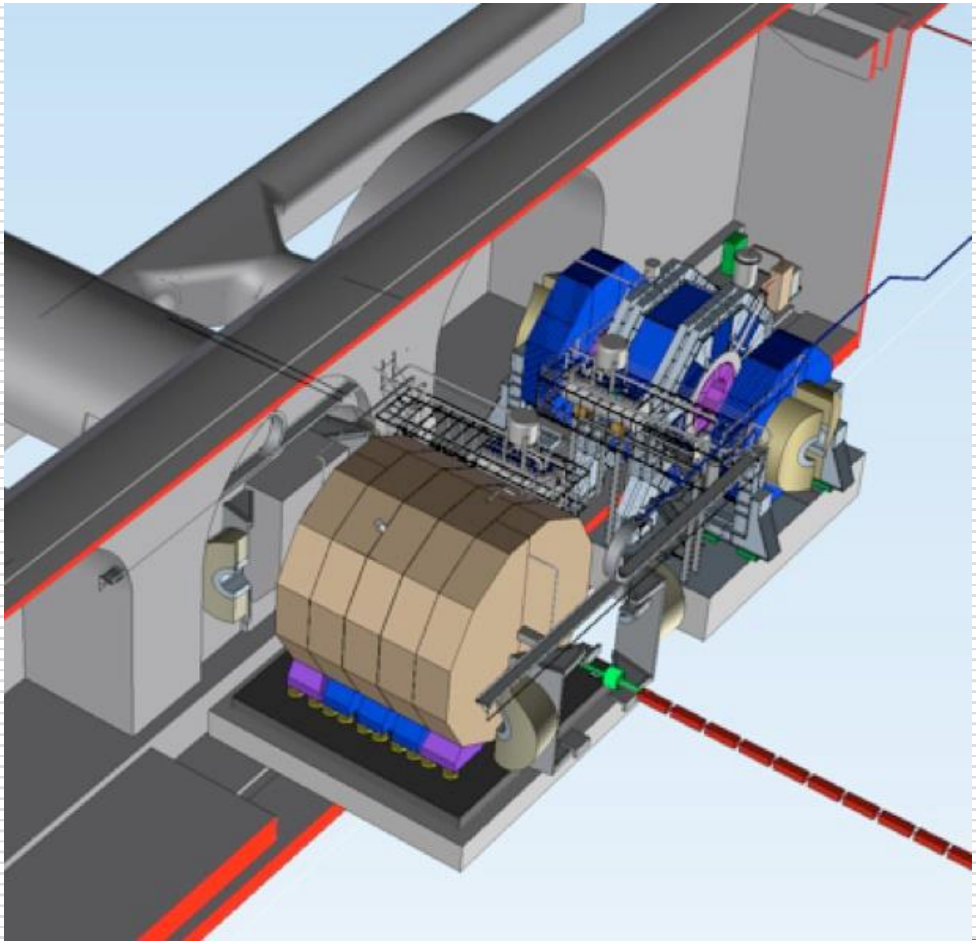
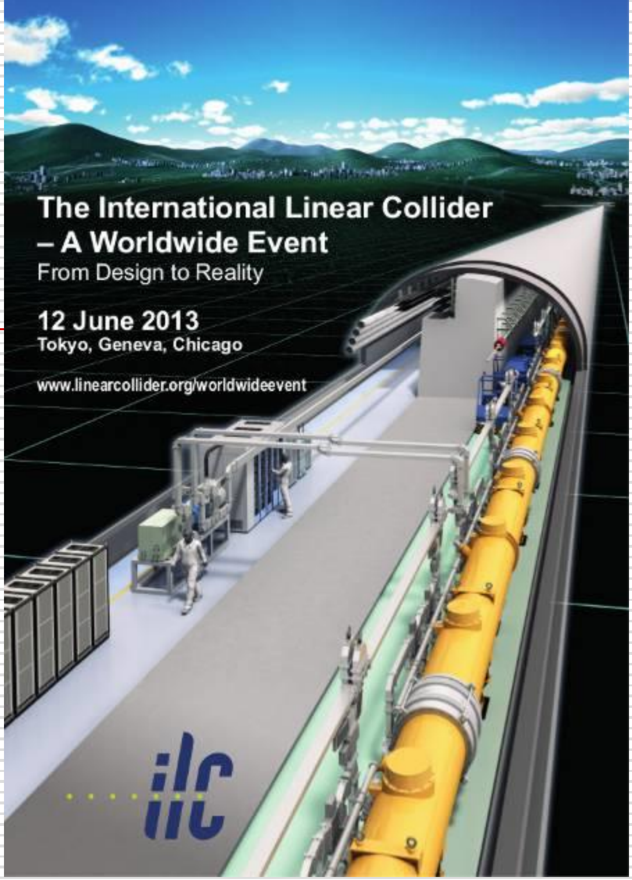
Detectors for a LC: from design to reality





The International Linear Collider
– A Worldwide Event
From Design to Reality

12 June 2013
Tokyo, Geneva, Chicago

www.linearcollider.org/worldwideevent

LINEAR COLLIDER COLLABORATION

François Richard LAL/Orsay

Outline

- What do we expect from LC detectors ?
- Are the two proposed detectors (ILD & SiD) fit for this mission ?
- What is the degree of realism achieved so far for the **D**etailed **B**aseline **D**esign
- How do these detectors differ from the existing ones ?
- What is still needed ?

LC physics environment

- Known (and speculated) physics channels dictate detector properties
- A LC is a H/top/W factory with well defined initial state (**mono-energetic** e+ and e- with adjustable energy for **scans**) and excellent signal/background (e.g. top quarks as often produced as ordinary quarks in contrast to LHC)
- Direct and very precise access to electroweak couplings using **polarized beams**
- Far easier environment than at LHC but with much more ambitious goals in terms of **accuracy** (below %) and **complexity** (high efficiency for multi-jet events)

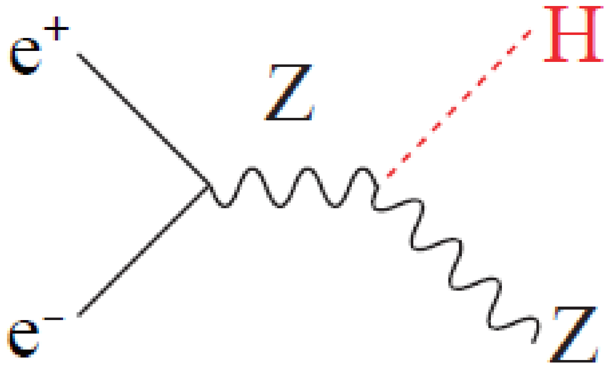
Physics at ECM=250 GeV

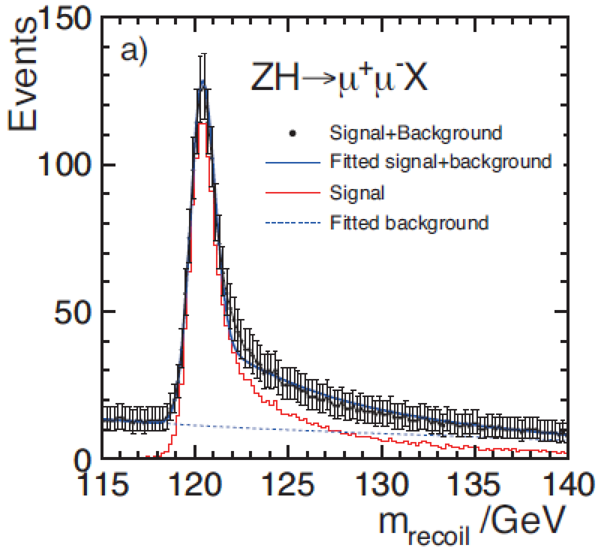
- H(=BEH particle) inclusive reconstruction near threshold
- Use Z->ee/μμ to isolate a very clean Higgs signal mass (HZZ coupling measurement)

-> high momentum resolution

- H into bb/cc/ττ and WW*/gg + invisible decay in BSM (role of **missing energy**)

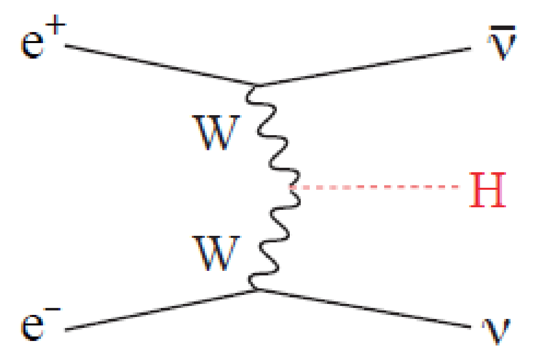
->Select c and b by measuring displaced vertices

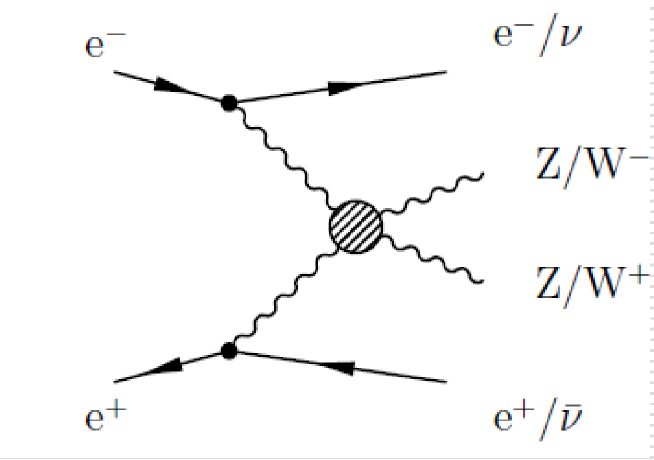


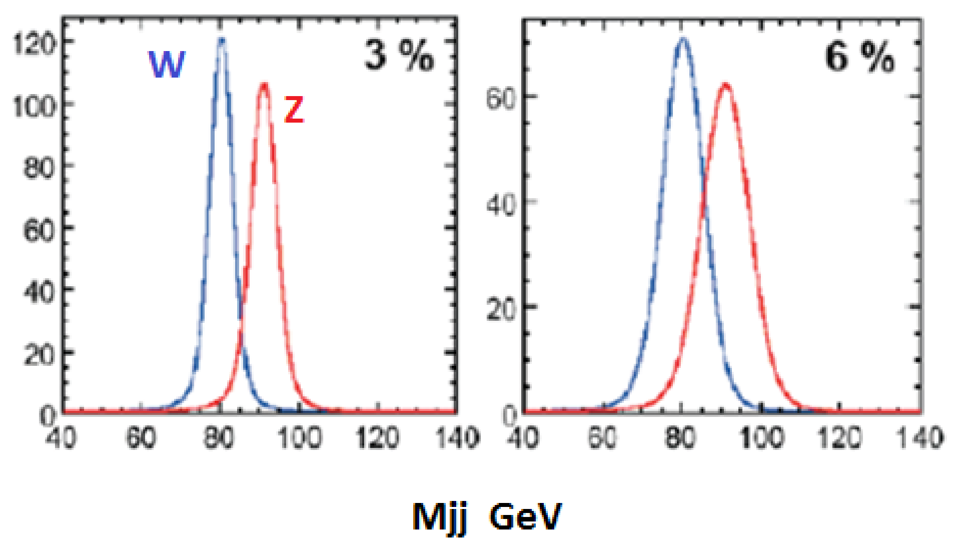


Physics at ECM≥500 GeV

- **Fusion** with missing neutrinos requires reconstruction of H decays into jets
- dEj/Ej~3% needed for a clean W/Z mass separation (worse by a factor 2 at LEP)

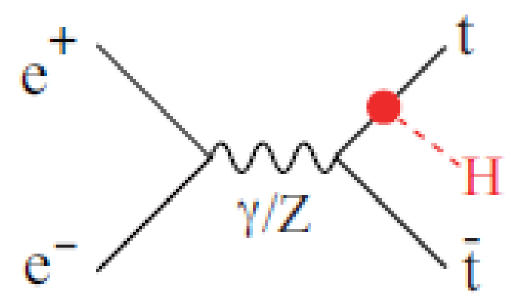


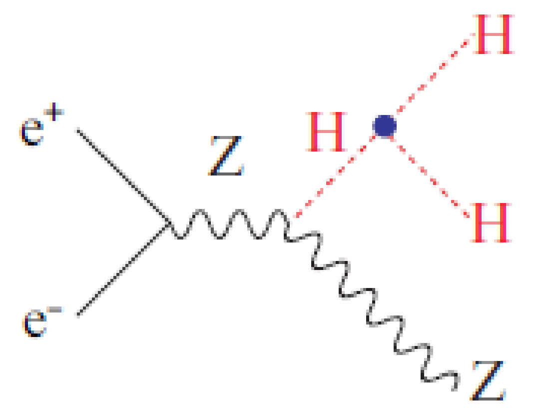




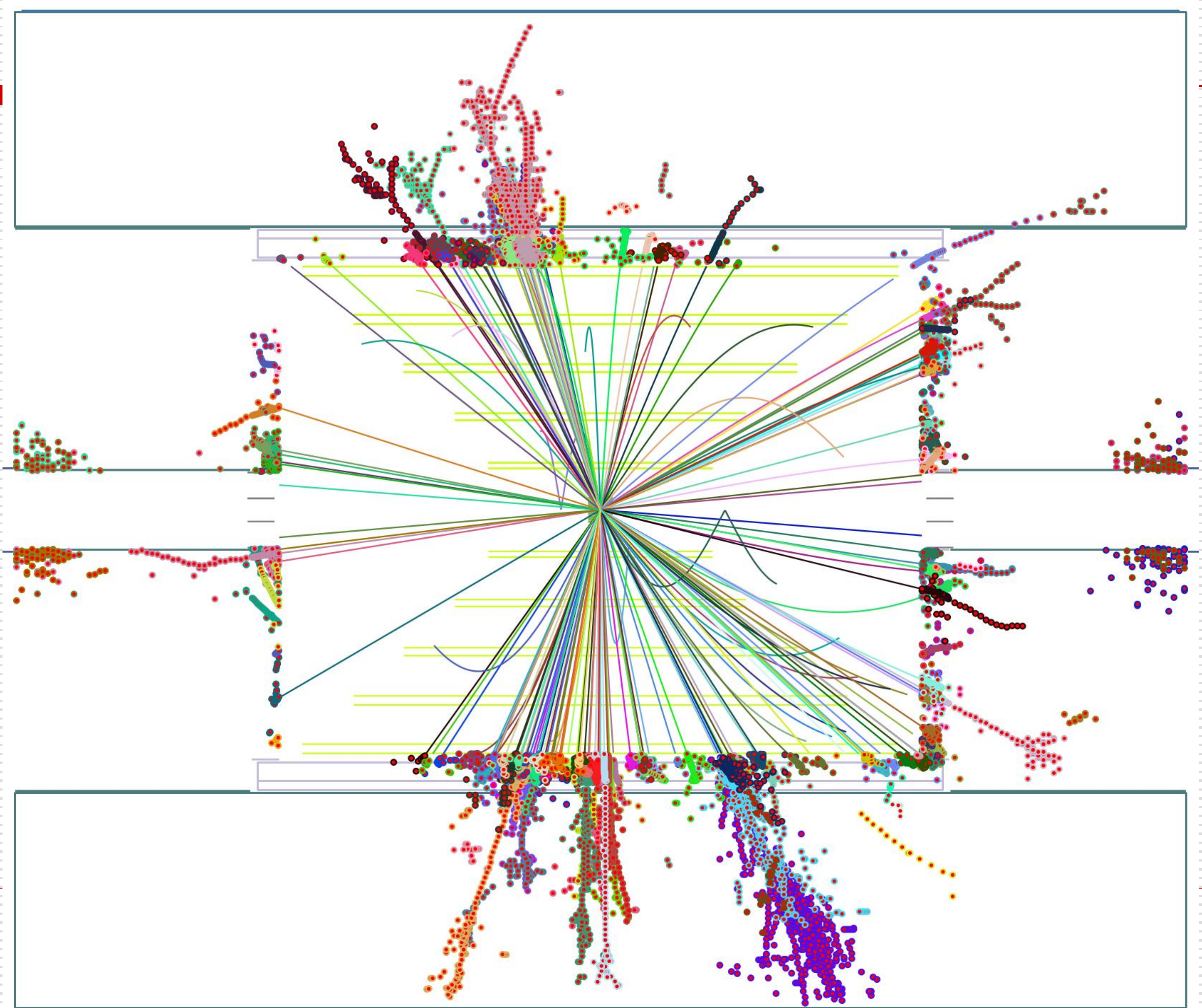
High jet multiplicity

- ttH and ZHH have low cross sections and complex final states with up to 8 jets
- **Full angular acceptance** needed keeping all tagging properties including for b/c/τ
- Was not the case for LEP detectors (coping with 4 jets) with weaker performances in the forward region





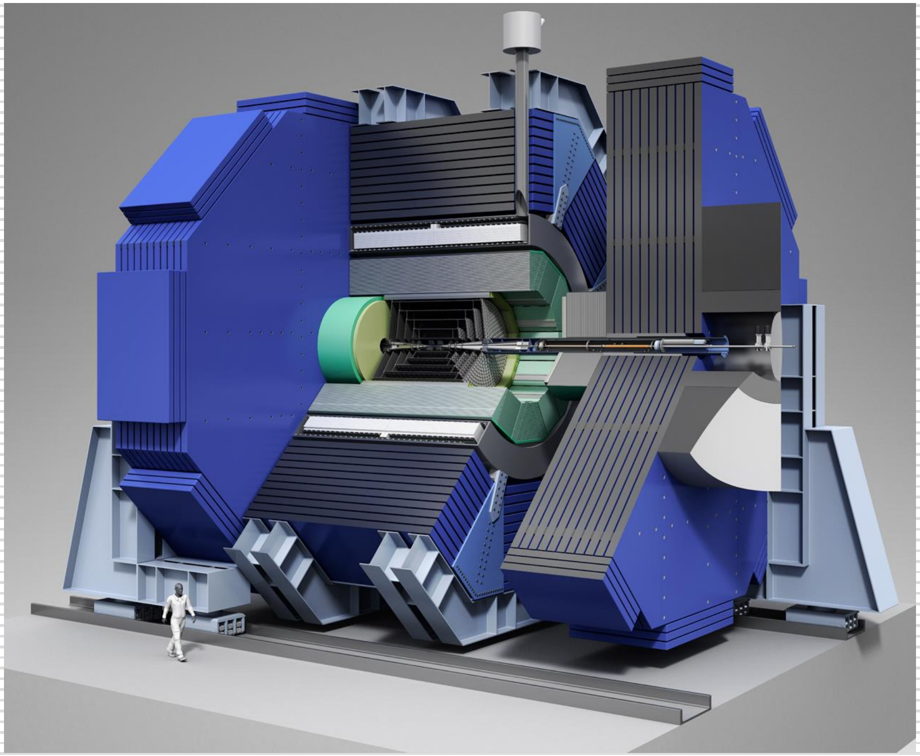
An example: ttH (from SiD)

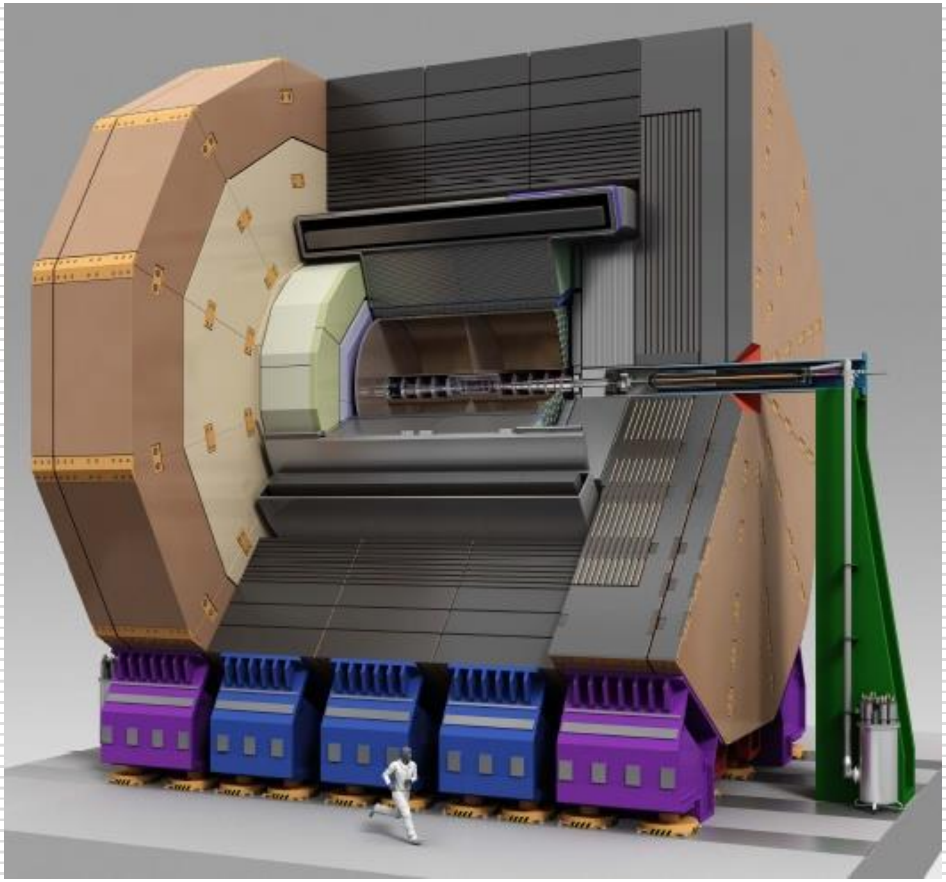


Bias free selection

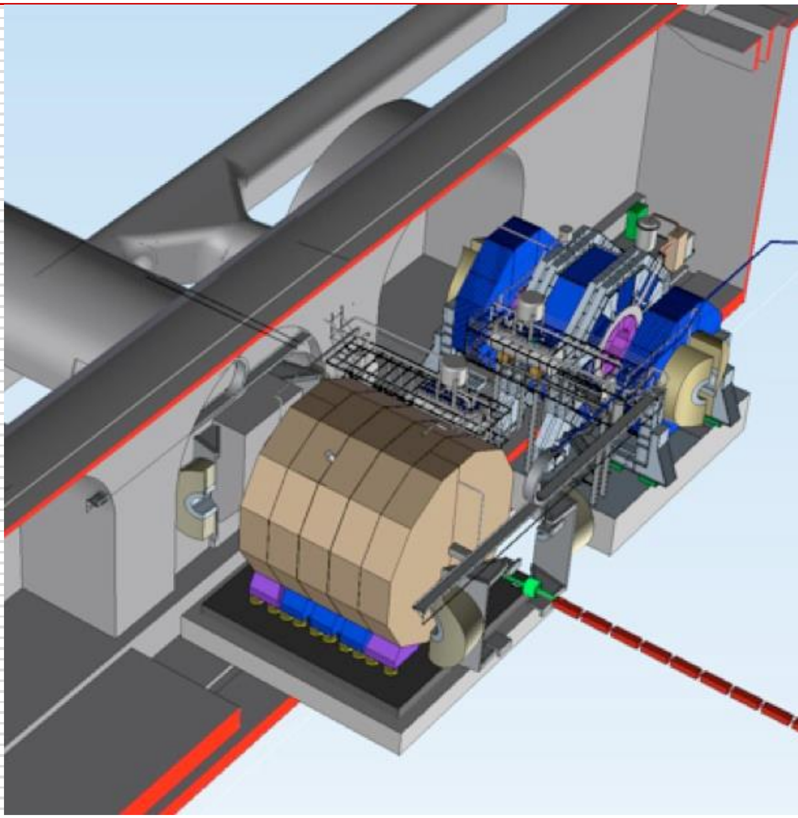
- Possible discoveries beyond LHC are not excluded
- A bias free selection is therefore essential to cover any unforeseen physics scenario
- The beam time structure (~ms bunch trains at 5Hz) allows to replace hardware triggering by **software triggering** in between trains
- Detectors act as a **camera** where all the useful information (noise suppressed) is stored during the whole bunch train

2 concepts: SiD & ILD



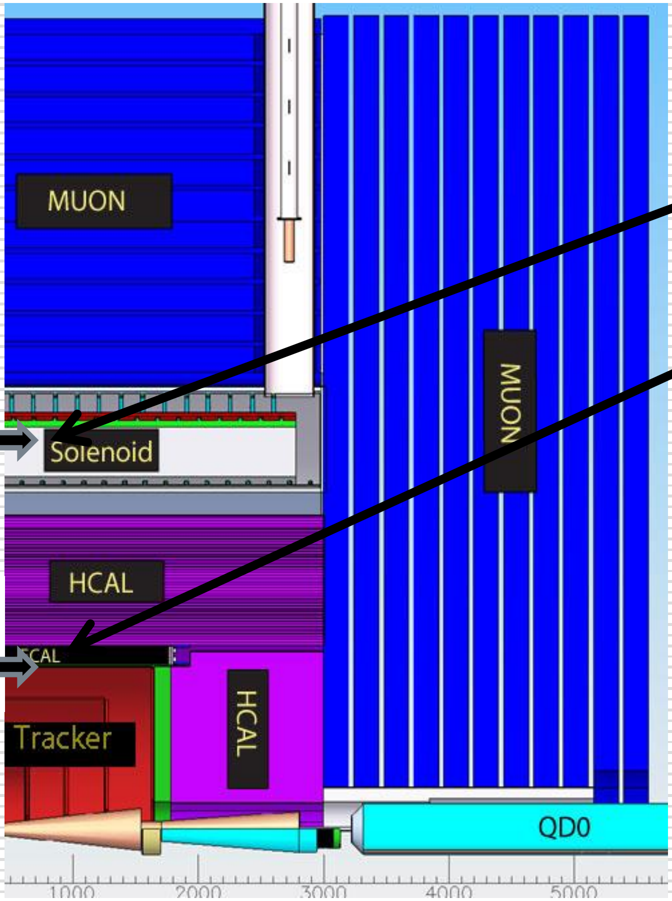


Common features



- Full **angular coverage** including for flavor tagging
- Large SC solenoidal magnetic field ‘a la CMS’ B>3 T ensuring excellent **momentum resolution**
- Almost ‘transparent’ trackers with calorimeters included inside the coil **minimizing material effects**
- **Imaging calorimetry** for PFA with a very large number of electronic channels(>10^8)
- **Push-pull** philosophy insuring scientific and technical safety

Differences



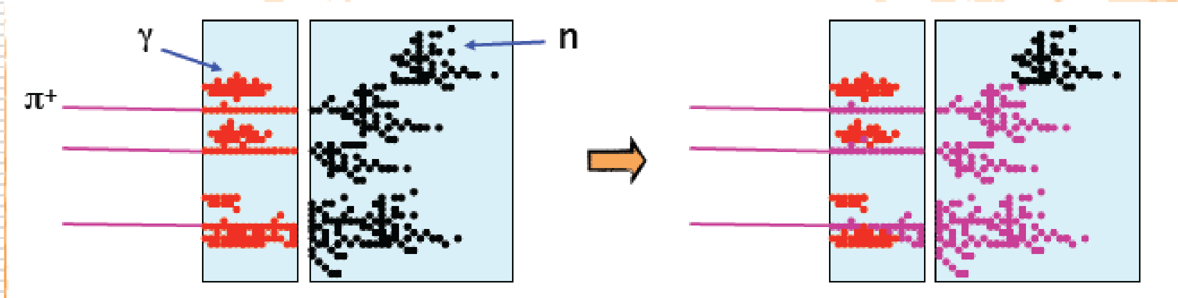
SiD 5T
ILD 3.5T

SiD 1.2m
ILD 1.8m

- Different B field & tracker radius achieving similar energy/momentum resolution
- 100% Silicon tracker for SiD
- ILD has a large volume gaseous tracker (TPC >>LEP) supplemented by silicon tracking
- Various calorimeter technologies are considered, ILD leaving open its final choice

Particle Flow Algorithm (PFA)

- Plays a major role in the optimization of the 2 detectors
- What is the problem ?



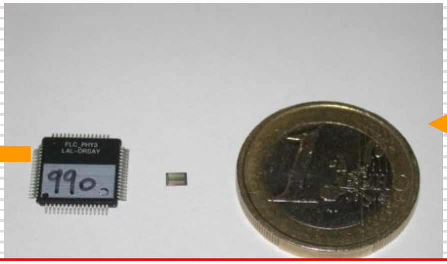
$E_{JET} = E_{ECAL} + E_{HCAL}$ $E_{JET} = E_{TRACK} + E_{\gamma} + E_{n}$

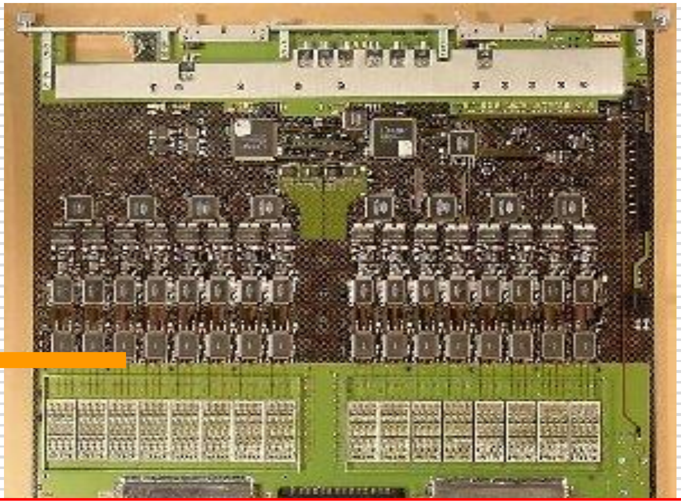
- Optimization of PFA shows that the main limitation is confusion not energy resolution
- **Compact (limited shower radial expansion) and granular** calorimeters needed (0.5x0.5 cm² Si pads for ECAL), excellent tracking efficiency (>99%) and low material in front

Imaging calorimetry

- High granular calorimetry with $>10^8$ channels becomes practical with low consumption µ-electronics inside the calorimeters
- Power pulsing at 5 Hz

  with ~1ms duration





ILC : 25µW/ch

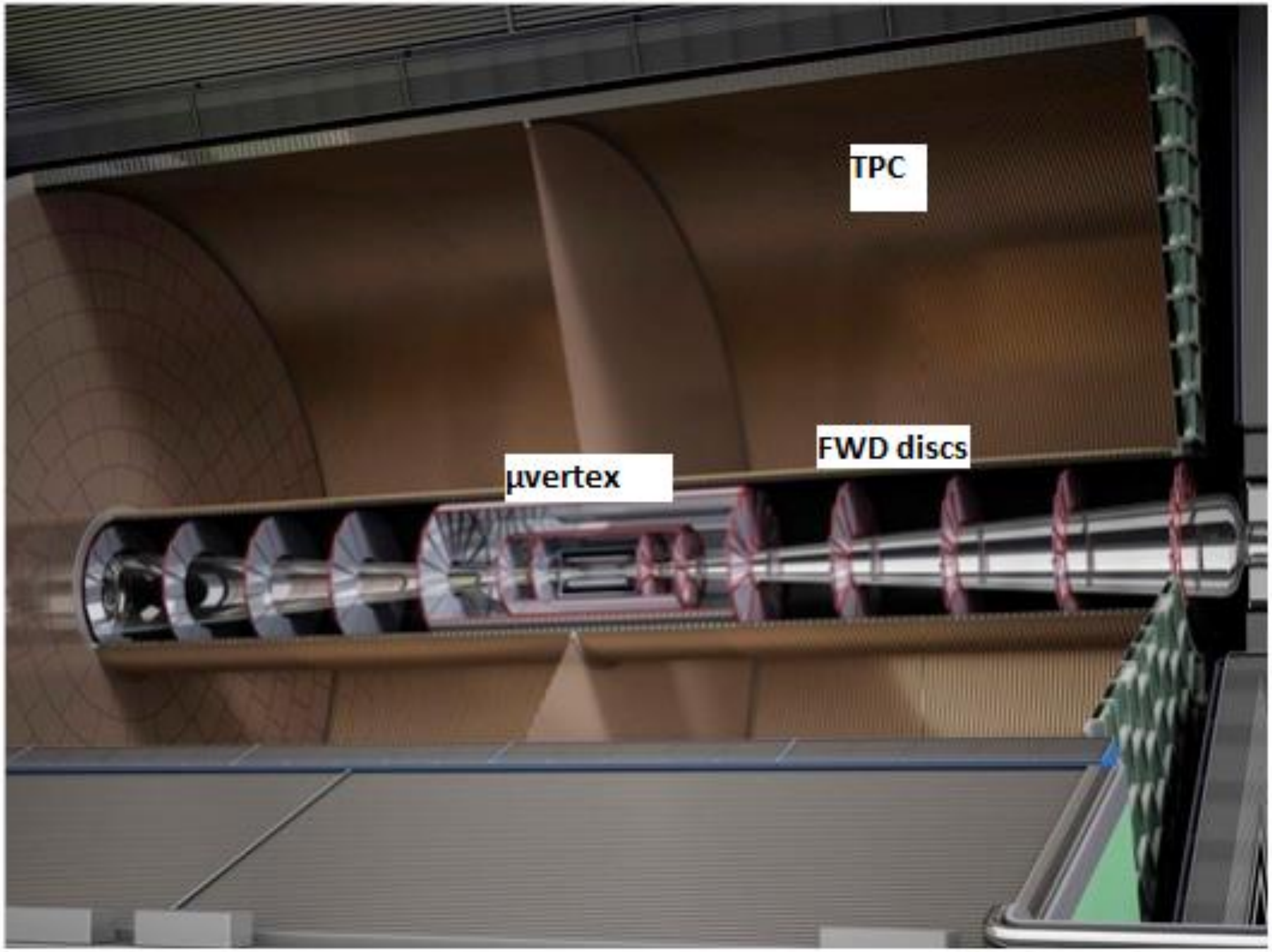
Physics Proto. 18ch 10*10mm 5mW/ch

ATLAS LAr FEB 128ch 400*500mm 1 W/ch

Flavor tagging

- Major breakthroughs with respect to existing detectors with many available new technologies
- 1^{st} layer at R<2cm (5cm at LEP)
- Detectors with very low material budget ~0.2% X0 per layer (~0.2mm Si) possible at ILC with low radiation
- Easy cooling with power pulsing
- Not only b/c separation is optimal but **b charge** determination becomes possible and very useful to measure t/b asymmetries

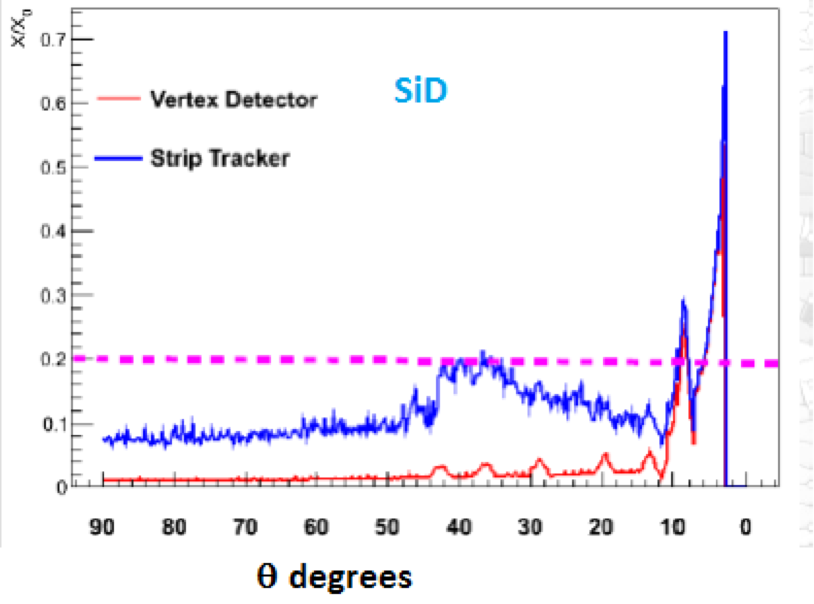
Full angular coverage ?

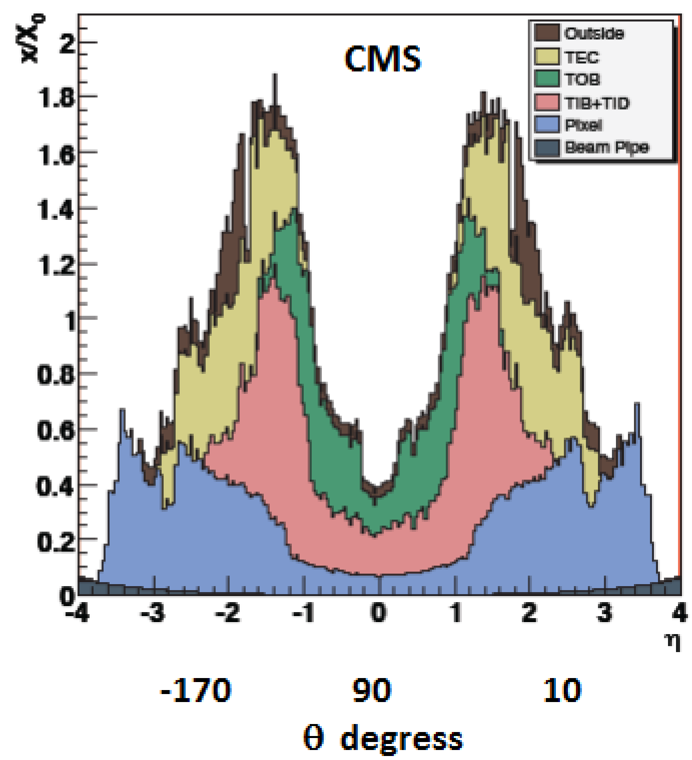


ILD

How do they compare to existing detectors ?

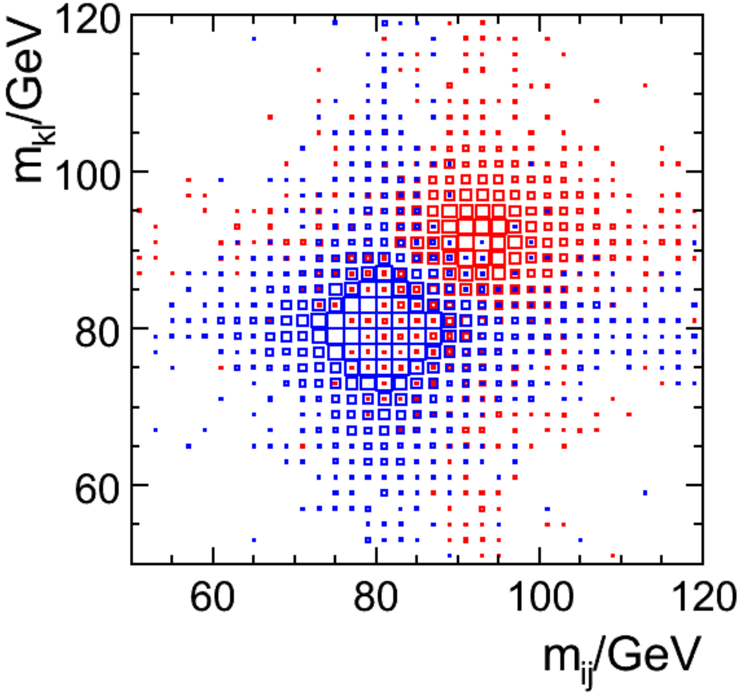
- Material budget

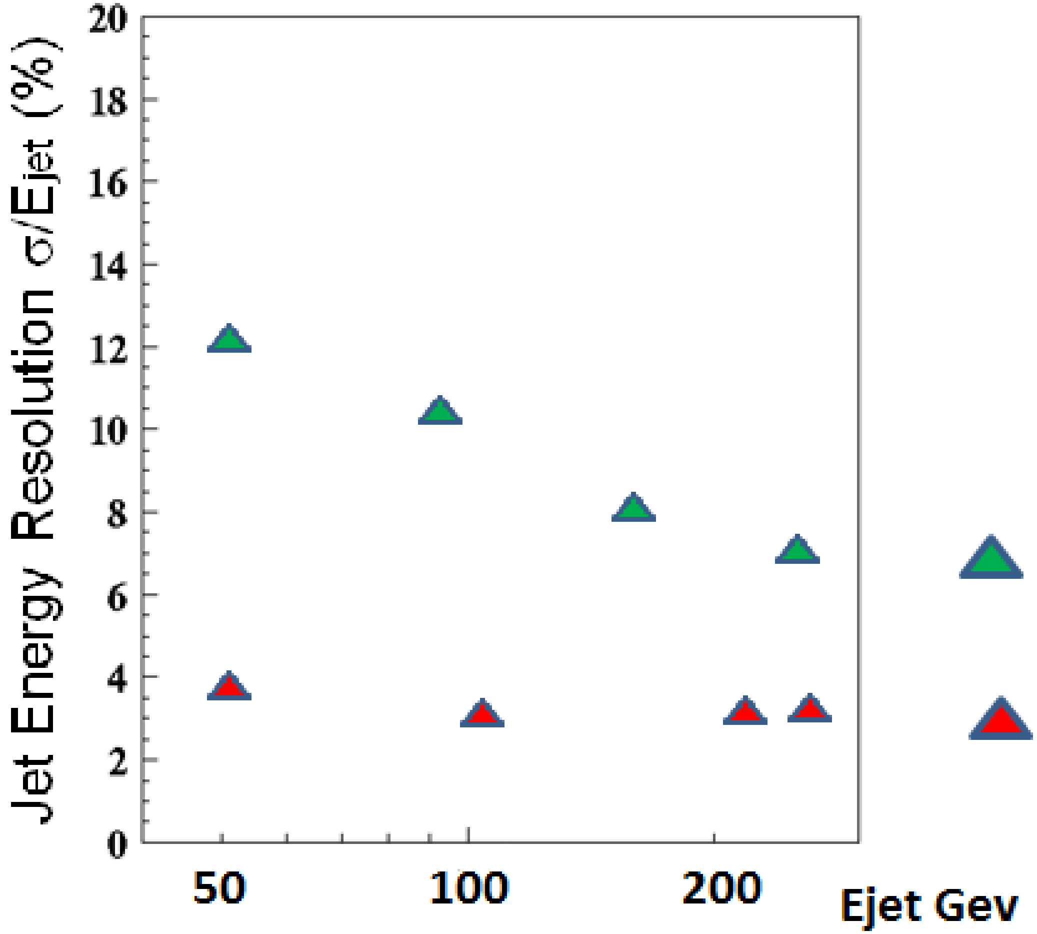




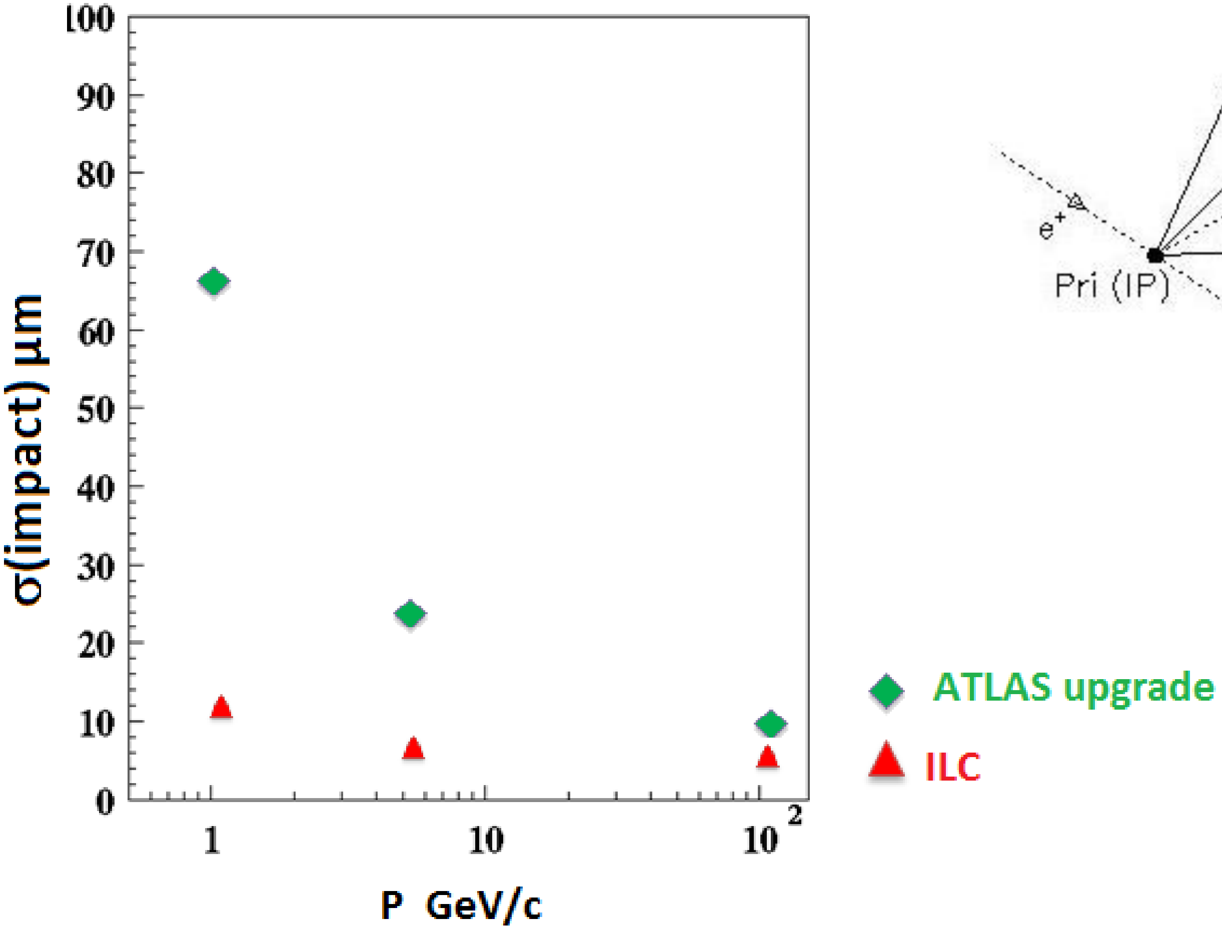
- Intrinsic reasons (radiation hardness) but we should remain very careful in maintaining this feature

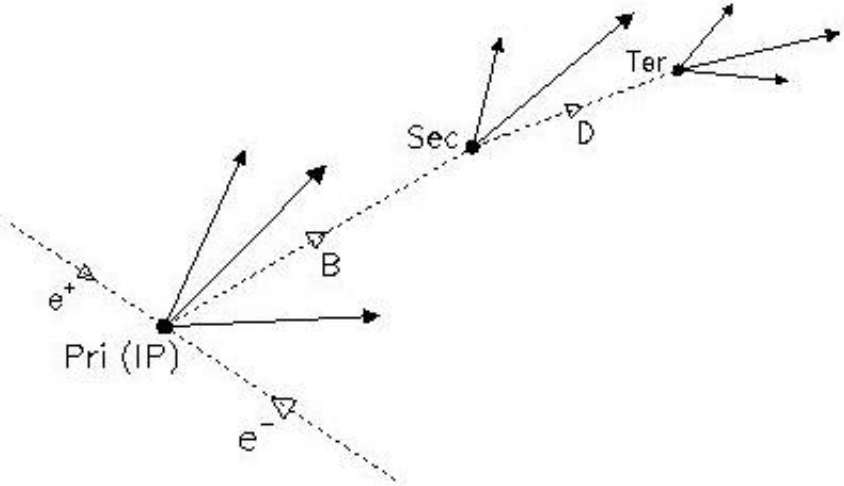
Particle Flow



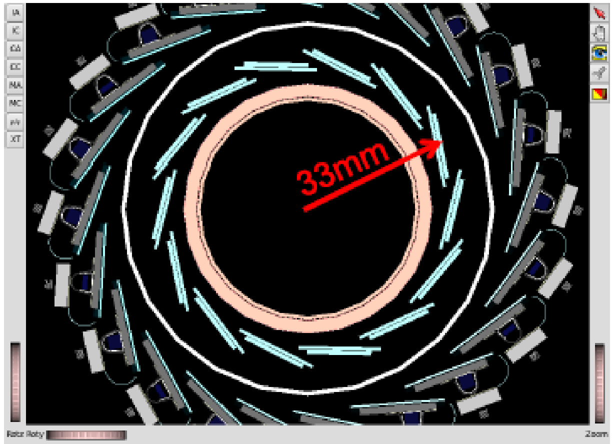


Microvertex accuracy



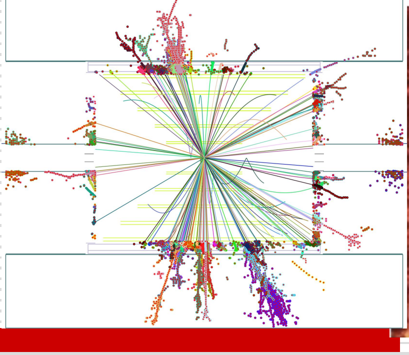


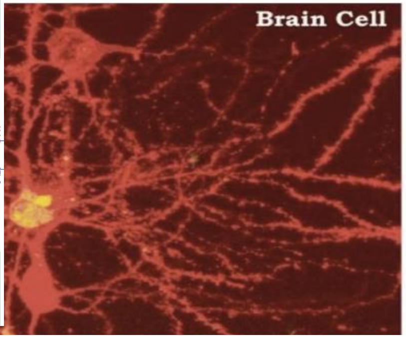
ATLAS IBL (phase-0)

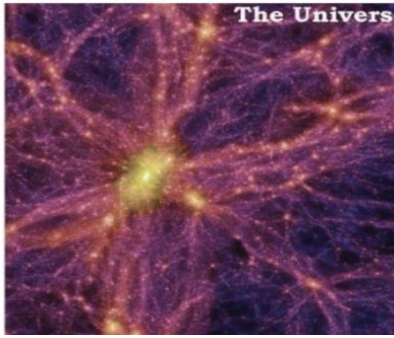


How realistic are these detectors ?

- More than 10 years of coordinated R&D with **large prototypes** allow **realistic evaluations** of innovative technologies and insure **moderate risks**
- This effort is internationally embedded in WW collaborations: CALICE, LCTPC, FCAL…with international peer reviewing
- Present DBD documents organized around 2 detector concepts with close connection to R&D
- Europe well structured through **European contracts** (AIDA etc…) and participation of CERN





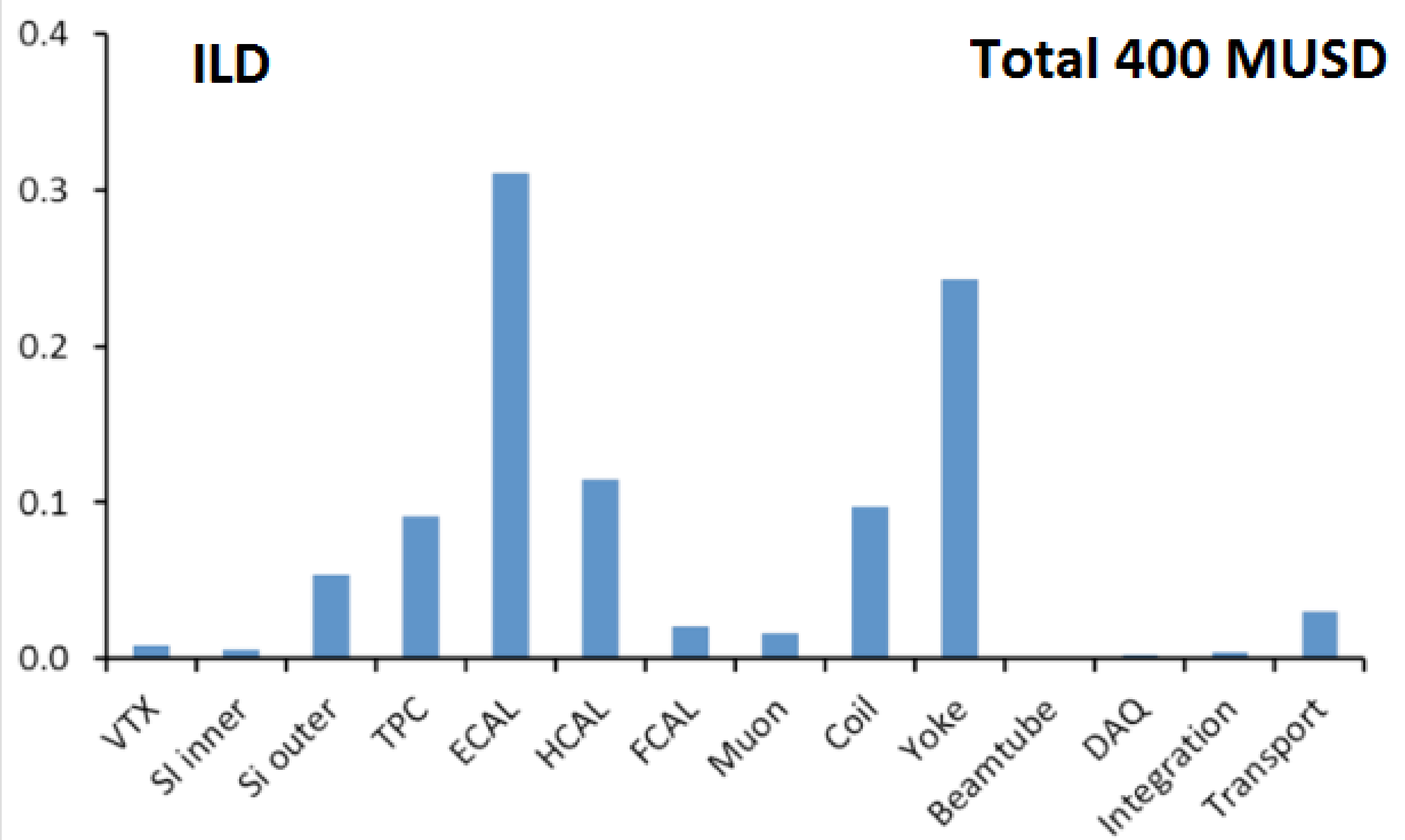


R&D

- Several alternate technologies are developed e.g. for calorimetry and µ-vertexing which allows a good safety margin in case of unexpected problems
- As an example 3 cubic m HCAL prototypes (500000 RO channels) with Fe and W absorbers tested at CERN, FNAL, DESY…
- An ECAL prototype with 10000 equipped Si channels has been associated to these prototypes
- A large scale TPC prototype is currently operated at DESY
- A wealth of applications has resulted from these efforts in various domains which extend **well beyond HEP**

Costs

- ☐ Cost drivers : coil+yoke and calorimetry



What remains to be done

- ‘Devil is in the details’: cabling, supports, cooling have been investigated but more is needed to fully assess the present set up
- A lot has been done including installation and integration aspects but this is a ‘DBD’ not a TDR which would require knowledge of the site chosen for construction
- More engineering efforts are therefore needed for a full TDR (ready for construction) level project
- Work with industry for construction has to start

Summary

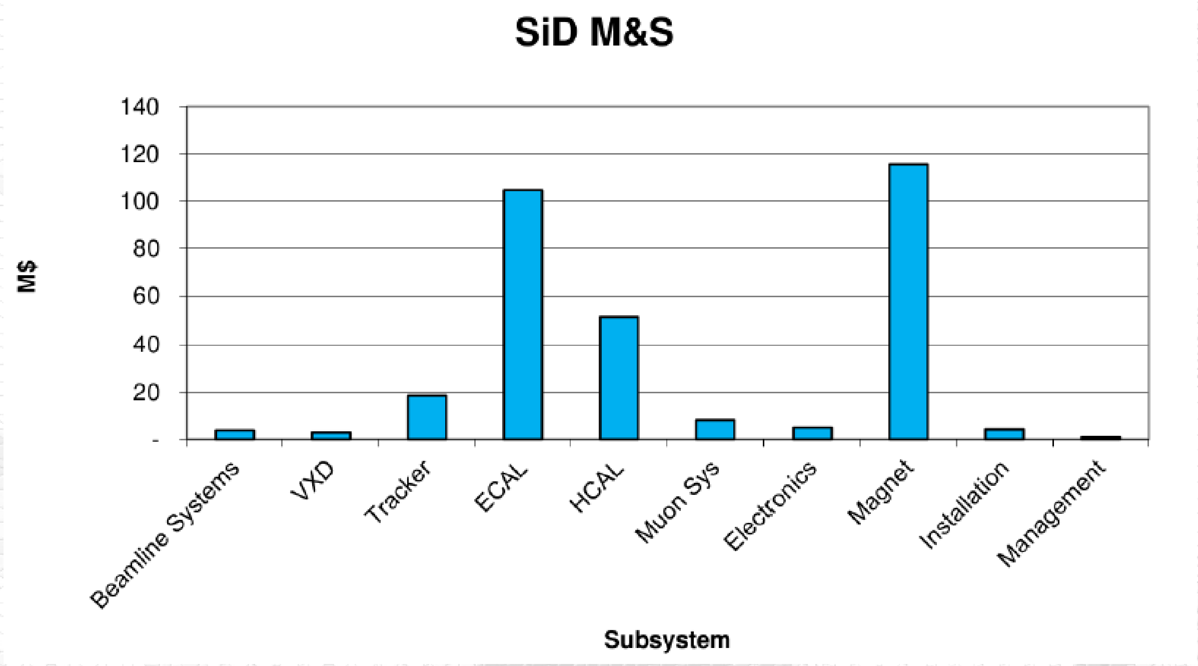
- After a long and intense phase of R&D at the worldwide level two detector concepts are proposed for a LC operating up to 1 TeV center of mass
- Realistic physics studies have shown that these detectors, with unprecedented reconstruction accuracies, optimally cover the physics needs
- Engineering studies provide a solid proof of realism of these detectors close to a ‘ready for construction level’ (TDR) but full realism requires industrialization and understanding of the various assembly constraints within a well defined site
- Resources should be provided to achieve these goals with a move toward two detector collaborations replacing the concept groups

Quoting a conclusion from **Erice:**

*‘The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and **European groups are eager to participate**’*

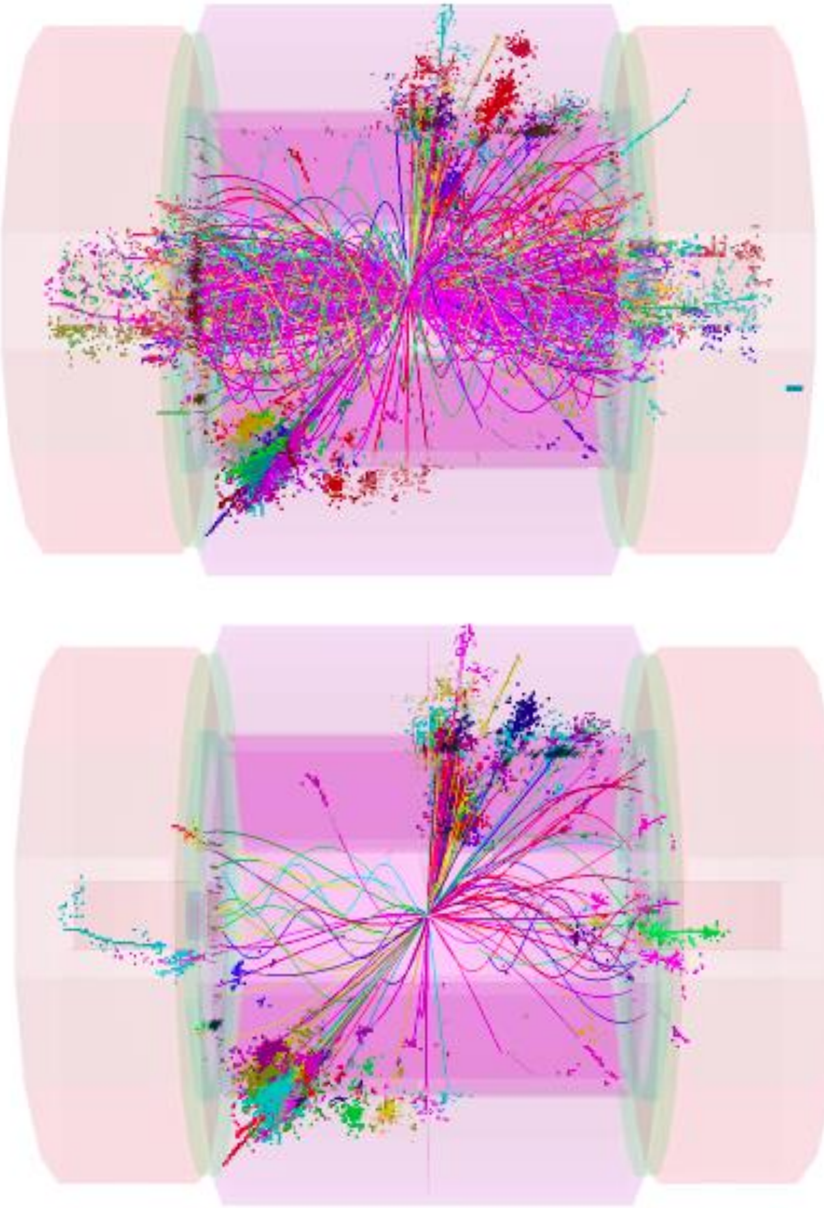
BACK UPS

SiD cost


SiD M&S
M$
140
120
100
80
60
40
20
-
Beamline Systems
VXD
Tracker
ECAL
HCAL
Muon Sys
Electronics
Magnet
Installation
Management
Subsystem

For CLIC

- Same concepts studied allowing a very nice synergy with ILC
- Extensions in size which can only be modest for B and the coil radius
- Better stopping power by using W instead of inox for hadronic calorimetry (non trivial changes needed)
- Special effort on time stamping with 0.5 ns separation between bunches (uses PFA)



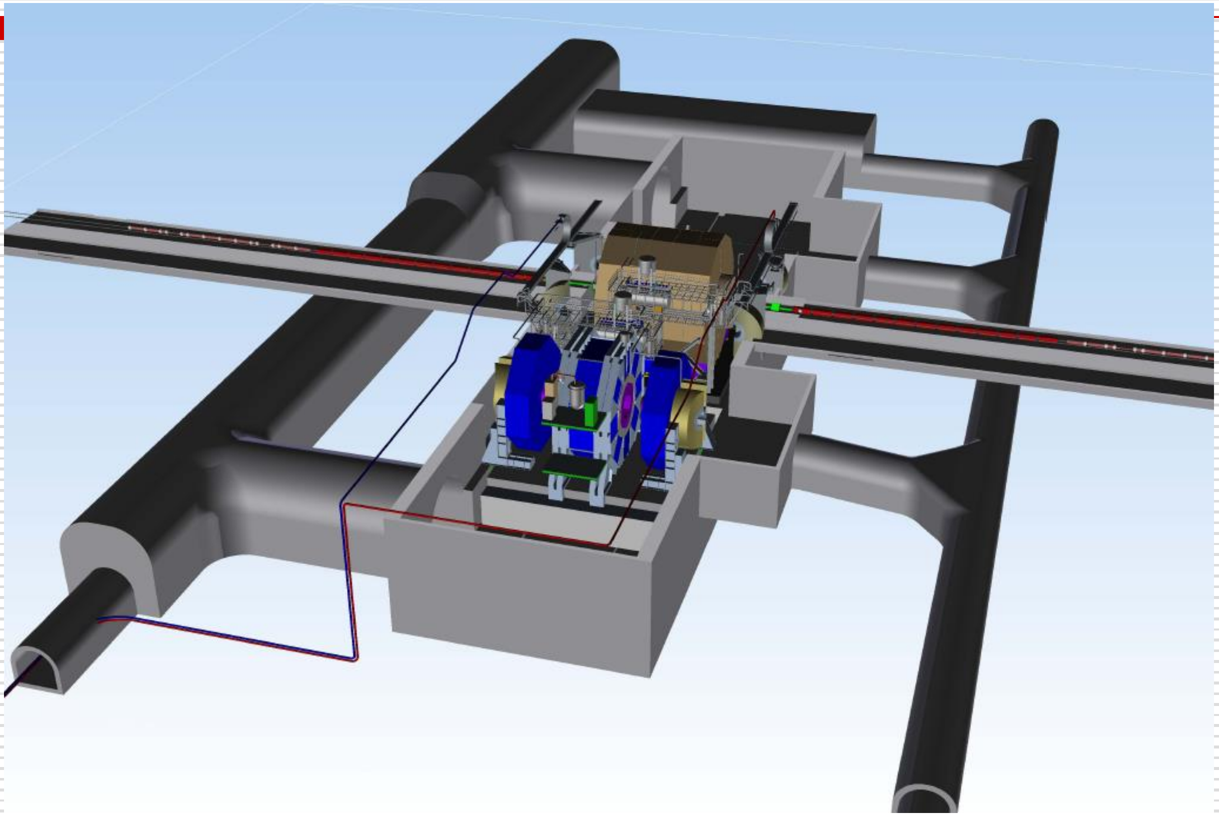
Some spin-offs

- Ref (M. Demateau at IEEE LC event):
- https://indico.desy.de/conferenceDisplay.py?confId=6537
- The LC effort has served various purposes:
- Particle physics itself with various synergies with ALICE (ALTRO chip forb TPC & Calorimetry), T2K (TPC, SiPM), Belle-II at Super-KeKb (DEPFET), STAR at RHIC (µvertex) , CMS (SiPM for calorimetry)
- Other research fields (PEBS ballon experiment with ASICS), X ray dectors for imaging in astronomy
- Medical : proton (SiPM for calorimetry) and PET positron emission tomography (ECAL technology) , gamma camera (ASICS)
- Vulcano tomography
- SiPM ‘everywhere’ was started by this activity

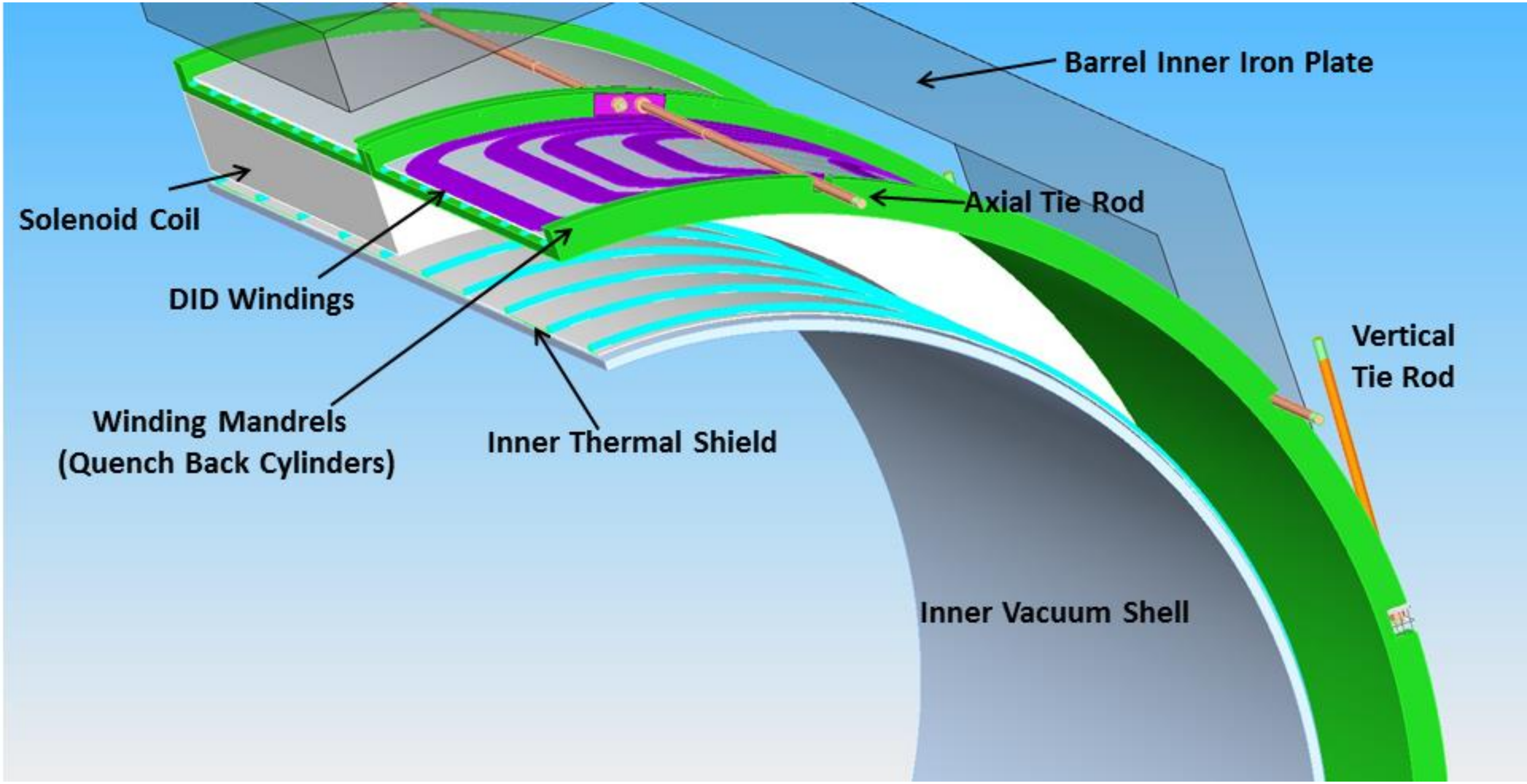
Machine-Detector interface

- In a LC the design of a detector is more tightly connected to machine constraints:
- Focusing elements are embedded inside the detector and require tight alignments (nm beam spots)
- Backgrounds aspects have to be studied in common
- Detectors need to be moved and realigned easily with the push-pull constraints
- ~One week needed for replacement and realignment

Japanese underground hall Design, ILC-EDMS

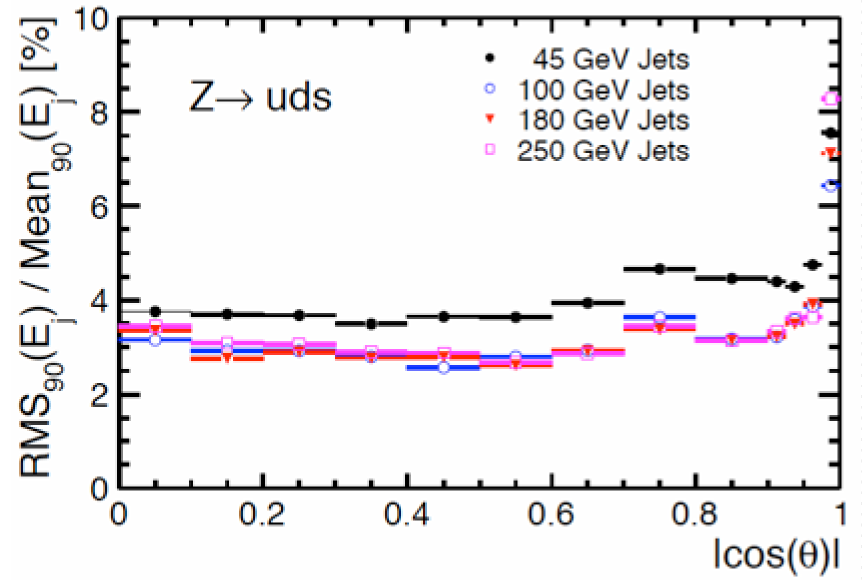


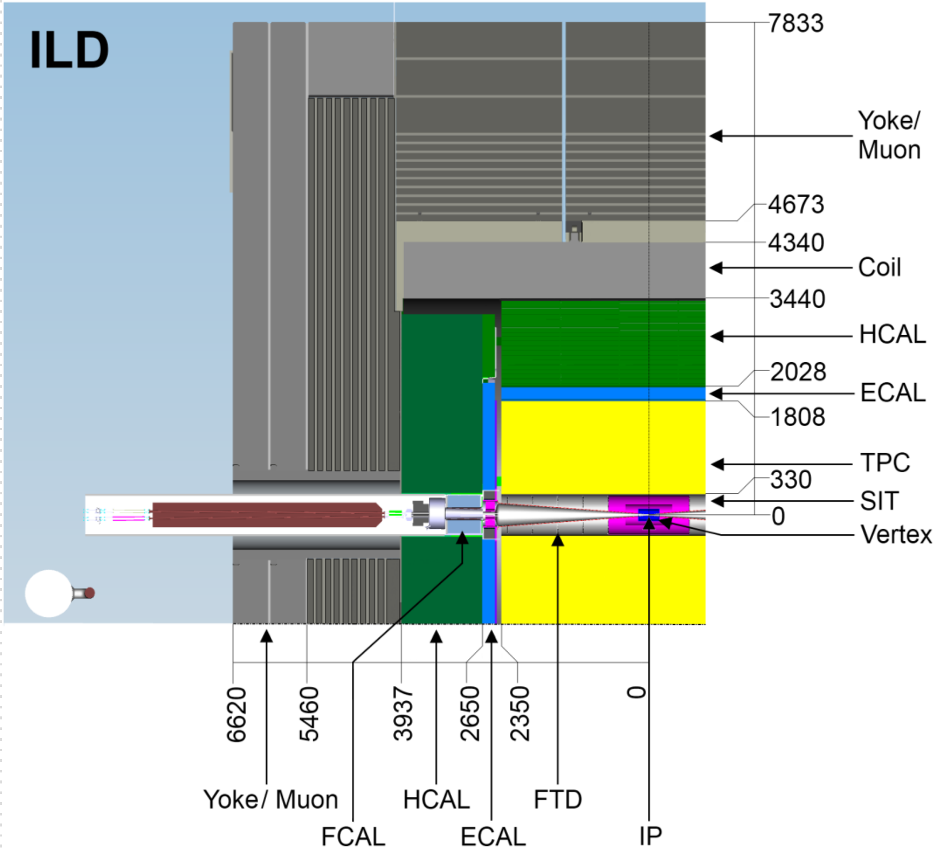
SID Solenoid, Wes Craddock (SLAC)



Simplified Magnet Section

Angular dependence

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Yoke/ Muon
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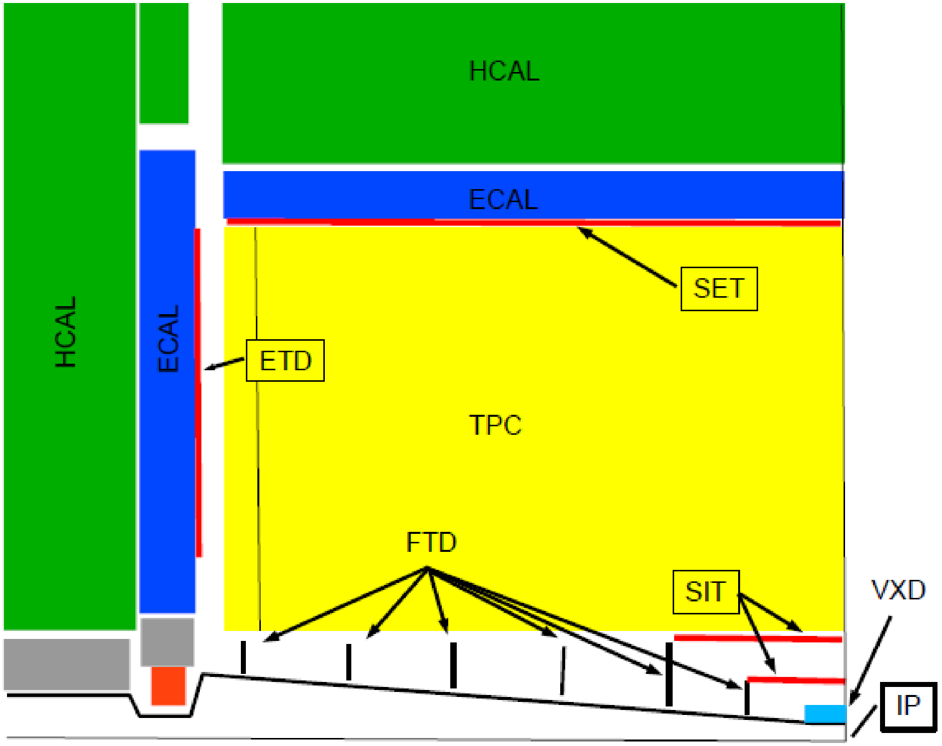
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