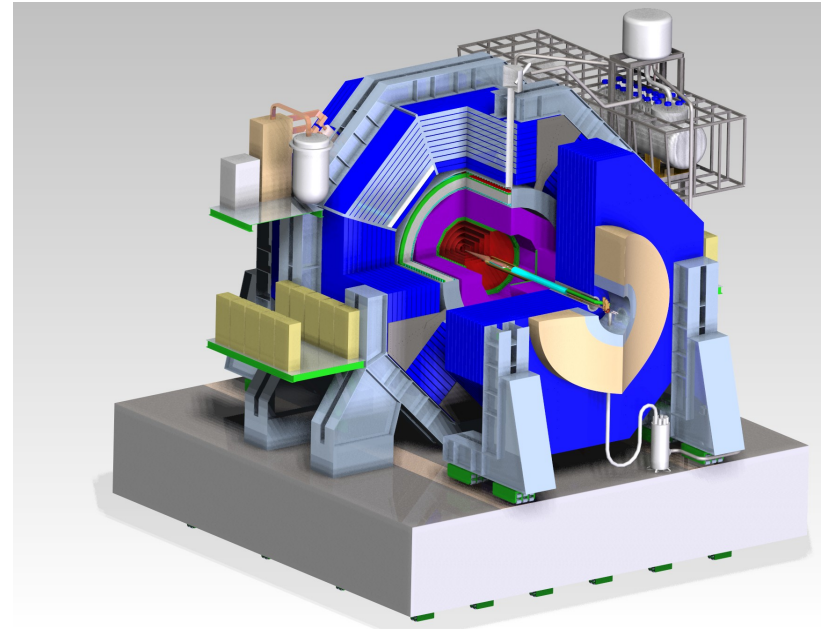


- General remarks heard in the LC community
- Compared to ILD which some consider
 - large (expensive)
 - unambitious (cost optimisation)
 - unfocussed (technology options)
- SiD appears
 - small
 - aggressive
 - weak
- These attributes could turn into advantages once symmetry breaking axis is defined

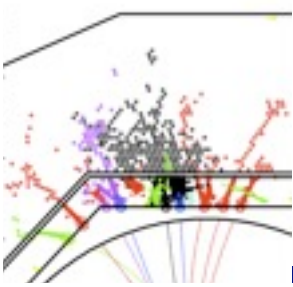


Only SiD

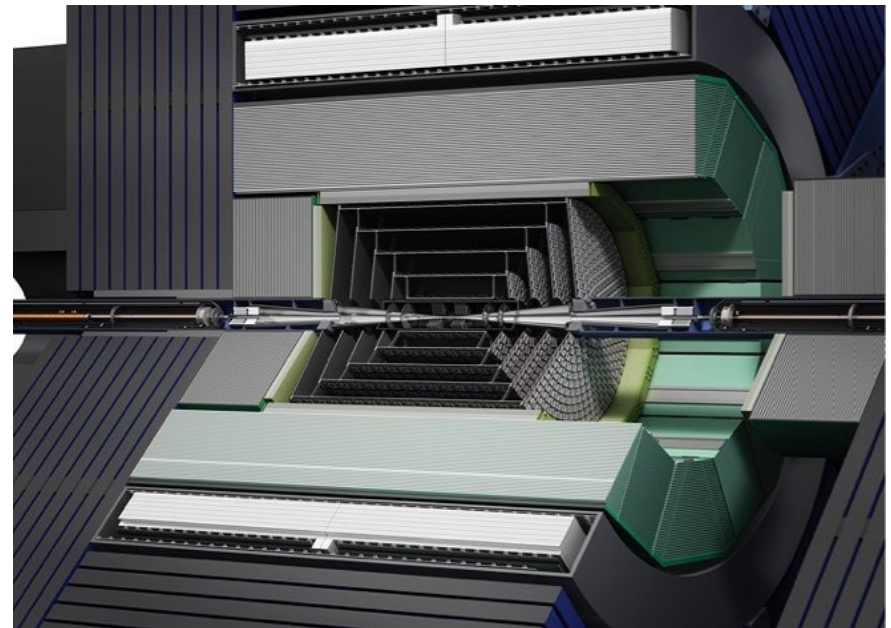
- SiD, considered per se, might be
- too small
- too aggressive
- too weak
- Pointless to argue between optimist and pessimist
- Constructive realist: For the time being, need to understand the derivatives
- Gain strength and flexibility

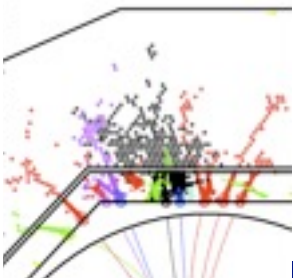


SiD concept



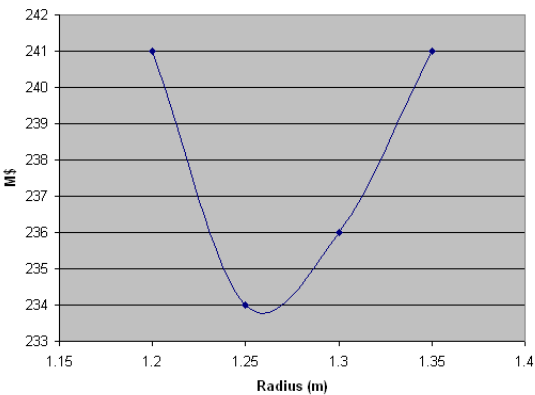
- Particle Flow detector, sure
- Central choice: an all-silicon tracking system
 - robust tracking even in harsh backgrounds
 - best momentum resolution with compact dimensions
- 10 years ago: exotic!
- Today supported by LHC: routine!
- Cost-driven choice of basic parameters such as radius and magnetic field
- R more expensive than B: small detector



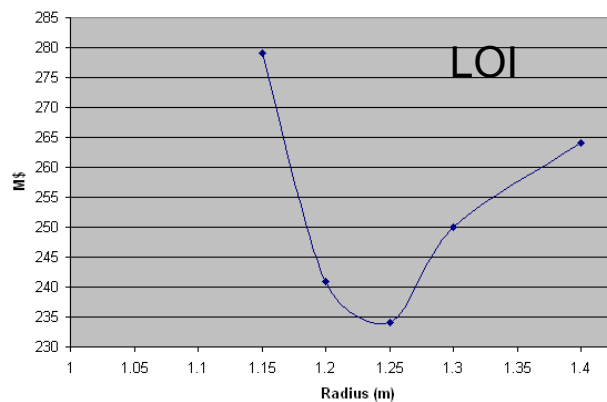


SiD optimisation

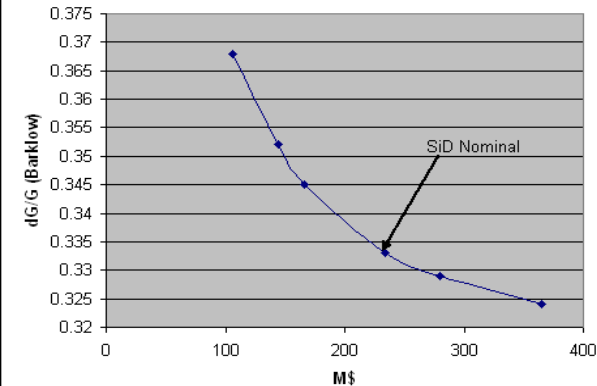
Vary R, B, de/E=0.0378



Vary R, Lambda, de/E = 0.0378

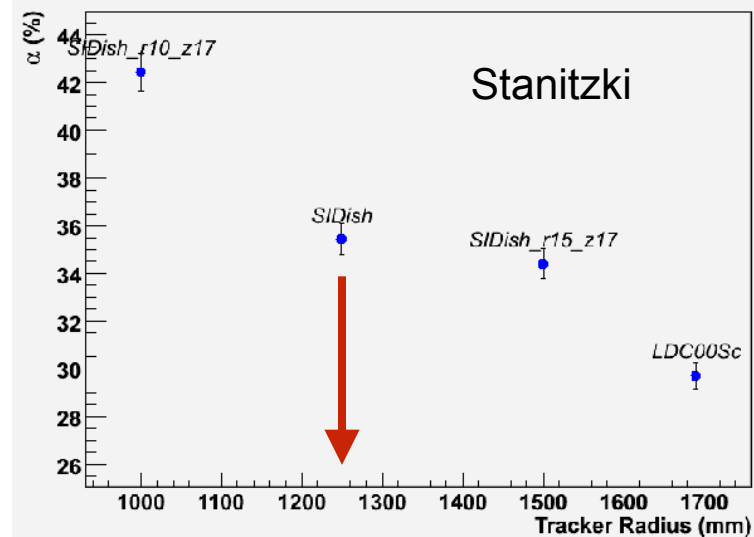


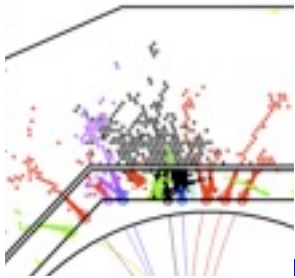
dG/G (Barklow)



- Use the Pandora master formula $\sigma \sim B^{-0.3} R^{-1}$ and fold in cost
- Find minimal cost for fixed JER
- Minimal JER from physics (HHH)
- Partially supported by studies using ILD software and Pandora
- Studies done 2008 for the LOI
- **Excellent! - But needs to be revised with realistic SiD simulation**
 - and prototype-validated cost functions

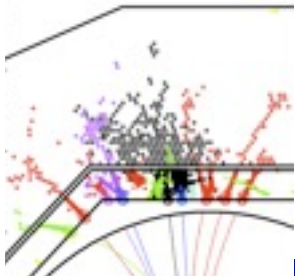
Radial Dependence 200 GeV





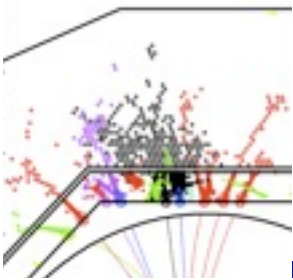
Safety margins?





Safety margins?



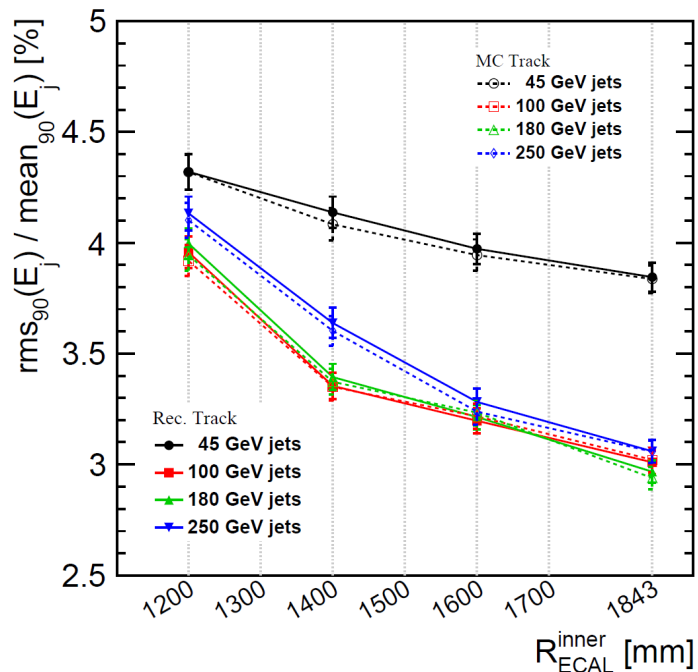
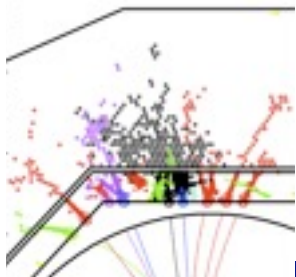


Safety margins?

- Exact position may depend on details
- May not reach some of other goals
 - R_M , material budget, B , # tracker layers



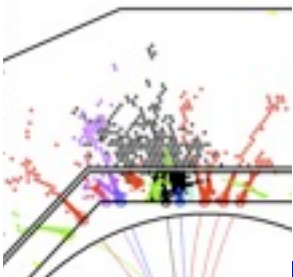
Safety margins?



Example:
ILD ECAL study,
T.H. Tran, LCWS13



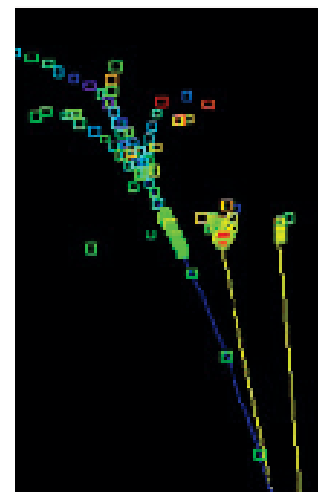
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- May not reach some of other goals
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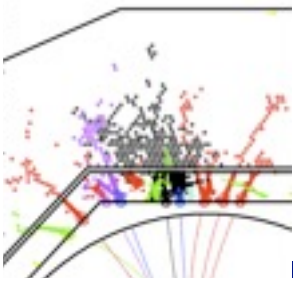
Beyond jet energy resolution

- SiD (like ILD) and its calorimeters have been optimised for jet energy resolution using particle flow
- JER is not everything!
- **Particle ID** is under-exposed
 - Indirect impact on PFLOW performance
 - Direct impact on other physics analyses
 - isolated leptons vs hadronic background
 - leptons in jets from heavy quark decays,
 - e.g. for calibration of vertex based b,c tag efficiencies
 - **Electron pion separation** : ECAL and HCAL
 - **Muon pion separation** : (ECAL,) HCAL and TCMT
- **Tau decays with π^0 reconstruction**
 - important tool to tag CP of e.g. Higgs decays
 - 2 photon separation \leftrightarrow R_M and R_{ECAL}

No picture



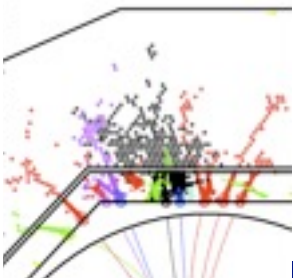
SiD concept



- The choice of silicon for the tracker gains in attractiveness and realism thanks to LHC experience and upgrade efforts
 - could be exploited more; e.g. study performance (efficiency and resolution) for LC events in present and future LHC detectors (a la TLEP)
- The early LOI studies with parameterisations or idealised detectors and reconstruction need to be replaced by realistic simulations (supports, services)
- Distance to “cliffs” must be known - existence of safety margins must be demonstrated
 - in terms of parameters like R and B
 - in terms of assumptions on, e.g, R_M , material budget or hit occupancy
- There must be prototypes!

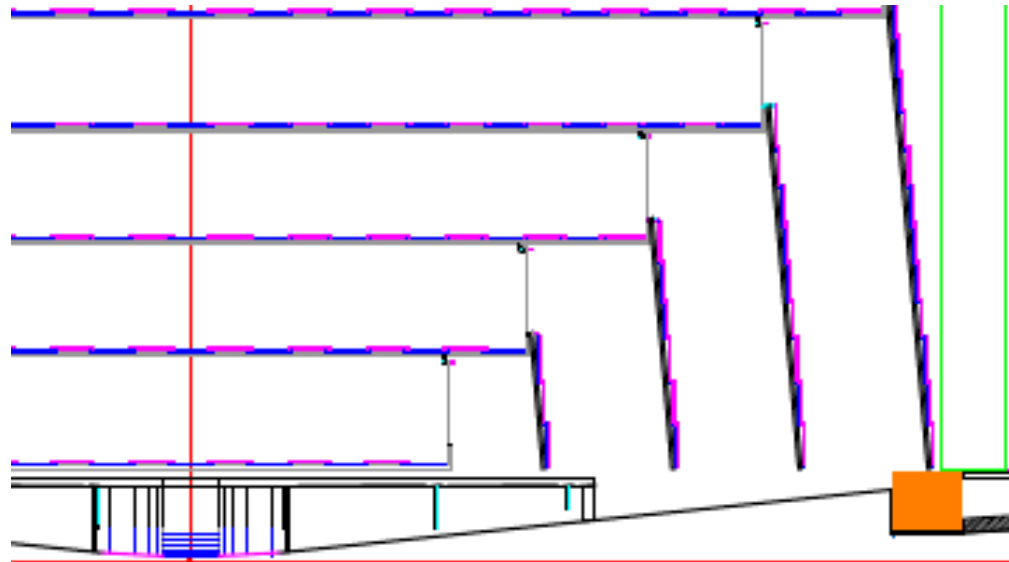


SiD detector

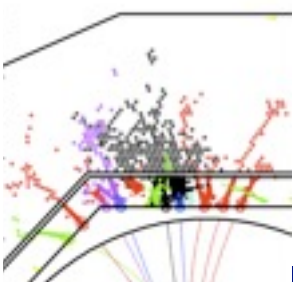


SiD vertex and track detector

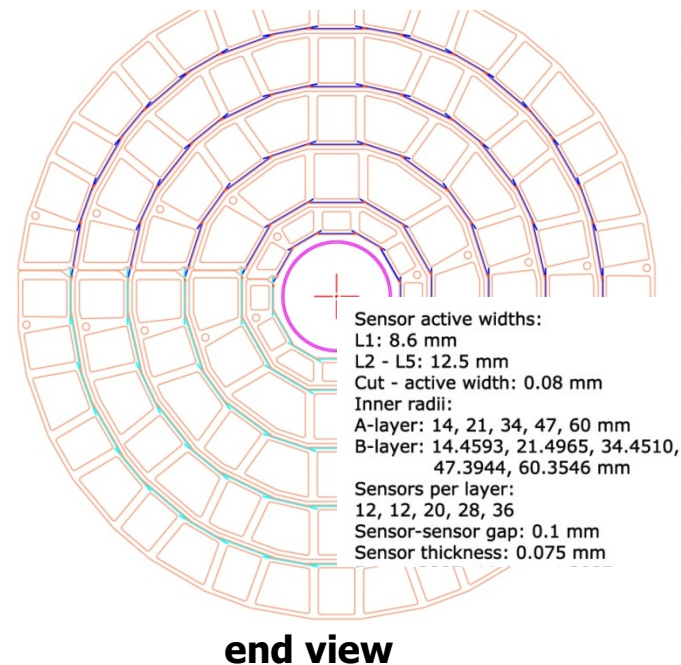
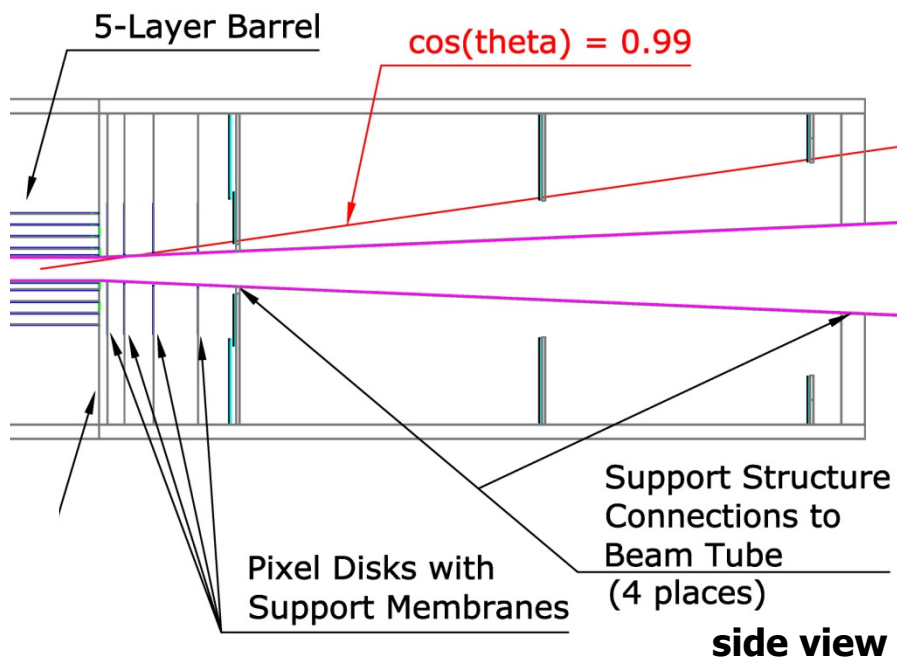
- In the SiD concept the vertex detector plays a central role and is much more than a nice addition to enhance heavy flavour tagging
- Si tracker implies track reconstruction “inside - out” with stand-alone track seeding in the vertex detector
- Like other experiments, SiD foresees to select vertex technology at a later stage and places bets on future progress in micro-electronics
- In SiD, the associated risks affect the concept as a whole

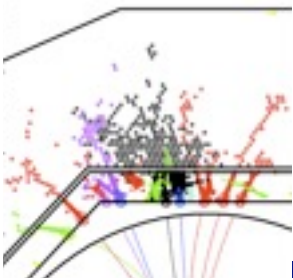


Vertex detector



- Role in track seeding requires time (bx) stamping of all hits
- Power budget $\sim 50\text{ W}$ \rightarrow read-out after bunch train
- Material budget $0.1\% X_0$ / layer, $20\ \mu\text{m}$ pixels
- Such a device (meeting all specs together) does not exist yet: timing capabilities of a hybrid, material budget of a monolith

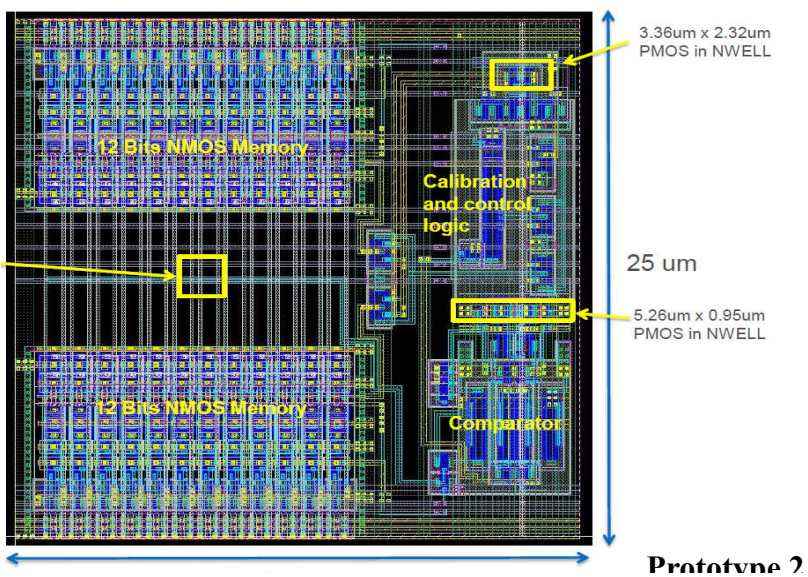




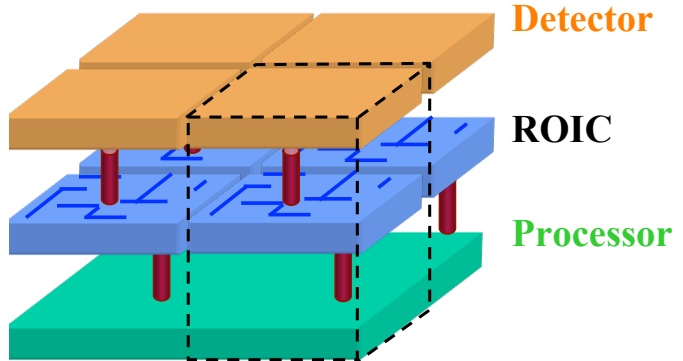
Vertex technology

- **Chronopixel:** monolithic CMOS
- 25 μm pixels
 - expect* $\sim 4 \mu\text{m}$ resol. - not 3 μm
 - not straightforward to make it smaller (goal 18 μm)
- Still some operation and Xtalk issues to be understood
- Power varies with occupancy
- Depends on single industrial partner

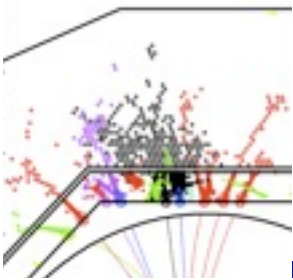
- **VIP:** 3D integrated chip
- first prototypes



3-D Pixel



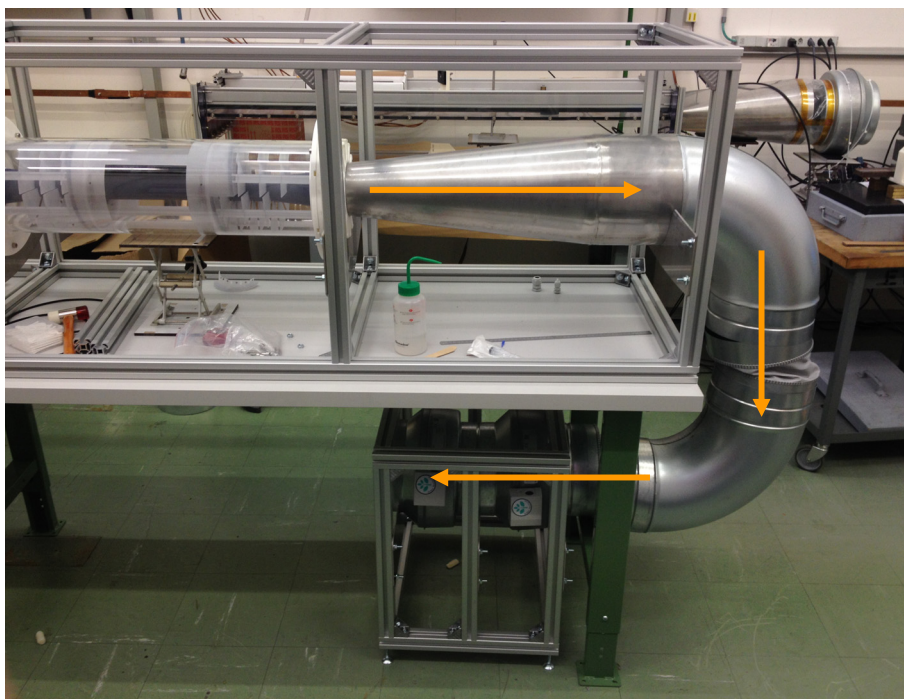
* Resolution examples:
 STAR: 21 μpix $\sigma = 3.7 \mu$
 EUDET: 18 μpix $\sigma = 3.1 \mu$



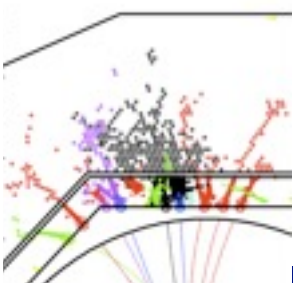
Vertex detector issues

- Occupancy is critical, safety margins need to be demonstrated
 - background calculations need factor 10
 - integration time may be longer than 1 BX
- Robustness of track seeding with more conservative assumptions
 - do not argue, look at derivatives
- Cabling and cooling concepts need to be worked out
 - may affect long vs short barrel choice
- Air cooling is ineffective and may require lots of space

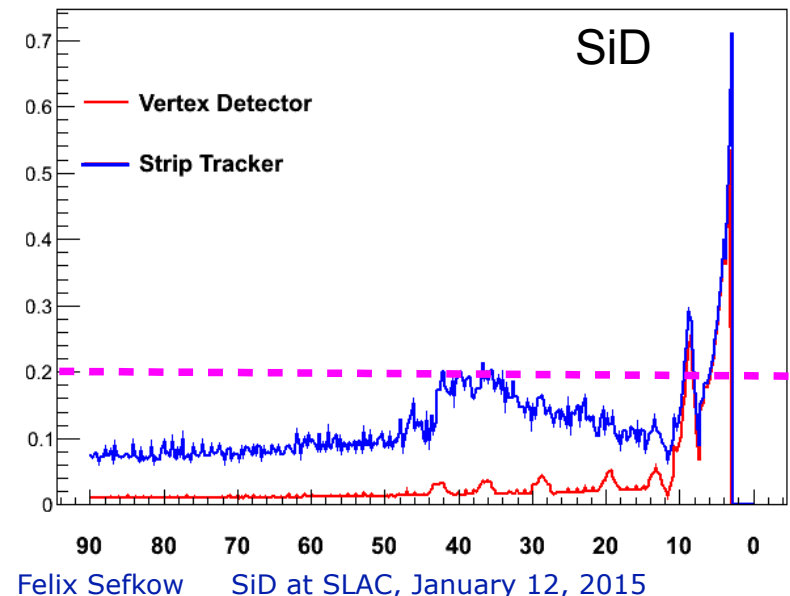
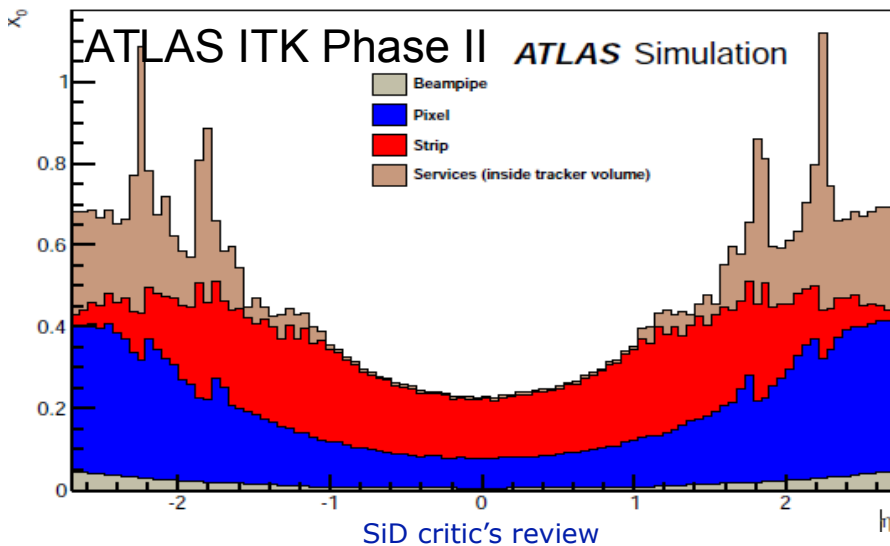
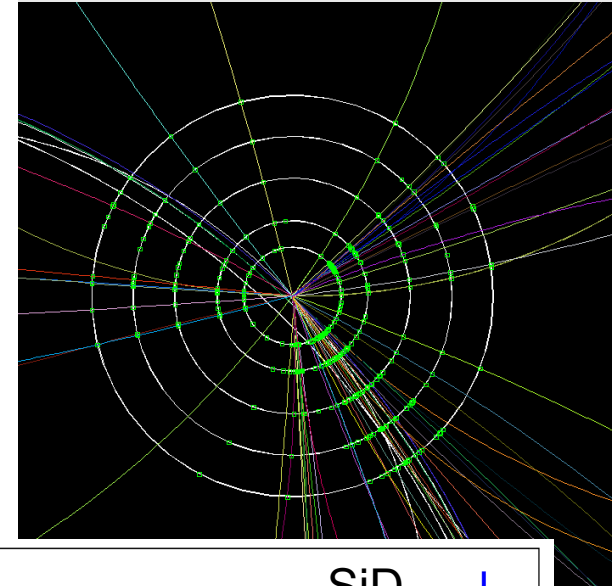
CLIC vertex detector cooling mock-up for 500W

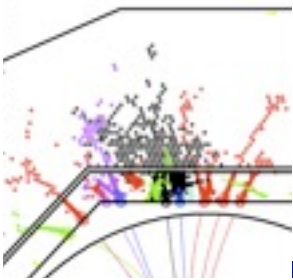


Si tracker



- 5 barrel layers, $r\phi$ only, 4 disks
- Many commonalities with LHC upgrades
- Advantage: No rad-hard issues, power pulsing
- Material budget goal twice as ambitious: 0.1 vs 0.2% X_0
- Some doubt whether this is realistic
- Show that with 0.2% performance not critically degraded (another cliff?)



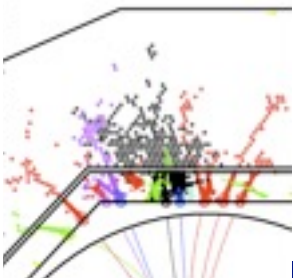


Si tracker resolution

- Toy MC study to understand ILD and SiD asymptotic $1/p_T$ resolution

ILD single point resolutions

Detector	R (mm)	Sigma (μm)
VTX	16.0	2.8
	18.0	6.0
	37.0	4.0
	39.0	4.0
	58.0	4.0
	60.0	4.0
	SIT	153.0
	300.0	7.0
TPC (220 points)	380 - 1694	100.0
SET	1811.0	7.0
I.P.	0.0	0.7



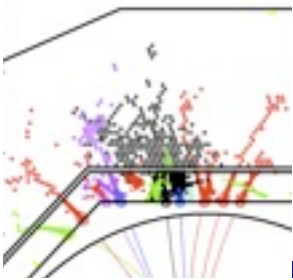
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ILD single point resolutions SiD single point resolutions

Detector	R (mm)	Sigma (μm)
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SIT	153.0	7.0
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TPC (220 points)	380 - 1694	100.0
SET	1811.0	7.0
I.P.	0.0	0.7

Detector	R (mm)	Sigma (μm)
VTX	14.0	2.5
	22.0	2.5
	35.0	2.5
	48.0	2.5
	60.0	2.5
	Tracker	219.5
Tracker	469.5	5.5
	719.5	5.5
	969.5	5.5
	1219.5	5.5
I.P.	0.0	0.7



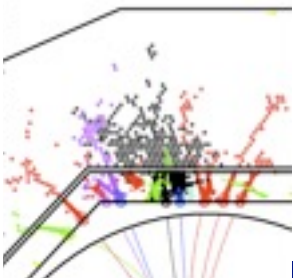
Si tracker resolution

- SiD $1/p_T$ resolution summary
(in units of 10^{-5} GeV^{-1})

Using M. Stanitzki's single p. resolutions	SiT 5 layers	SiT 4 (inner) layers	SiT 3 (inner) layers	SiT 2 (inner) layers
VTX + n SiT layers	1.75	2.95	5.78	13.7
IP + VTX + n SiT layers	1.60	2.56	4.58	9.17

Remember: for (nominal) ILD 1.89 resp. 1.66

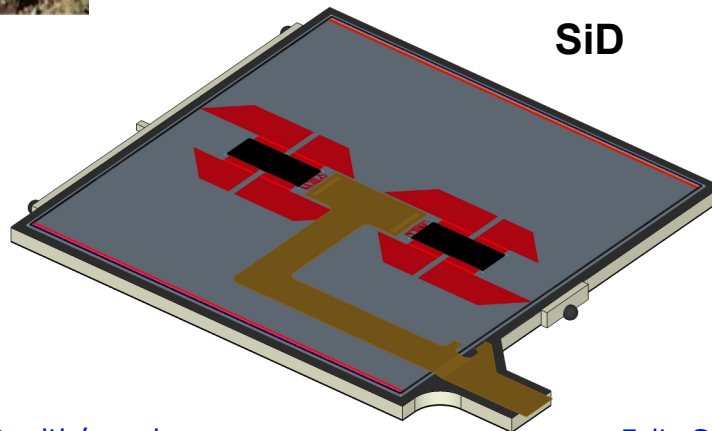
Using ILD single p. resolutions	SiT 5 layers	SiT 4 (inner) layers	SiT 3 (inner) layers	SiT 2 (inner) layers
VTX + n SiT layers	2.21	3.70	7.20	17.0
IP + VTX + n SiT layers	1.99	3.16	5.57	11.1



Si tracking issues

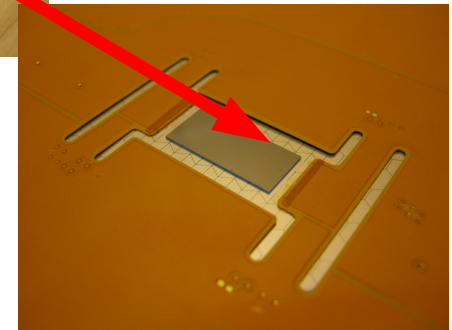
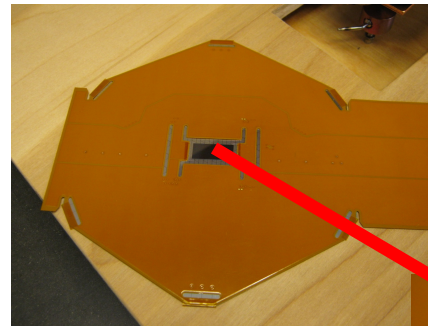
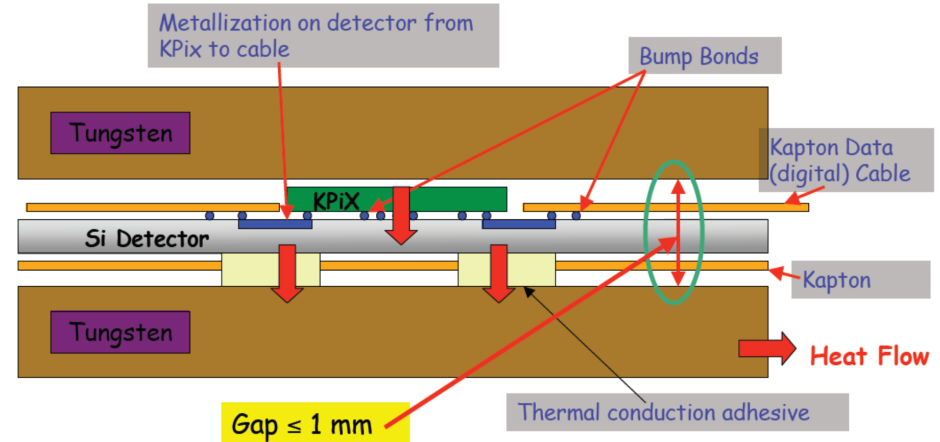


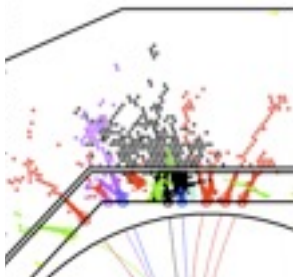
- An engineering prototype meeting the design goals would eliminate these concerns completely
- For the time being, understand the derivatives: simulations with more conservative assumptions should show that there are no cliffs nearby
- The claim that SiD and ILD performance (and thus cost) comparisons are not fair must be addressed
- Space points in the barrel (e.g. strixels) could enhance background robustness



SiD ECAL

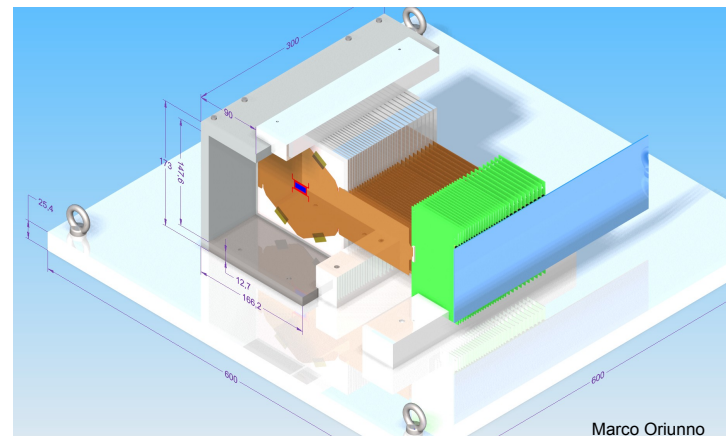
- Very advanced integration concept - unfolds the potential of Si for calorimetry and competes favourably!
- Small R_M key to small R_{ECAL}
 - is it critical at all depths?
- KPiX offers standardised electronics for tracker and calorimeters - the way it should be
 - can we add a test beam mode?
- Buffer depth: safety margins for adverse background conditions?

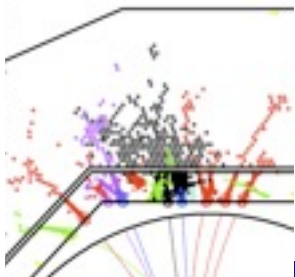




ECAL test beam

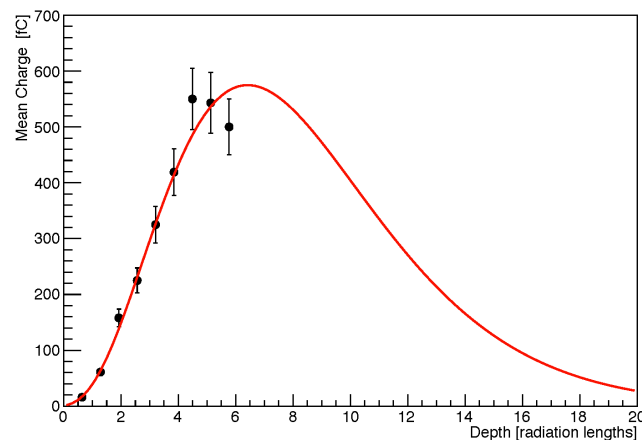
- First beam test: major step from powerpoint to reality, nice success!
- Also revealed some cross-talk issues
 - being addressed in next KPiX version
- *ALL* Si ECAL prototypes so far had cross talk issues
- Si valued for its compactness and stability, cost seen as the only disadvantage.
- Focus was on ASIC and interconnect.
- No intrinsic amplification: analogue measurement over large dynamic range, digitisation close to sensor
- Not a show stopper, but **system tests are of highest importance**
 - may well influence overall design
- Need full e.m. stack and demonstrate σ_E
- Test long slab (maybe use dummy wafers)

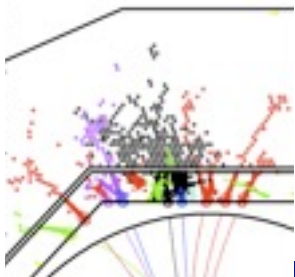




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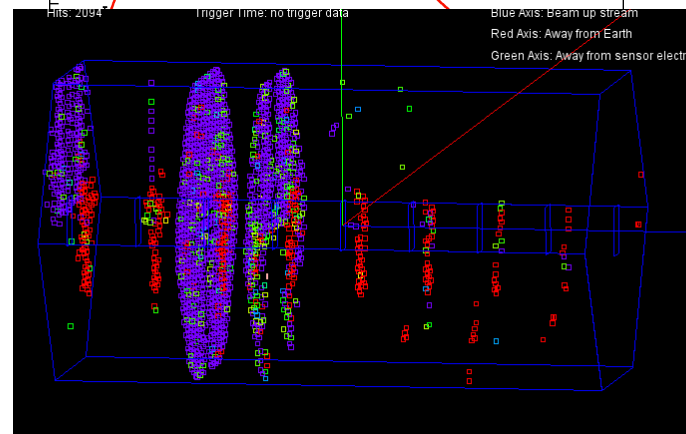
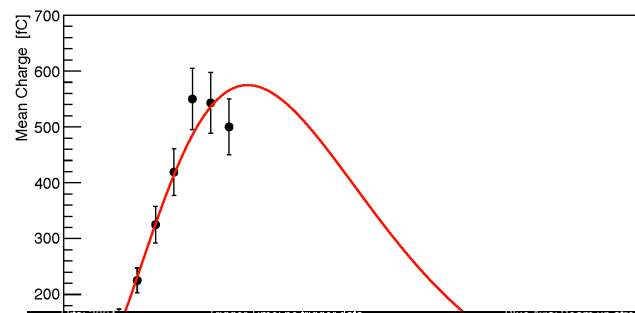
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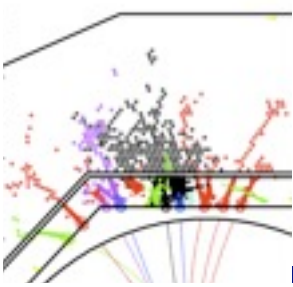


ECAL test beam

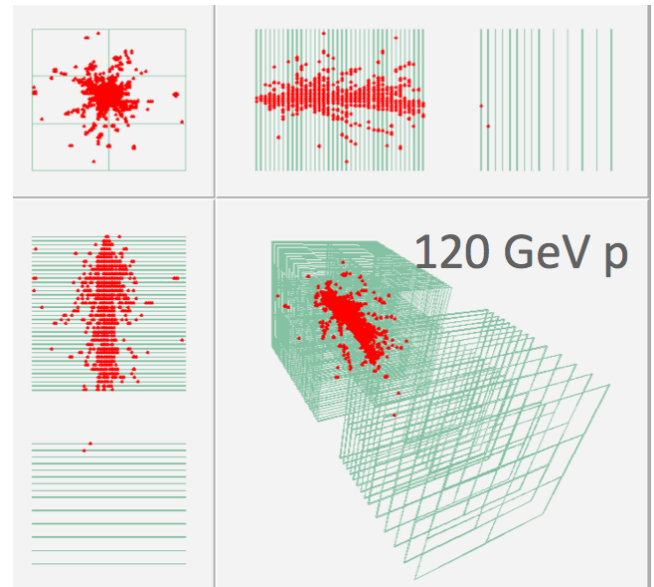
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DHCAL

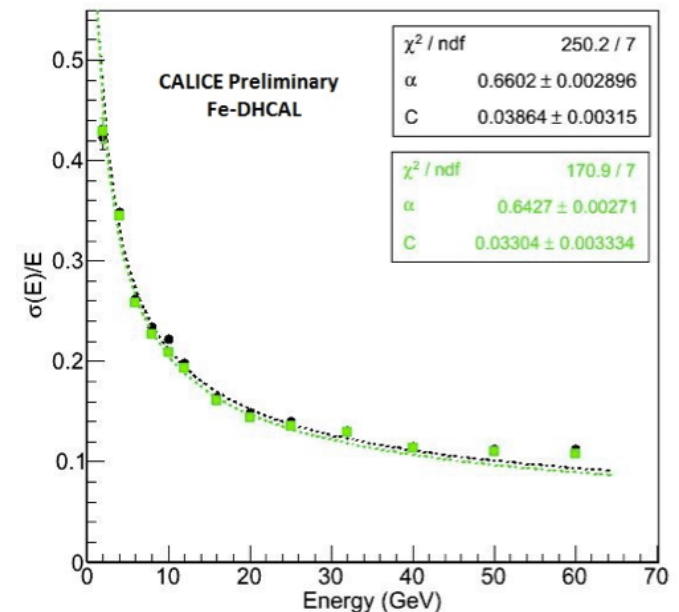


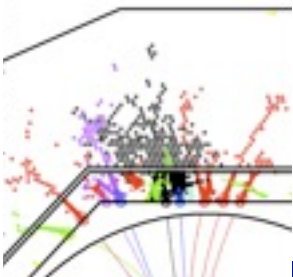
- The biggest prototype endeavour of SiD so far. Success and major scientific contribution.
 - Proof-of-principle: digital calorimetry works
- Unique opportunity to understand (i.e. model) gaseous calorimeters at fine grain
- This is still on its way and will take a few years more time
 - analysis effort very weak
- There is room to improve the link to SiD simulations and optimisation study
- Still to demonstrate the benefit of higher granularity for particle flow (beyond single particle resolution)



DHCAL

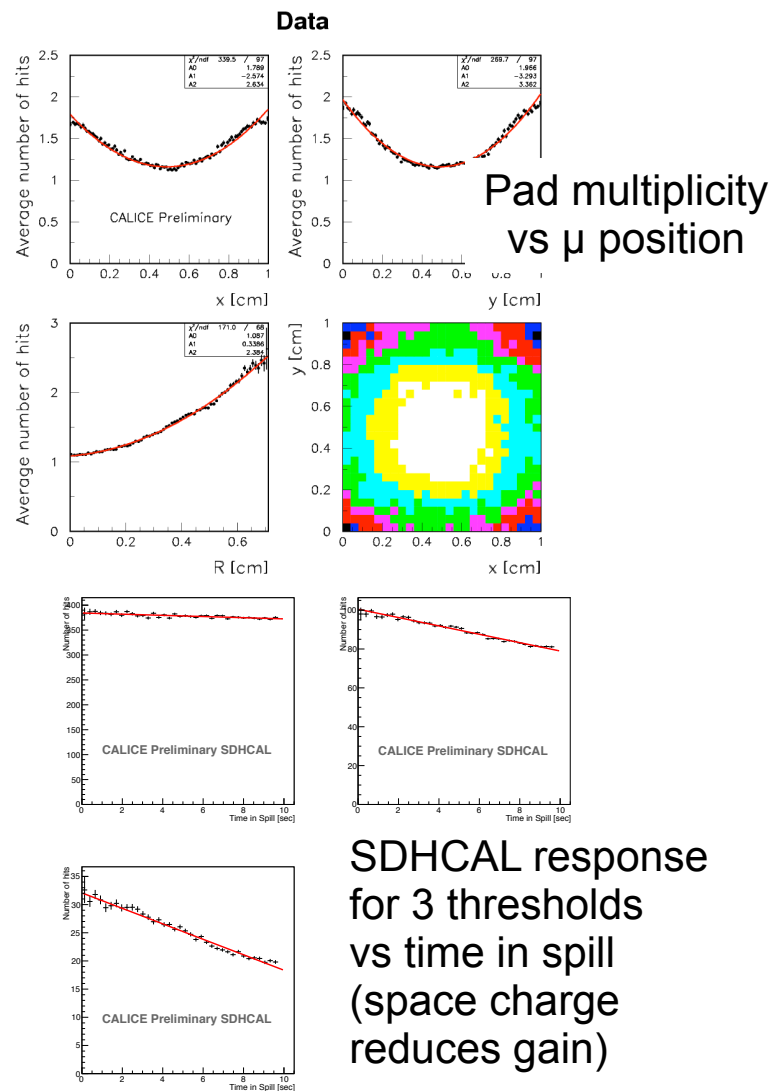
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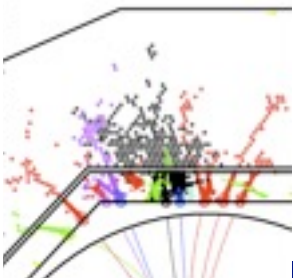




DHCAL response

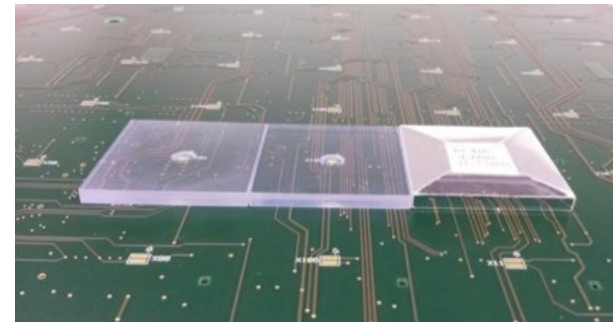
- Main difficulty is that the DHCAL is not digital
- Response in number of hits depends on gas gain and thus on many factors
 - T , p , thickness, purity, rate, local occupancy
 - calibration & monitoring not simple
- May be mitigated for other technologies with $m \sim 1.0$
 - μ M, GEM, 1-glass RPC
 - to be seen
- Response saturates, so does resolution at $\sim 10\%$
- Semi-digital readout helps
 - but aggravates environmental dependence
- For the use of analog information the (semi-) digital read-out lacks redundancy for calibration & monitoring
 - concepts to be developed

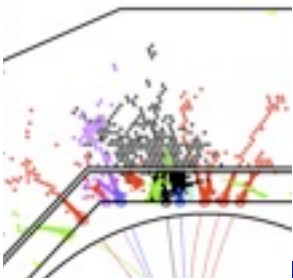




Calorimeter issues

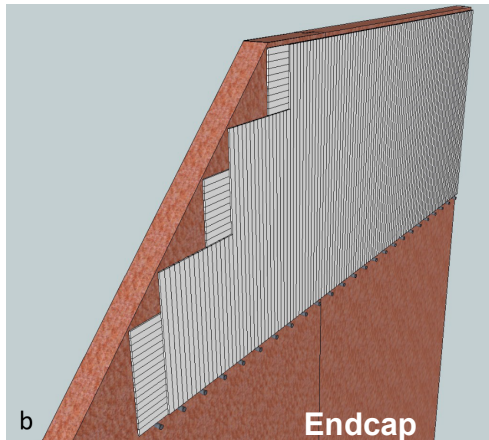
- The SiD ECAL joined the test beam club and changed the landscape - following this up is of utmost importance.
- Address the system issues: these are NOT easy simply because it is silicon. Go to interface design, cooling, services, long modules - and maintain the close link between R&D and concept.
- The DHCAL data treasure must be secured, the analysis effort be re-enforced.
- The goal of test-beam validated SiD performance optimisation is still out there.
- An SiD group should take the (few) SiD specific issues of the AHCAL on board and strengthen the link between R&D and SiD concept.





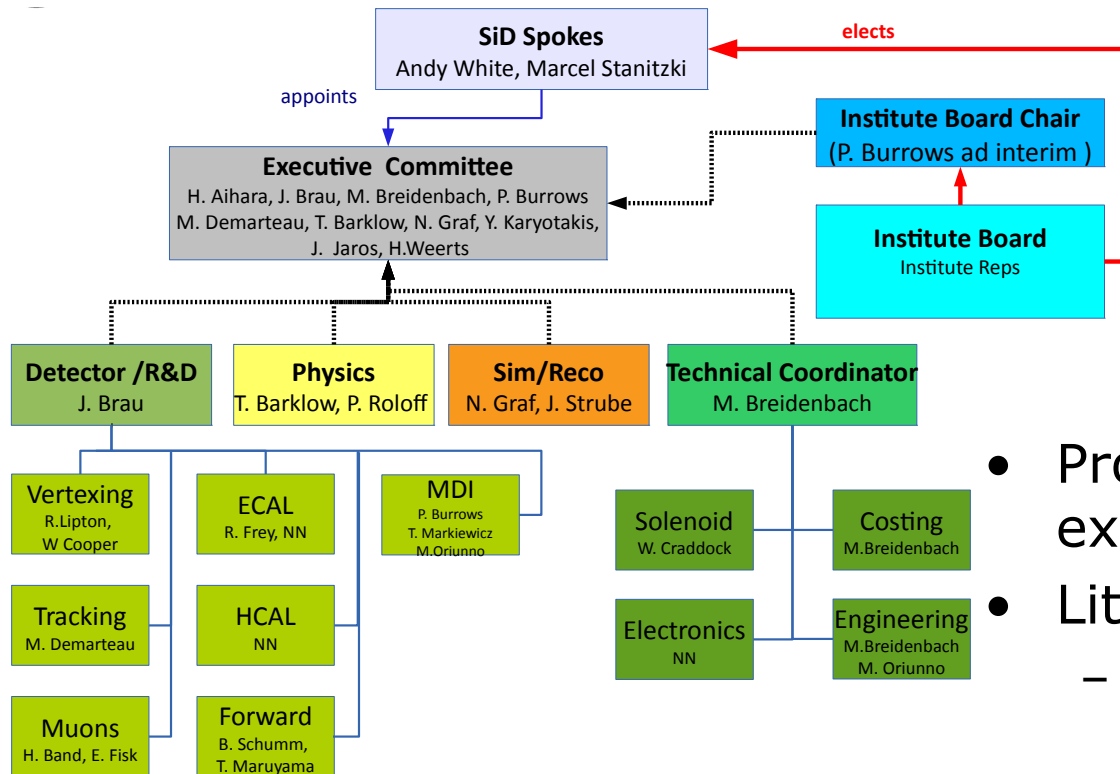
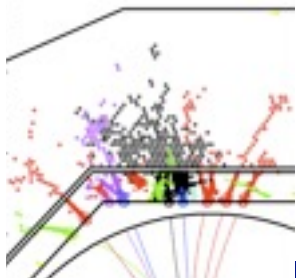
Things left aside

- FCAL: well catered by FCAL collaboration - difficult to say anything SiD specific.
 - Link to R&D collaboration does work well, SiD present in FCAL and vice versa.
- Muons: SiD is the only framework where muon R&D takes place at all.
 - Fulfils an important role in the LC community.
- Software: SiD software depends on developments - PANDORA, LCFI - which are mainly taking place in other frameworks.
 - Close cooperation with ILD, CLICdp, maybe FCC-ee is essential, DD4HEP is an important effort.



SiD structure and community

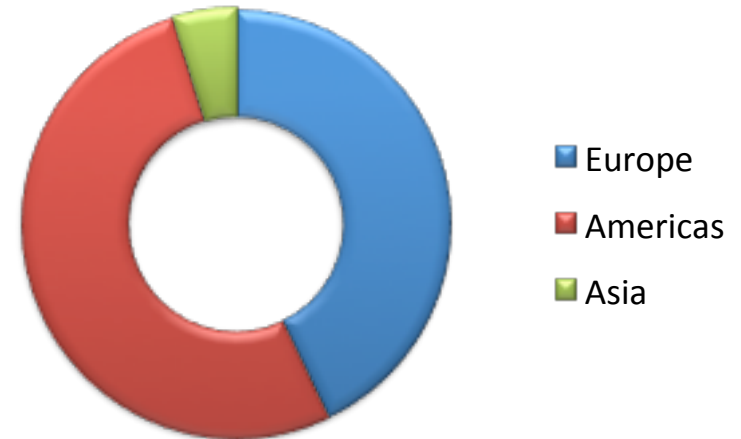
SiD structure

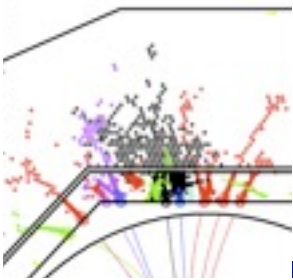


- Proven to be highly efficient, example for others
- Little to improve:
 - clarify role of EC members without mandate
 - At some point will need a publication office / speakers' bureau
 - chair should be elected by IB

SiD community

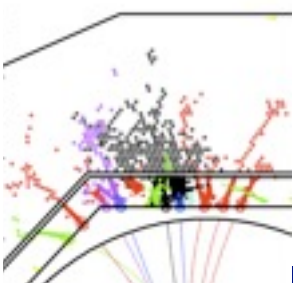
- 22 groups, 40% from Europe
 - LOI: 72 groups
- Half the size of ILD
- Strong weight of American participation
 - root of the consortium's dynamism, courage, vision
 - but represents a bulk risk for funding and continuity
- Need less volatile portfolio admixtures
- Will come at a price: different approaches and thus diversity
 - culture
 - technology





Community building

- (From personal experience)
- Balance and relationship between big labs and universities are key
 - no big labs, no prototypes
 - no universities, no community
- There is nothing as efficient for bringing people together as the long days and nights of common test beam campaigns
 - task sharing in prototype construction
 - distributed data analysis software environment
- In that respect CALICE and SiD so far failed to unravel the full potential of the DHCAL
- In the “epsilonic” funding environments essential to build consensus about next big SiD prototype and unite behind it
 - candidates ECAL or tracker
 - impact on the LC landscape also beyond SiD guaranteed
- Use the SLAC test beam



Summary

- SiD has the right genes -
- let it mature and grow !



from Bruce Schumm's Belgrade talk