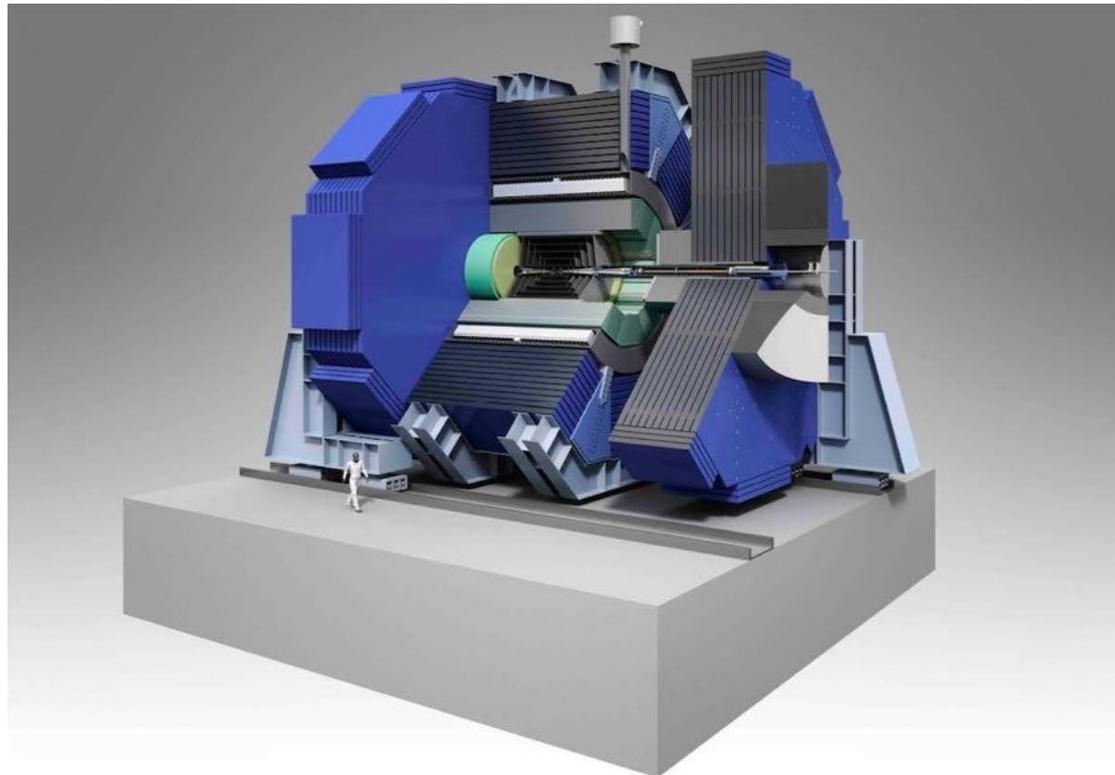
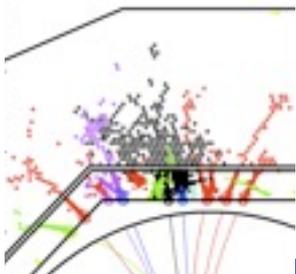


SiD detector design - a critic's view

Felix Sefkow
DESY

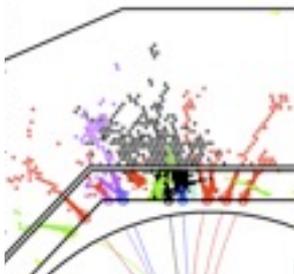


SiD workshop, SLAC, January 12-14, 2015



Outline

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



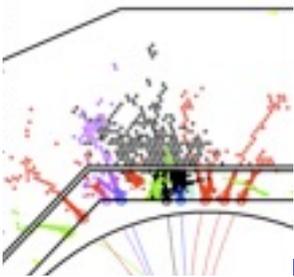
Disclaimer

- 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.



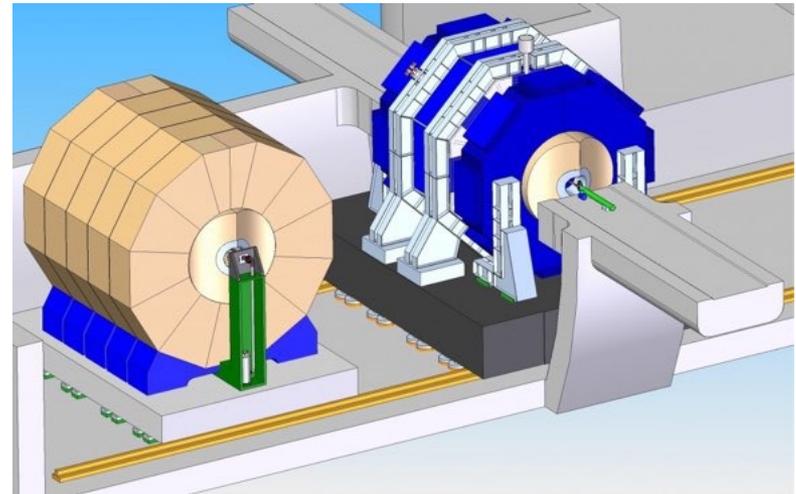
Not me, I hope !!

SiD concept

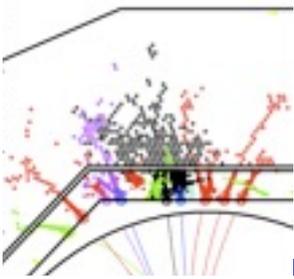


Two detectors - or one?

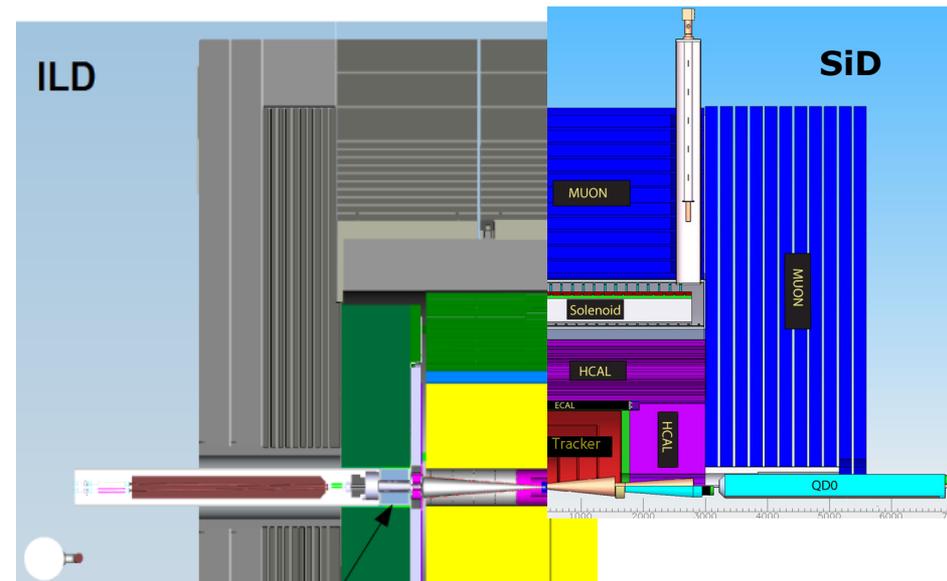
- Current baseline: 2 detectors
- But presently there is *no premium* for being *different*
- No guidance for, e.g.
 - cheap vs expensive
 - simple vs complex
 - aggressive vs conservative
 - low E_{CM} vs high E_{CM}
 - gaseous vs still
- Convergence not unlikely
- Consider myself as friend of and contributor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



ILD and SiD

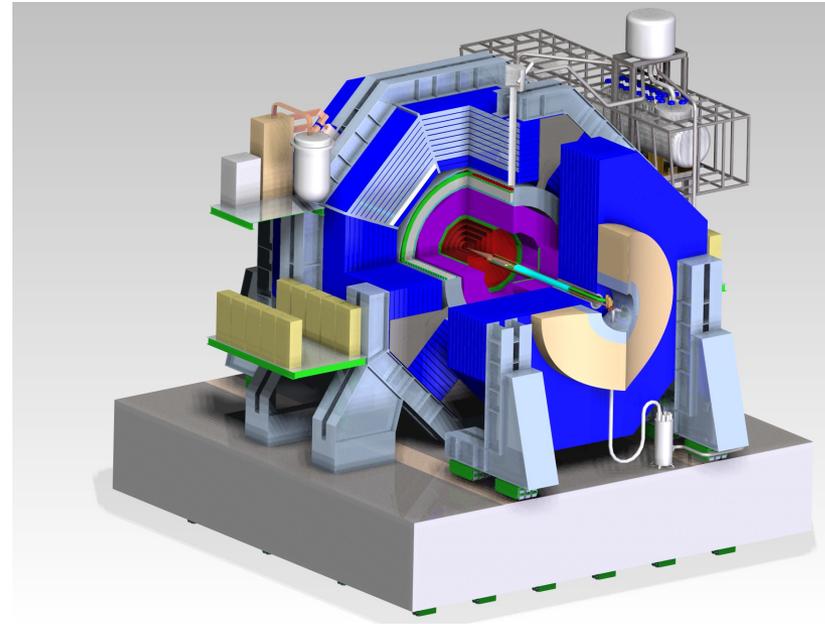


- General remarks heard in the LC community
- Compared to ILD which some consider
 - large (expensive)
 - unambitious (cost optimisation)
 - unfocussed (technology options)
- SiD appears
 - small
 - aggressive
 - weak
- These attributes could turn into advantages once symmetry breaking axis is defined

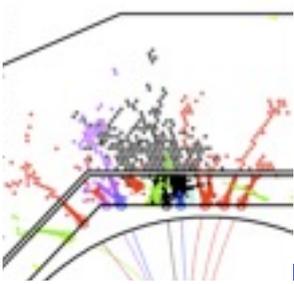


Only SiD

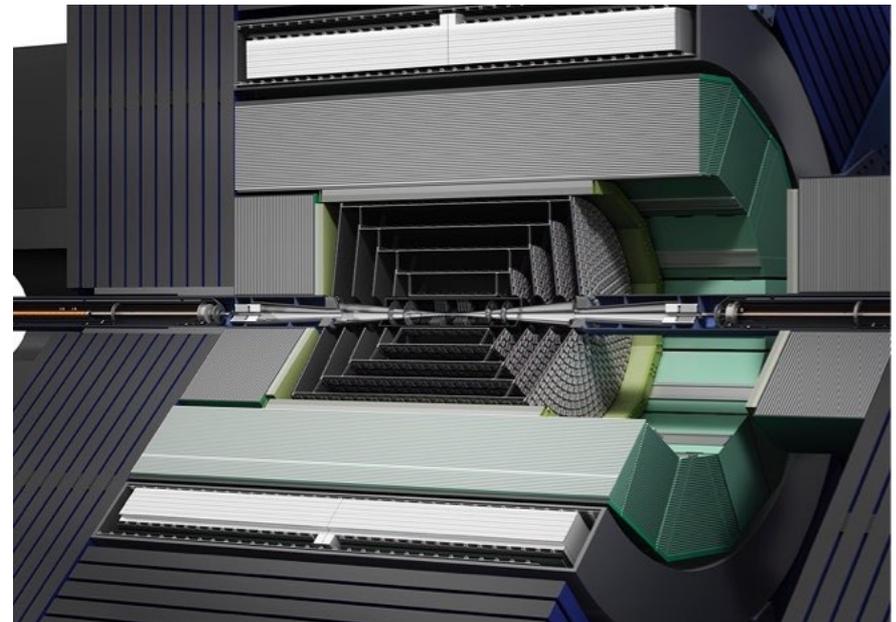
- SiD, considered per se, might be
- too small
- too aggressive
- too weak
- Pointless to argue between optimist and pessimist
- Constructive realist: For the time being, need to understand the derivatives
- Gain strength and flexibility

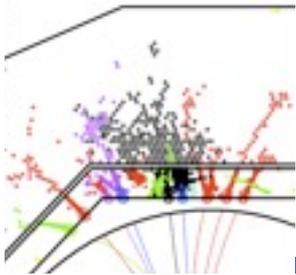


SiD concept



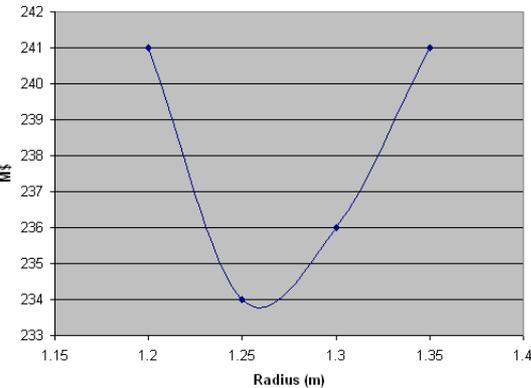
- Particle Flow detector, sure
- Central choice: an all-silicon tracking system
 - robust tracking even in harsh backgrounds
 - best momentum resolution with compact dimensions
- 10 years ago: exotic!
- Today supported by LHC: routine!
- Cost-driven choice of basic parameters such as radius and magnetic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



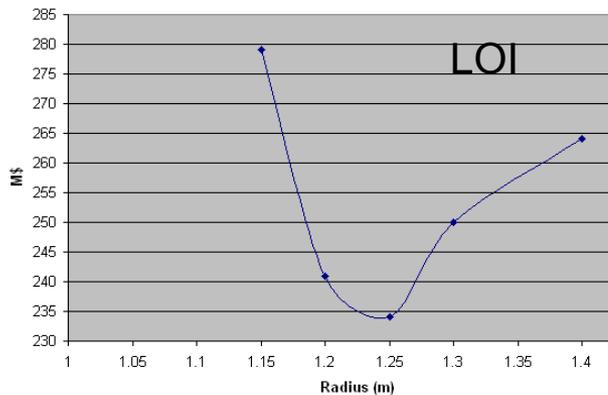


SiD optimisation

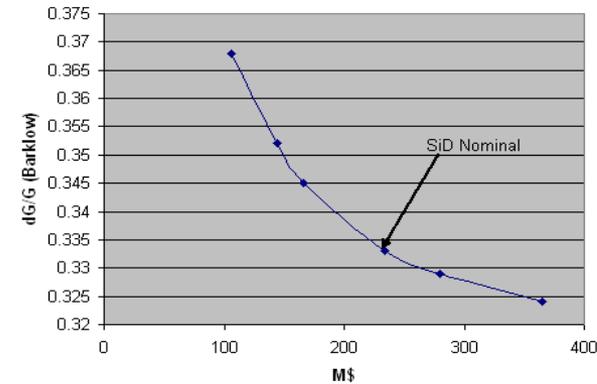
Vary R, B, de/E=0.0378



Vary R, Lambda, de/E = 0.0378

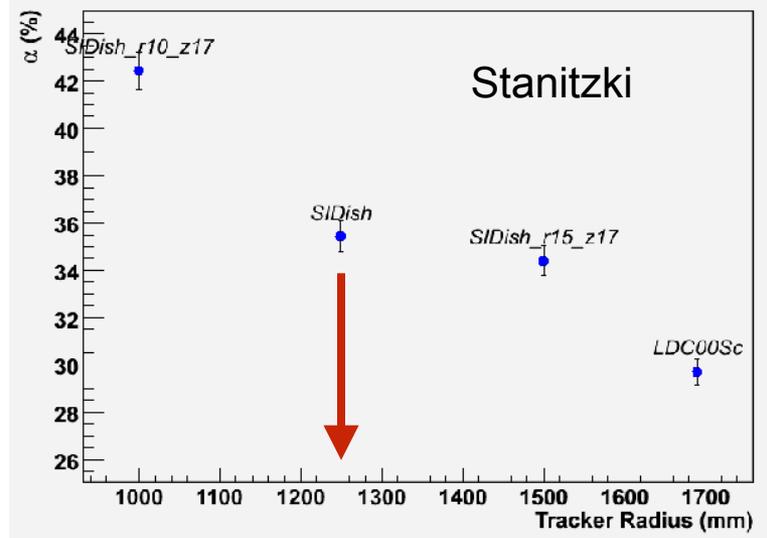


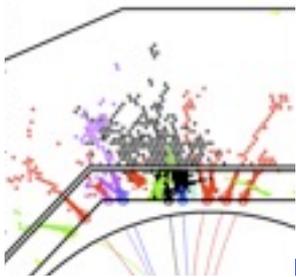
dG/G (Barklow)



- 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

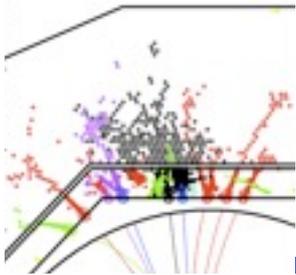
Radial Dependence 200 GeV





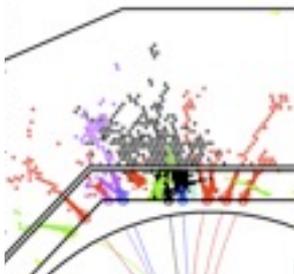
Safety margins?





Safety margins?



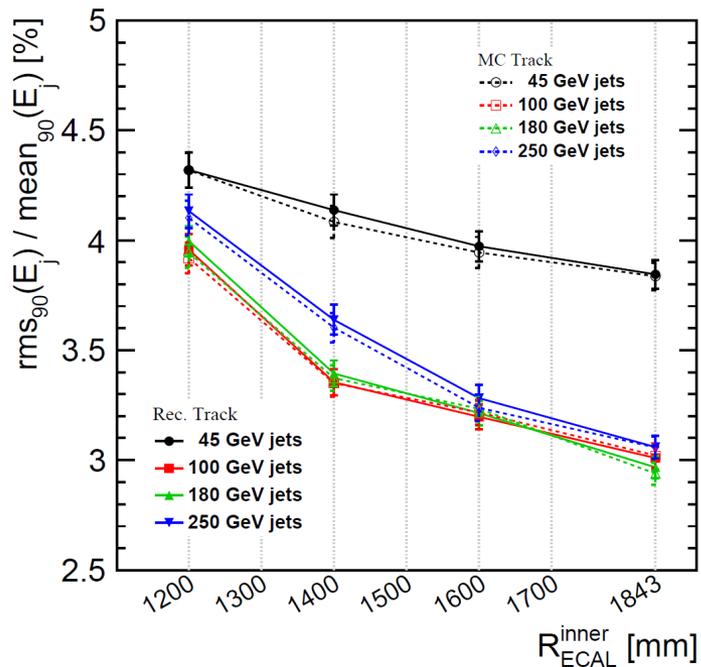
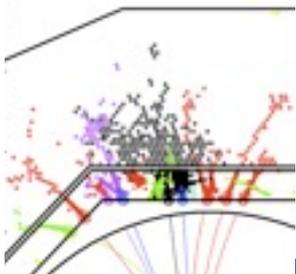


Safety margins?

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



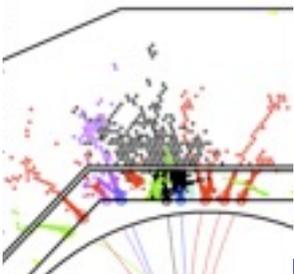
Safety margins?



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



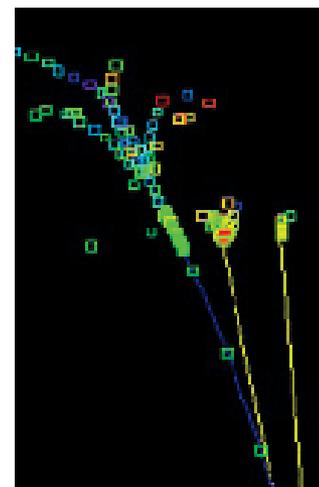
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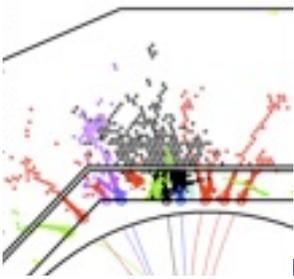
Beyond jet energy resolution

- 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



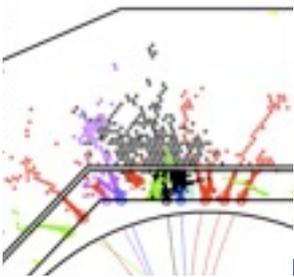
SiD concept



- 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!

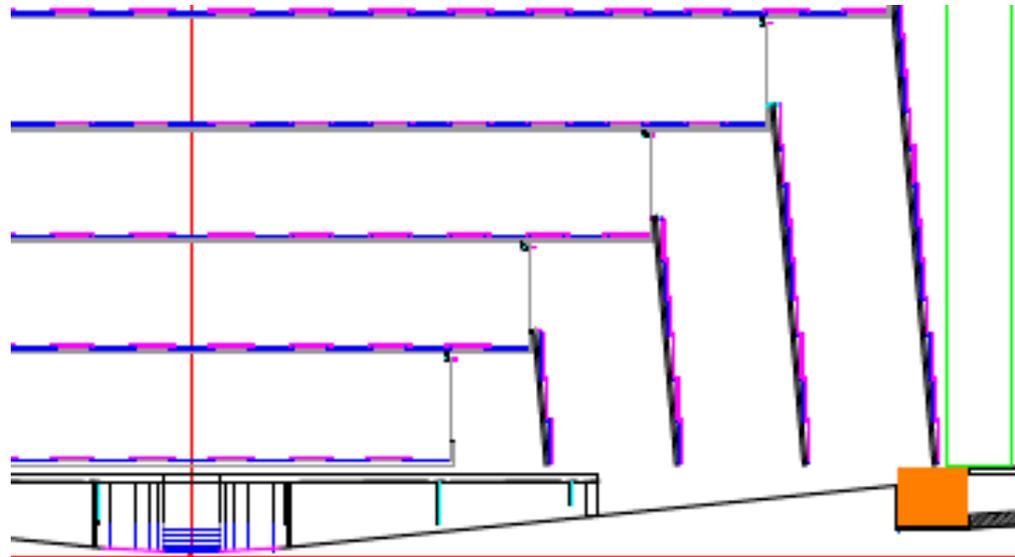


SiD detector

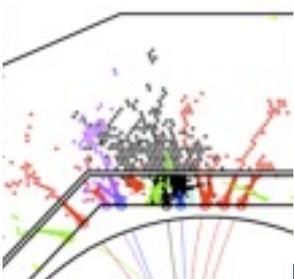


SiD vertex and track detector

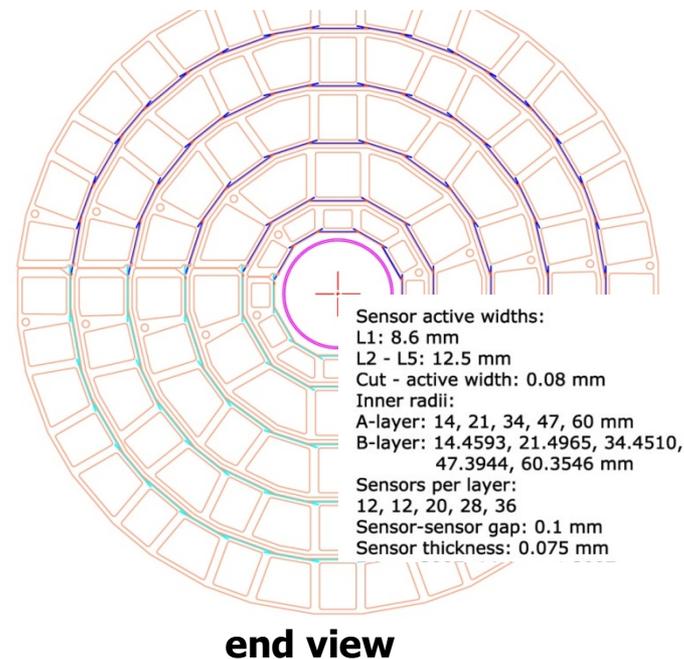
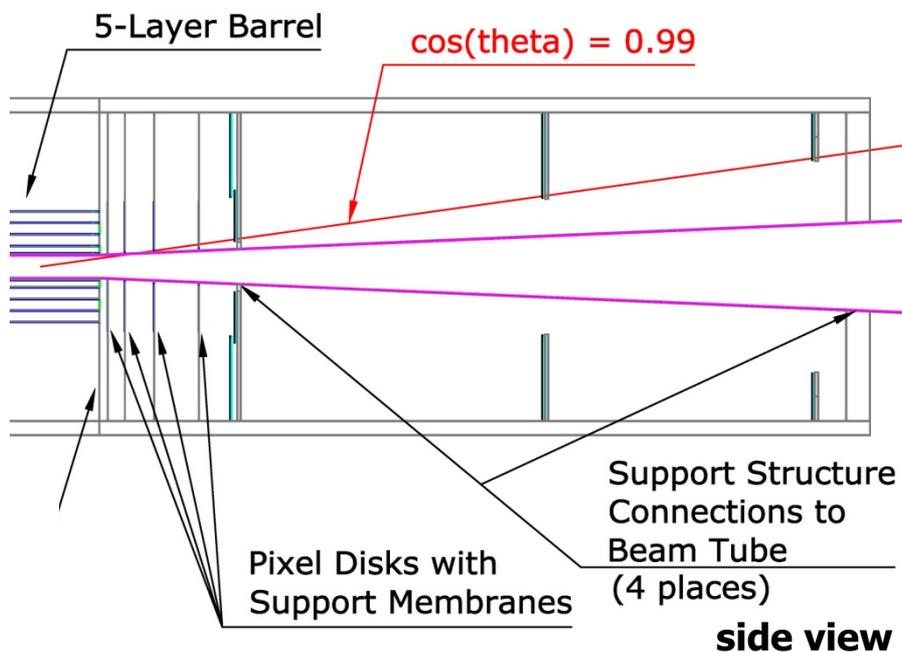
- In the SiD concept the vertex detector plays a central role and is much more than a nice addition to enhance heavy flavour tagging
- Si tracker implies track reconstruction “inside - out” with stand-alone track seeding in the vertex detector
- Like other experiments, SiD foresees to select vertex technology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

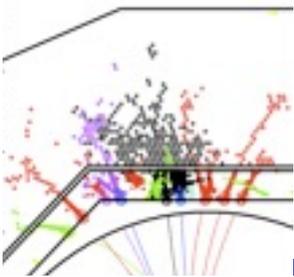


Vertex detector



- 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

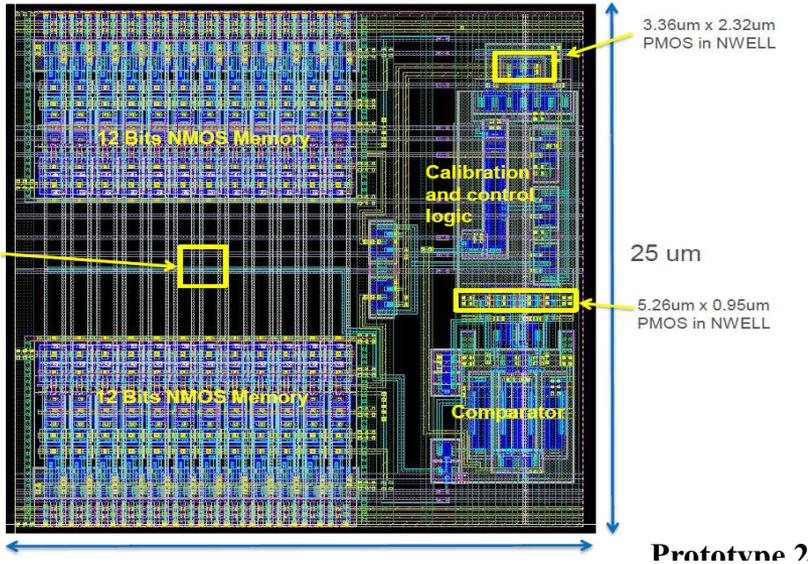




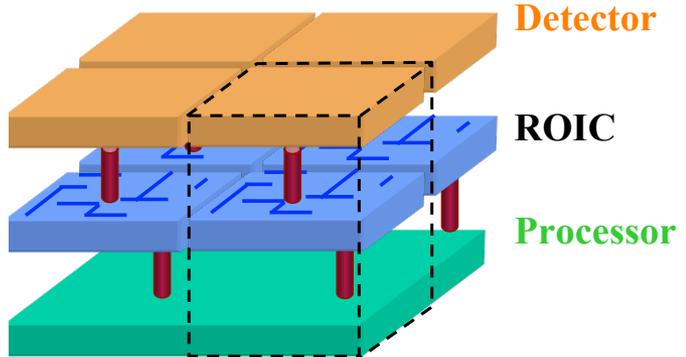
Vertex technology

- **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

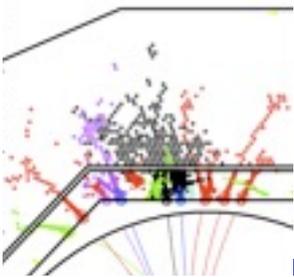
- **VIP:** 3D integrated chip
- first prototypes



3-D Pixel



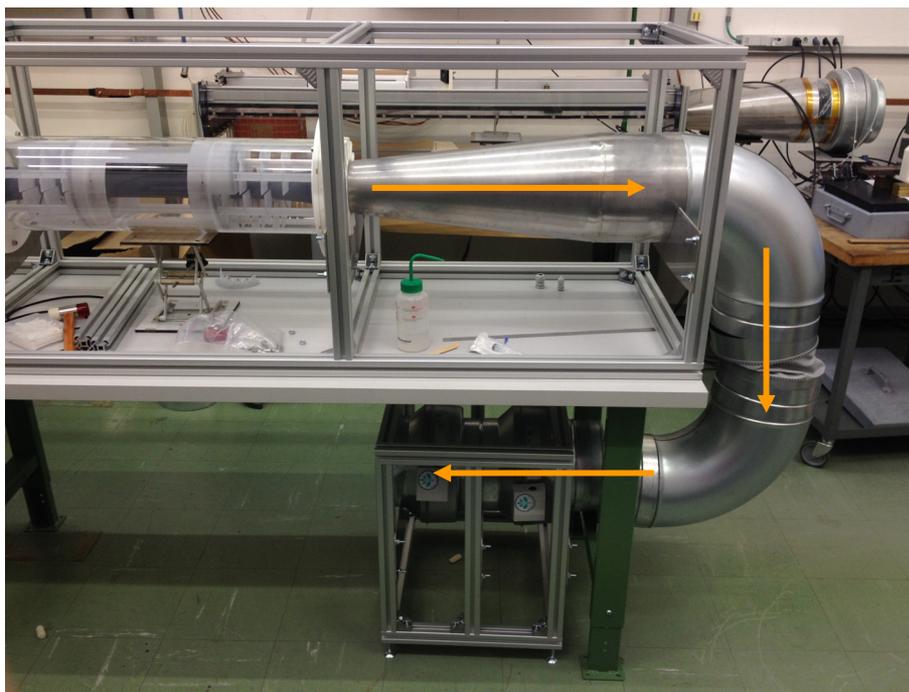
* Resolution examples:
 STAR: 21 μpix $\sigma = 3.7 \mu$
 EUDET: 18 μpix $\sigma = 3.1 \mu$



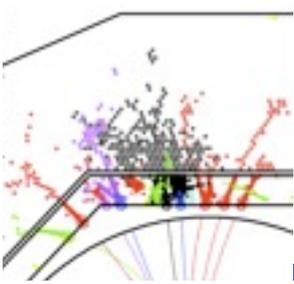
Vertex detector issues

- 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

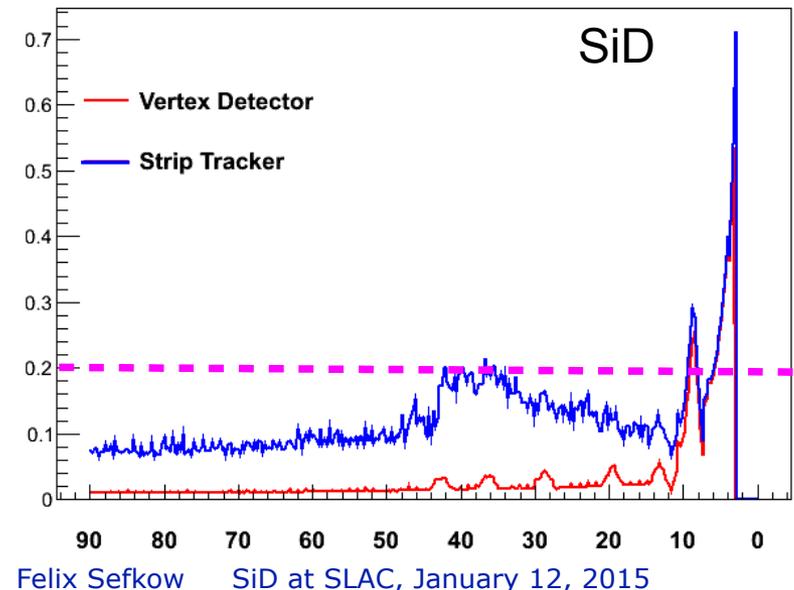
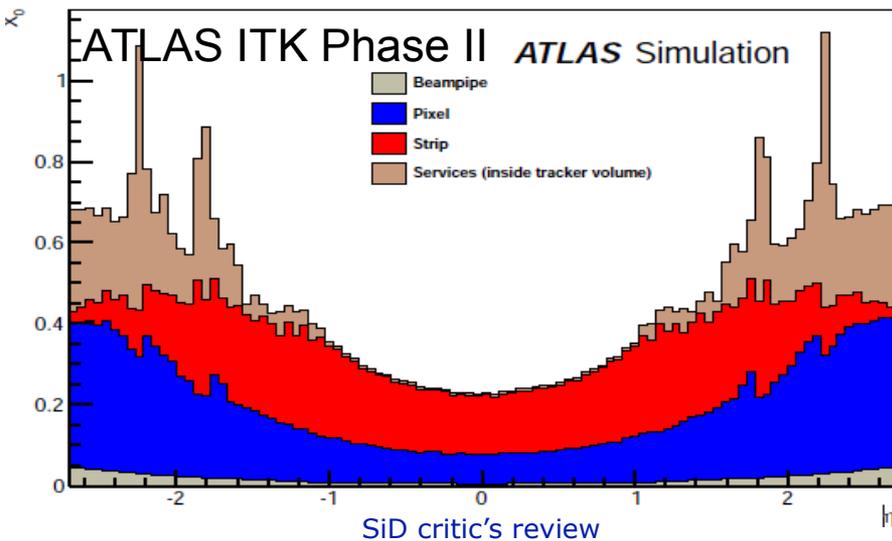
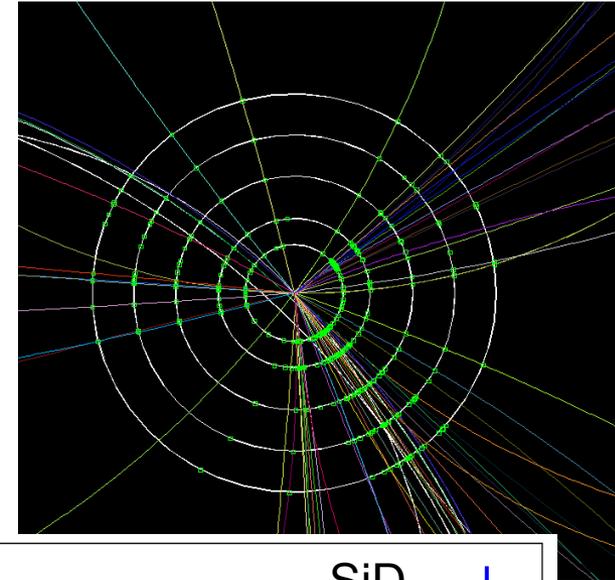
CLIC vertex detector cooling mock-up for 500W

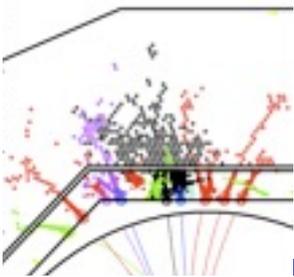


Si tracker



- 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?)



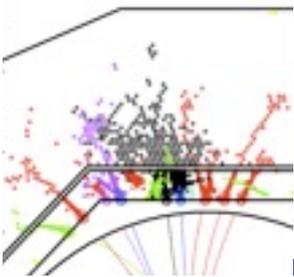


Si tracker resolution

- 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	7.0
	300.0	7.0
TPC (220 points)	380 - 1694	100.0
SET	1811.0	7.0
I.P.	0.0	0.7



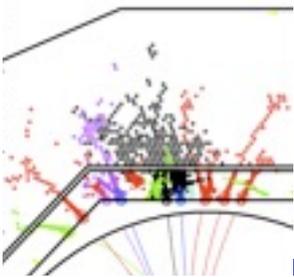
Si tracker resolution

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ILD single point resolutions SiD 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	7.0
	300.0	7.0
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



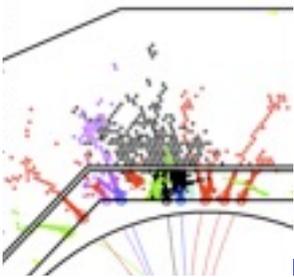
Si tracker resolution

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

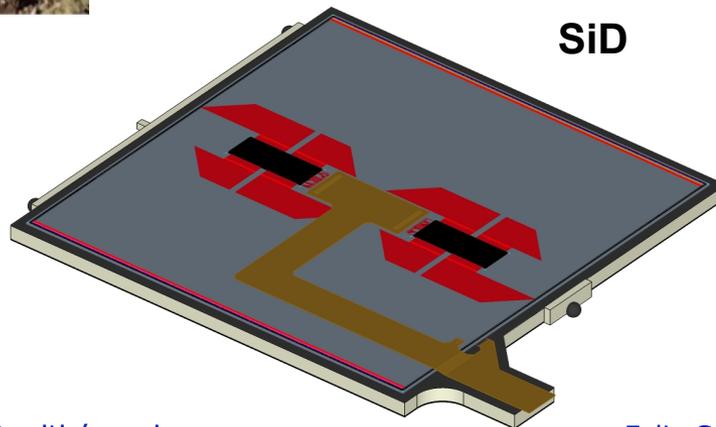
Using ILD single p. resolutions	SiT 5 layers	SiT 4 (inner) layers	SiT 3 (inner) layers	SiT 2 (inner) layers
VTX + n SiT layers	2.21	3.70	7.20	17.0
IP + VTX + n SiT layers	1.99	3.16	5.57	11.1



Si tracking issues

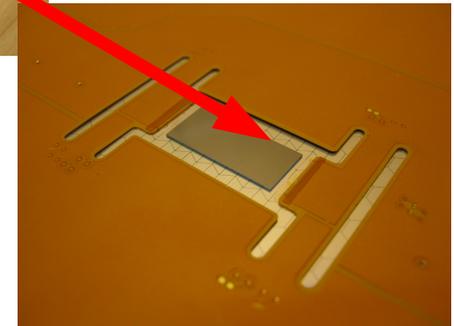
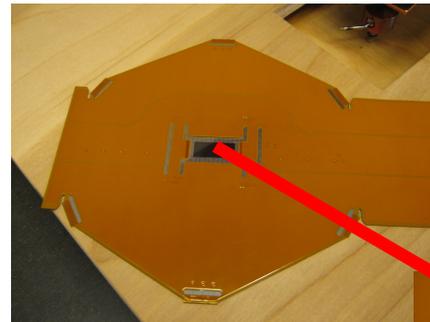
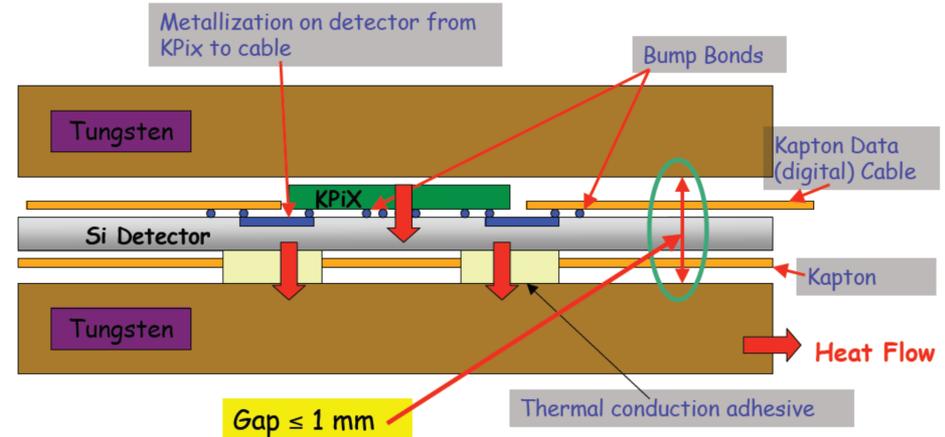


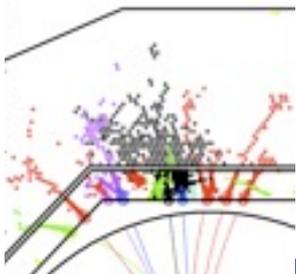
- An engineering prototype meeting the design goals would eliminate these concerns completely
- For the time being, understand the derivatives: simulations with more conservative assumptions should show that there are no cliffs nearby
- The claim that SiD and ILD performance (and thus cost) comparisons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



SiD ECAL

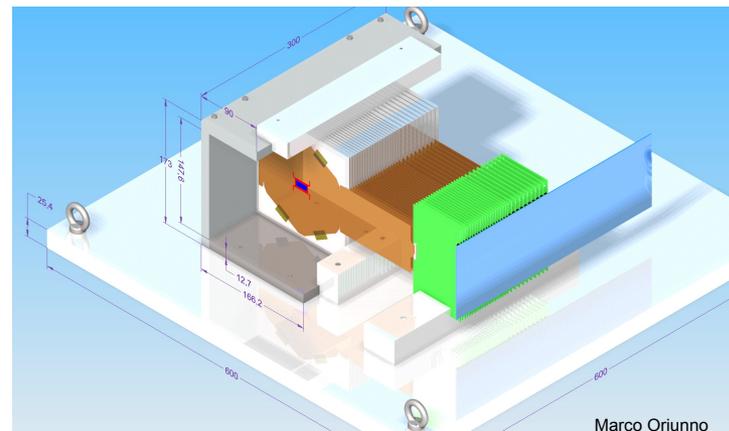
- Very advanced integration concept - unfolds the potential of Si for calorimetry and competes favourably!
- Small R_M key to small R_{ECAL}
 - is it critical at all depths?
- KPiX offers standardised electronics for tracker and calorimeters - the way it should be
 - can we add a test beam mode?
- Buffer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

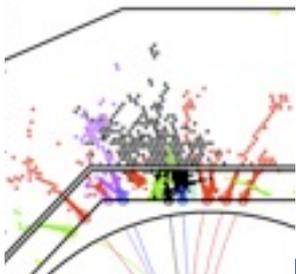




ECAL test beam

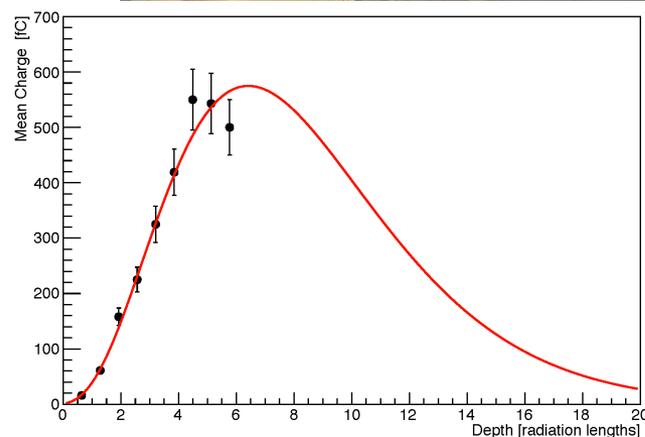
- First beam test: major step from powerpoint to reality, nice success!
- Also revealed some cross-talk issues
 - being addressed in next KPiX version
- *ALL* Si ECAL prototypes so far had cross talk issues
- Si valued for its compactness and stability, cost seen as the only disadvantage.
- Focus was 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)

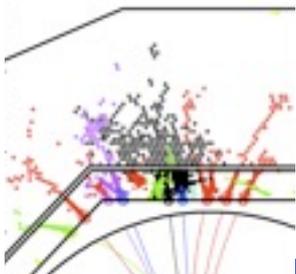




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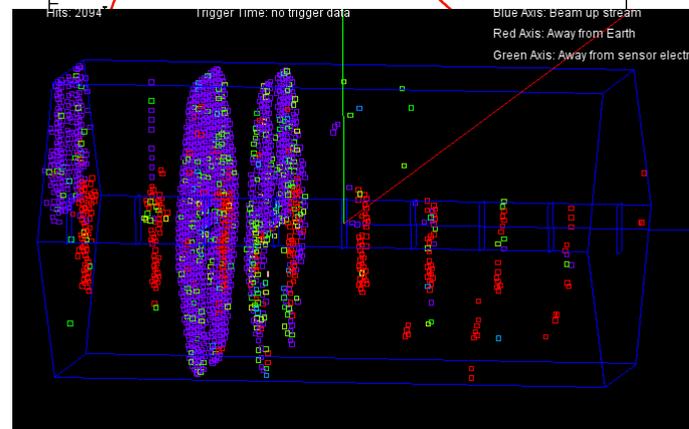
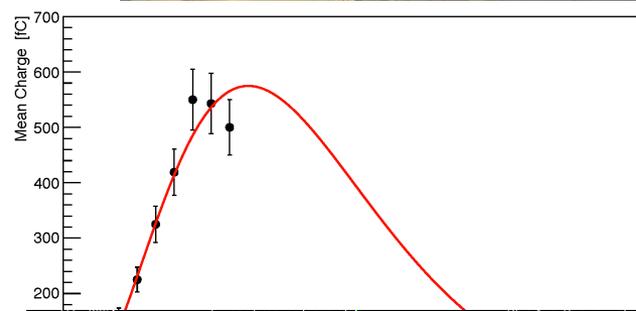
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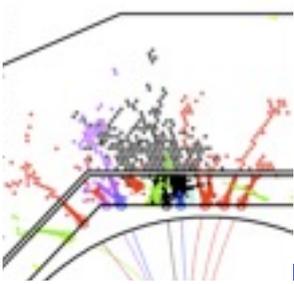


ECAL test beam

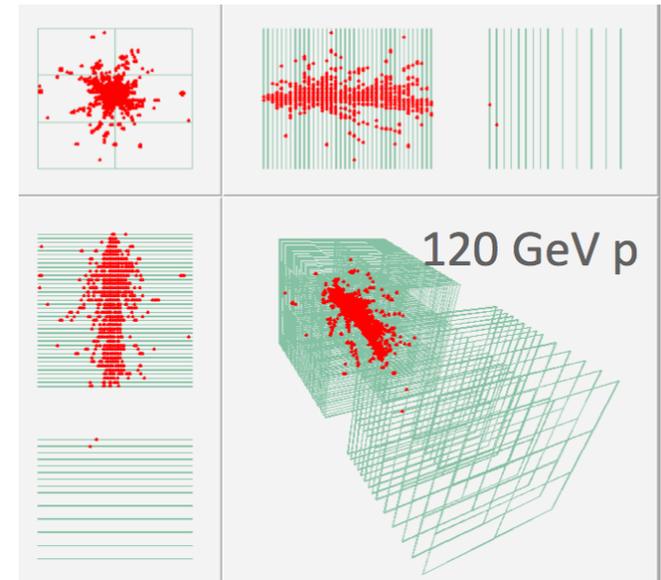
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DHCAL

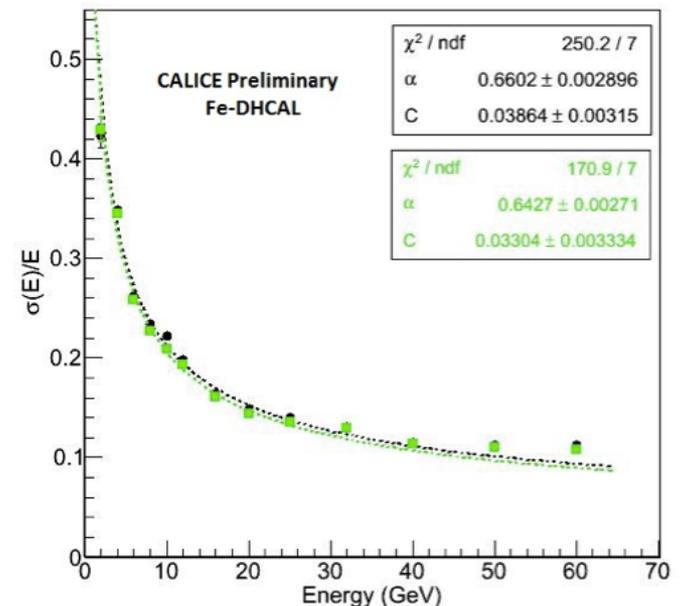


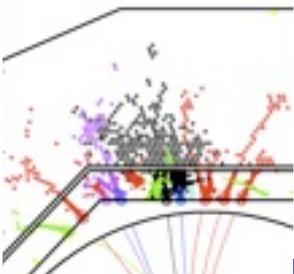
- The biggest prototype endeavour of SiD so far. Success and major scientific contribution.
 - Proof-of-principle: digital calorimetry works
- Unique opportunity to understand (i.e. model) gaseous calorimeters at fine grain
- This is still on its way and will take a few years more time
 - analysis effort 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

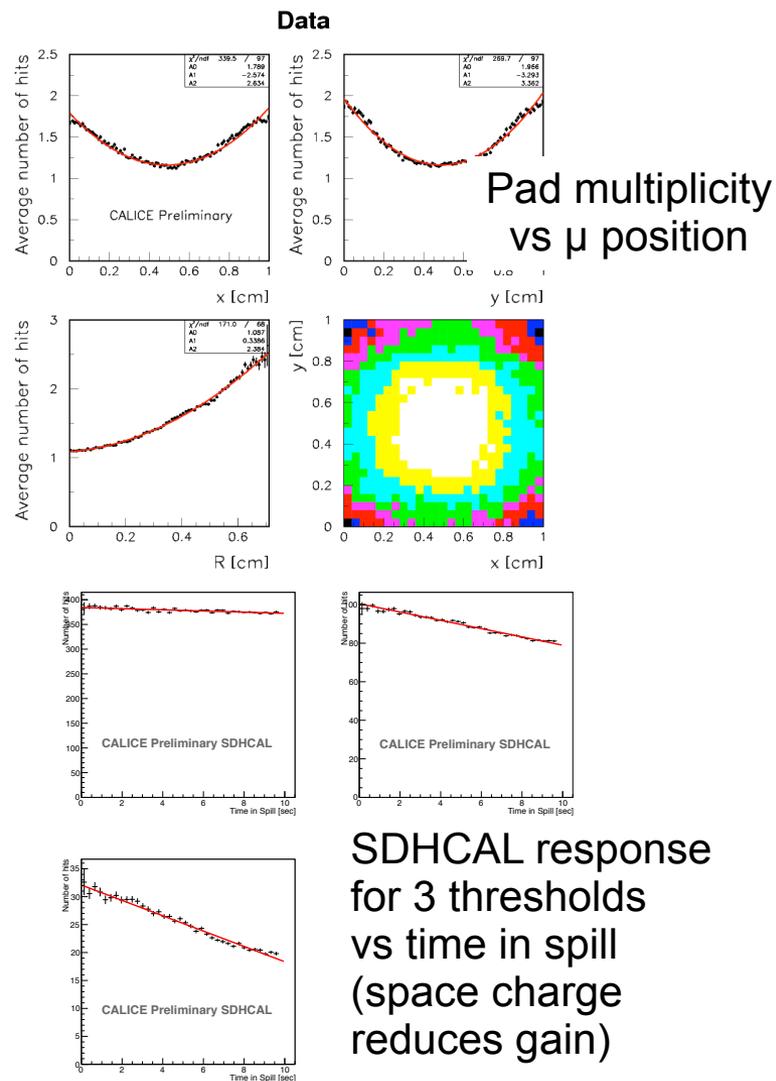
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- There is room to improve the link to SiD simulations and optimisation study
- Still to demonstrate the benefit of higher granularity for particle flow (beyond single particle resolution)

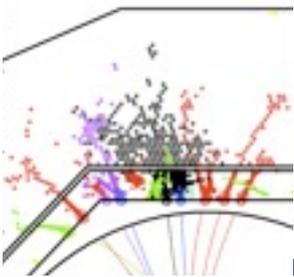




DHCAL response

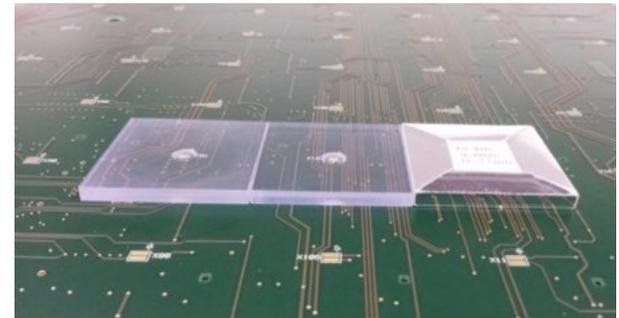
- Main difficulty is that the DHCAL is not digital
- Response in number of hits depends on gas gain and thus on many factors
 - T, p, thickness, purity, rate, local occupancy
 - calibration & monitoring not simple
- May be mitigated for other technologies with $m \sim 1.0$
 - μ M, GEM, 1-glass RPC
 - 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

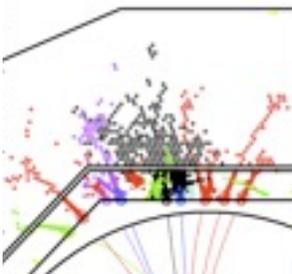




Calorimeter issues

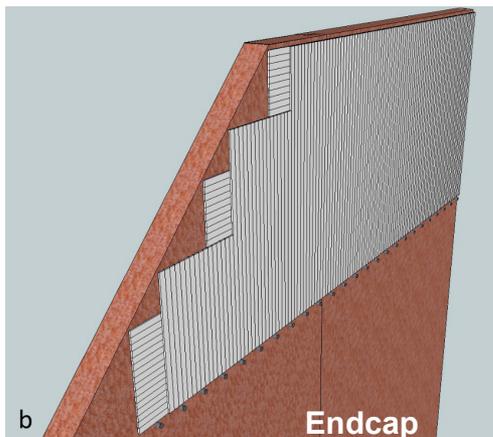
- The SiD ECAL joined the test beam club and changed the landscape - following this up is of utmost importance.
- Address the system issues: these are NOT easy simply because it is silicon. Go to interface design, cooling, services, long modules - and maintain the close link between R&D and concept.
- 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.





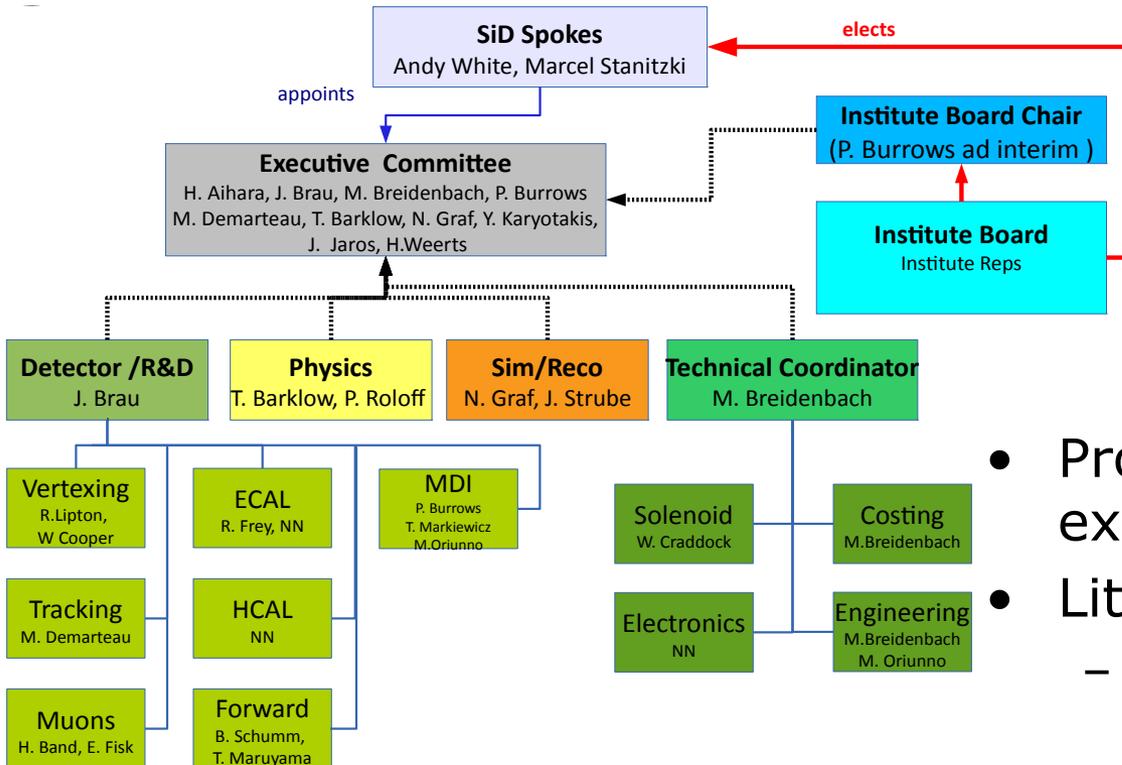
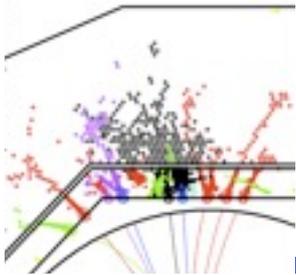
Things left aside

- 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

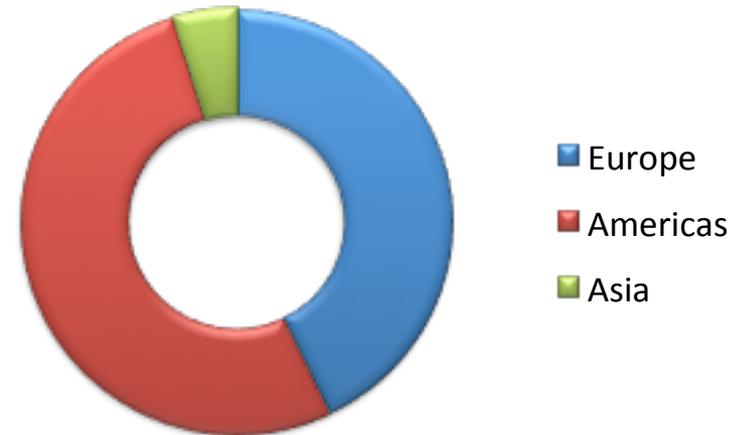
SiD structure

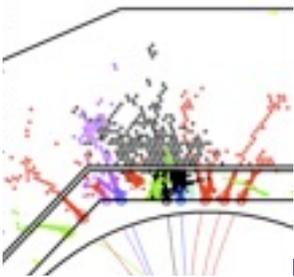


- Proven to be highly efficient, example for others
- Little to improve:
 - clarify role of EC members without mandate
 - At some point will need a publication office / speakers' bureau
 - chair should be elected by IB

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