Technical Draft Content of the ILD Design Report

Version of April 16th, 2018

C. Vallée

Abstract

This document provides preliminary inputs for discussion of the detailed technical content of the ILD Design Report (IDR), following the overall IDR sketch presented by Ties in the concluding session of the ILD meeting in Ichinoseki. The IDR technical part is expected to provide a self-consistent description of the current design of the ILD detector including remaining open options and possible improvements for the future. For completeness it should shortly remind the unchanged features described in the ILD LoI (2009) and DBD (2013), and focus on the studies performed since then on technological prototypes, spinoffs, ILD integration and costing. The developments of the past 5 years should be comprehensively documented, with a few highlights spotted in the IDR figures and all details referred to in technical publications.

This document is primarily intended to survey the available technical information, to identify the main missing items on which the work of the coming months should focus, and to frame the level of details of the various sections. It is not designed to seed the actual editing of the IDR, which will be done in another collaborative framework. In each section names of possible editors are given for participation to the future formal IDR editing. The present figures are indicative of the spirit of the expected illustrations, but not intended to be kept as such: once the formal editing is started, the subsection editors will be in charge of defining the suitable highlights for the IDR illustrations and to collect the corresponding figures. They will also have to provide the initial texts of their subsections. For an IDR of ~150 pages, the technical part should not exceed ~60 pages, corresponding to ~40 pages of plain text on top of the figures. The following includes a proposal of how to share this quota among the technical subsections.

Content

1. THE SCIENCE CASE FOR THE ILC 3

2. ILC ENVIRONMENT 3

3. ILD CONCEPT 4

3.1. OVERALL CONCEPT 4

3.2. OPTIMISATION PATH 5

4. DETECTOR LAYOUT AND TECHNOLOGIES 6

4.1. OVERALL DETECTOR STRUCTURE 6

4.1.1. Global structure and parameters 6

4.1.2. Subdetector layouts 7

4.2. SUBDETECTOR TECHNOLOGY STATUS 10

4.2.1. Vertex *(~3 pages of plain text)* 10

4.2.2. Forward&Central Inner SiliconTrackers 11

4.2.3. TPC *(~3 pages of plain text)* 12

4.2.4. Calorimeters *(~5 pages of plain text)* 13

4.2.5. Very Forward System *(~2 pages of plain text)* 14

4.2.6. Iron Instrumentatlon *(~1 page of plain text)* 14

5. ILD GLOBAL INTEGRATION 15

5.1. INTERNAL INTEGRATION 15

5.2. EXTERNAL INTEGRATION 16

5.2.1. Cavern ancillary services 16

5.2.2. Data Acquisition 16

5.3. MECHANICAL STRUCTURE STUDIES 17

5.4. COIL & YOKE STUDIES 17

5.5. BEAM BACKGROUND STUDIES 18

5.6. ALIGNMENT/CALIBRATION PROCEDURES 19

6. DETECTOR MODELLING 20

7. DETECTOR PERFORMANCE 20

8. COSTING 21

8.1. WBS TABLES 21

8.2. GLOBAL COSTING 21

9. SCIENCE WITH ILD 22

10. ILD AS AN ORGANISATION 22

11. ABBREVIATIONS 22

12. REFERENCES 22

1. THE SCIENCE CASE FOR THE ILC

Short summary of the ILC physics case, at the different center of mass energies. This is based on the recent papers published by the LCC physics group.

2. ILC ENVIRONMENT

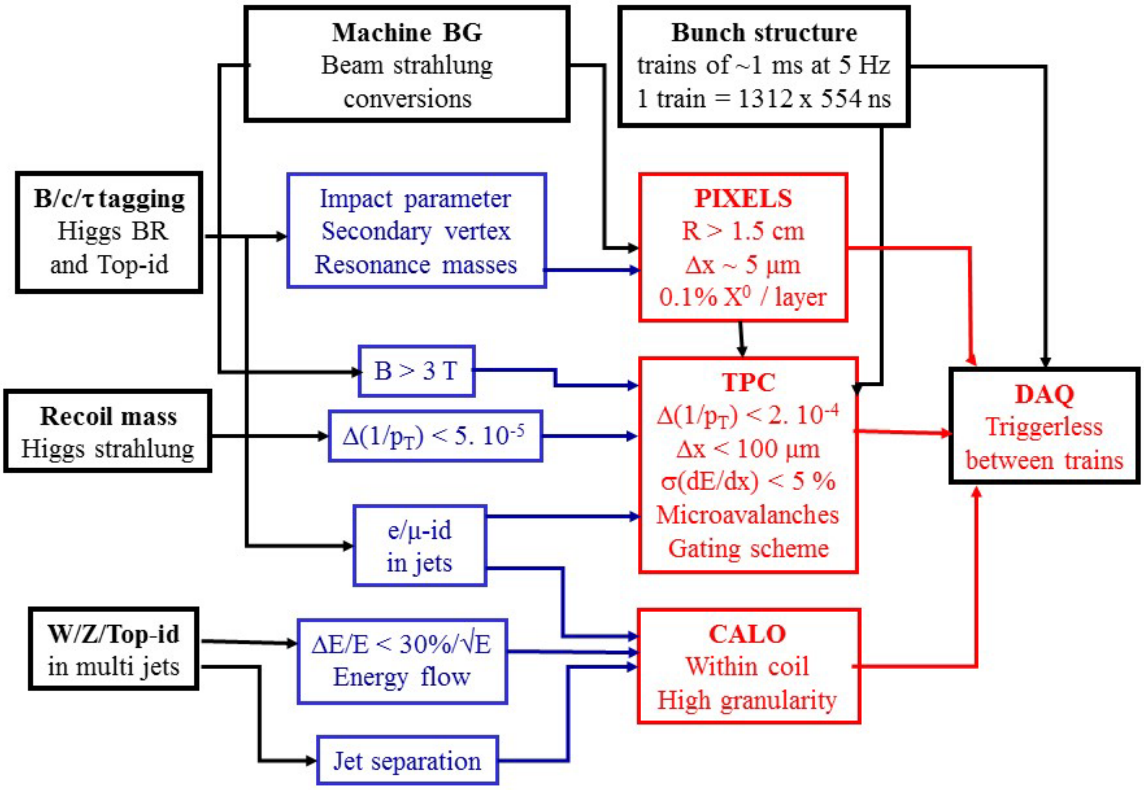
Overall ILC constraints : could be adapted from LoI intro
Updated beam conditions since DBD: new L*, backgrounds, energy profile … Main plots from machine study group.
Initial focus on 250 GeV with future upgrades to higher energies
Critical channels/issues at 250 GeV

3. ILD CONCEPT

3.1. OVERALL CONCEPT

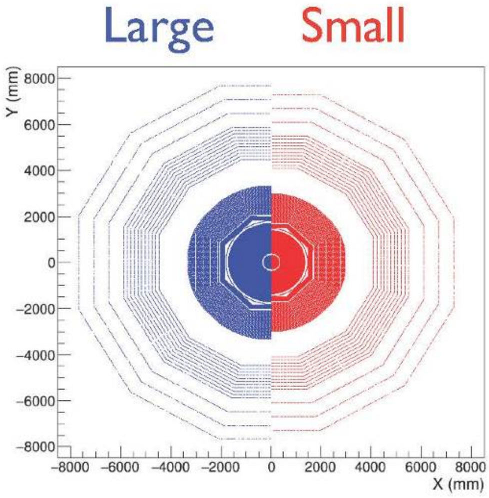
The ILD overall concept: low tracker material, high granularity, particle flow, triggerless …
Reminder of main arguments from the LoI reference for sizes, B, depth, etc…
Detector performance aspects to be anticipated for higher energies

The link between physics requirements, machine conditions and detector technical specifications could be summarized visually in a plot similar to the following (initially made 15 years ago for TESLA advertizing…)



3.2. OPTIMISATION PATH

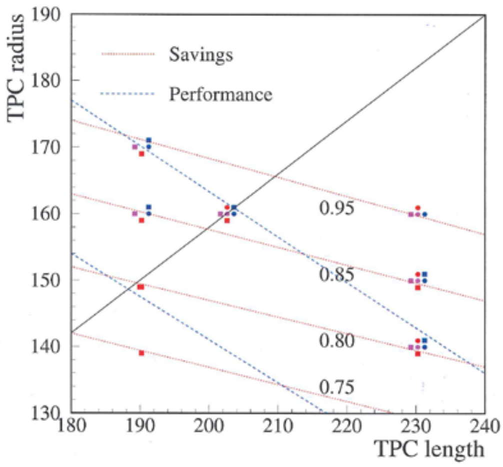
The 2 global size options and their rationale: 1 DBD-like as reference and 1 smaller radius/same length



Main parameters for the 2 size options
(table to be updated)

Detektor	DBD (ILD-L)	Small ILD (ILD-S)
B-Field	3.5 T	4 T
VTX inner radius	1.6 cm	1.6 cm
TPC inner radius	33 cm	33 cm
TPC outer radius	180 cm	146 cm
TPC length (z/2)	235cm	235 cm
Inner ECAL radius	184 cm	150 cm
Outer ECAL radius	202.5 cm	168.5 cm
Inner HCAL radius	206 cm	172 cm
Outer HCAL radius	335 cm	301 cm
Coil inner radius	344 cm	310 cm

Michael's aspect/ratio performance plot to justify the r-z scaling



4. DETECTOR LAYOUT AND TECHNOLOGIES

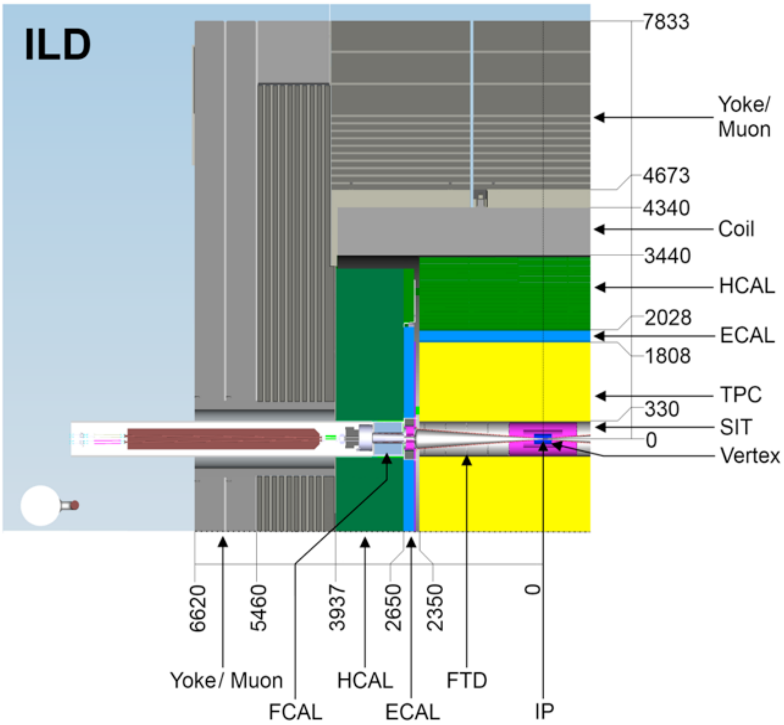
4.1. OVERALL DETECTOR STRUCTURE

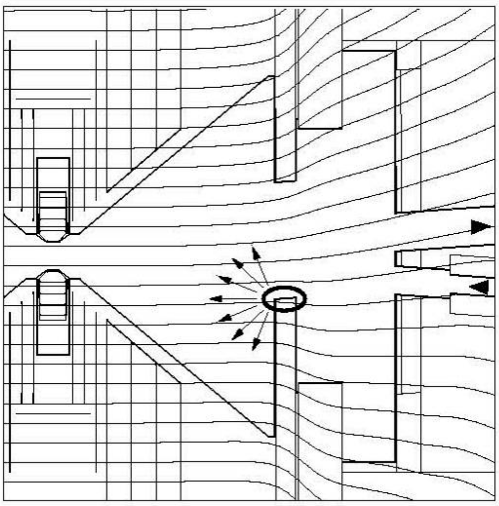
This section should be kept of reasonable size (while self-consistent) since it will mainly repeat the LoI/DBD. Details should focus on the few changes since the DBD.

4.1.1. Global structure and parameters

Proposed main editors: CDI technical conveners (~1 page of plain text)

Reminder of the global structure of the ILD detector





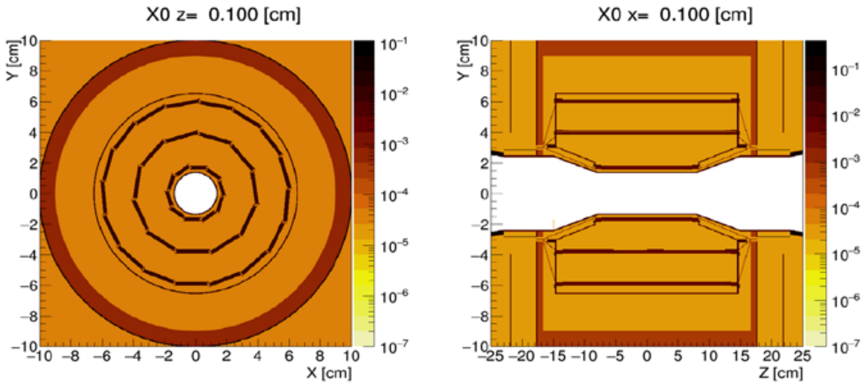
Open option for beam-beam BG mitigation: additional small dipole field ("anti-DID" option)

4.1.2. Subdetector layouts

Proposed main editors: Subdetector technical conveners (~4 pages of plain text)

Description of the latest baseline design of subdetectors, including open options. Each technology option description should indicate its advantages (pro) and critical aspects (cons) in respect to ILD specifications. Potential new capabilities for the future (e.g. calorimeter timing) should also be indicated.

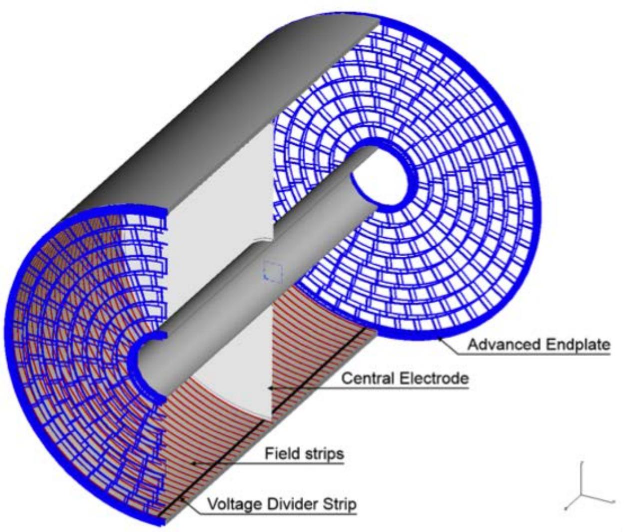
Generic vertex detector structure (# layers, dimensions, technology options)



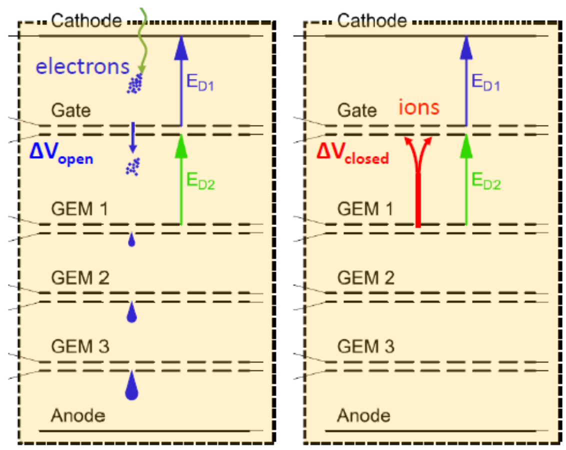
Very forward tracker (#disks, dimensions, technology per disk)

Pixel option for SiT. Short discussion status outer TPC silicon layers

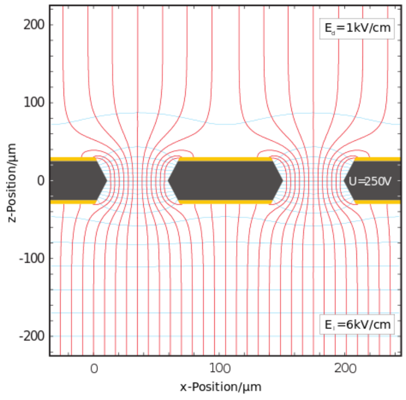
TPC layout



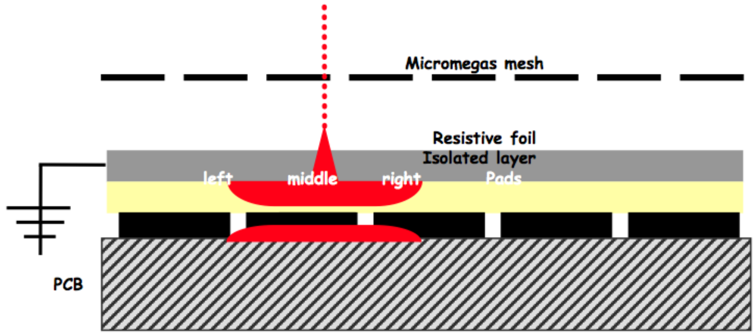
TPC gating



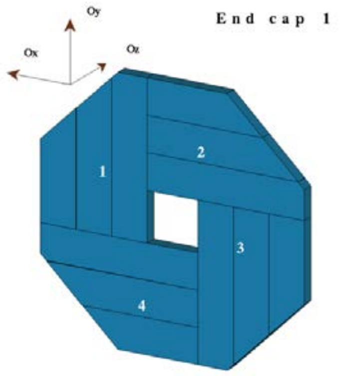
TPC readout options: GEM

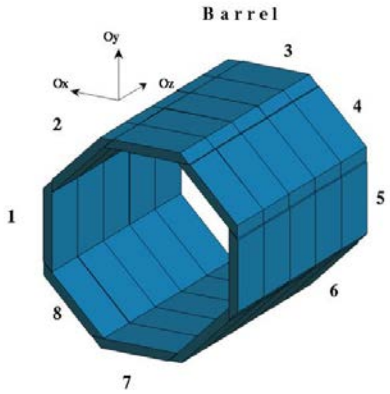


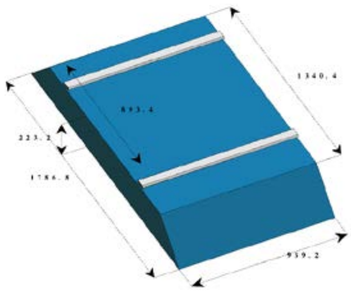
Micromegas



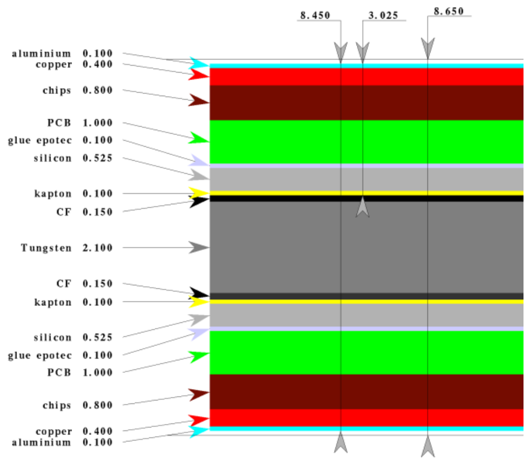
ECAL: mechanical layout

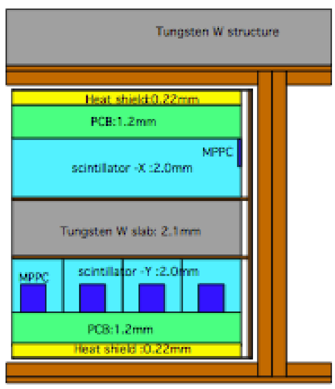




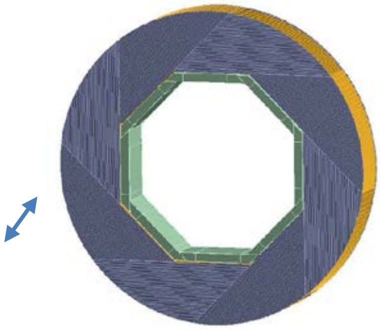


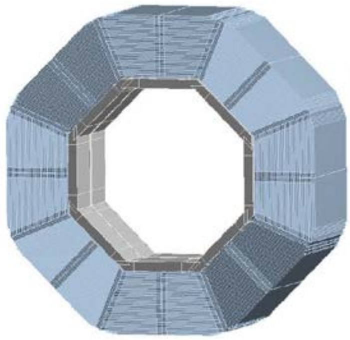
ECAL readout options: Si-ECAL updated Sc-ECAL (to be updated)

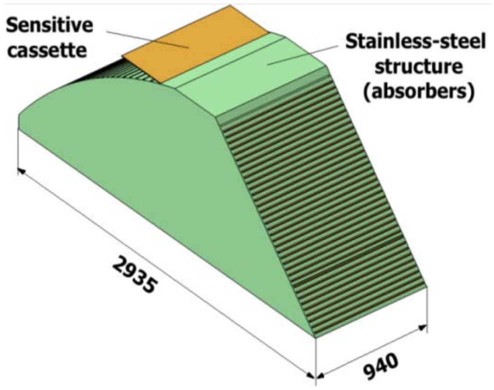


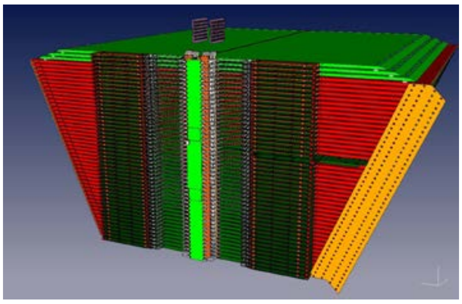


HCAL mechanical options: Videau/TESLA



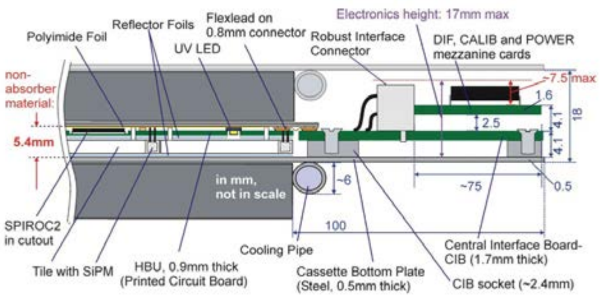




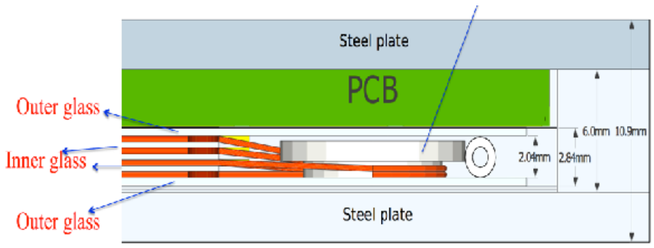


HCAL readout options:

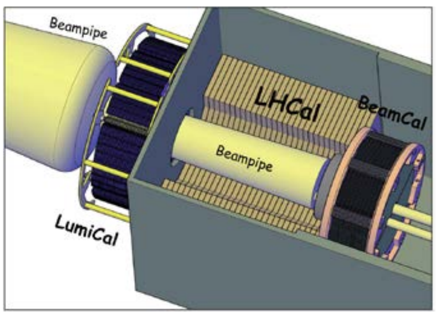
Scintillator (AHCAL)

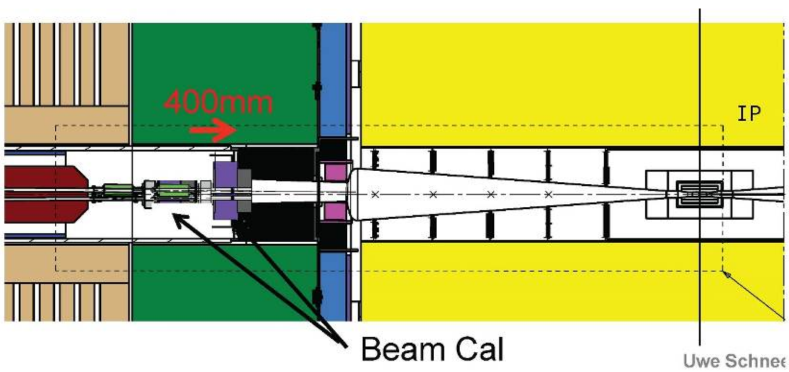


RPC (SDHCAL)

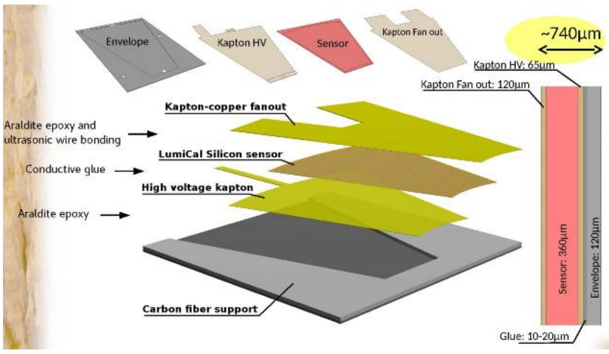


VFS layout adapted to new L*

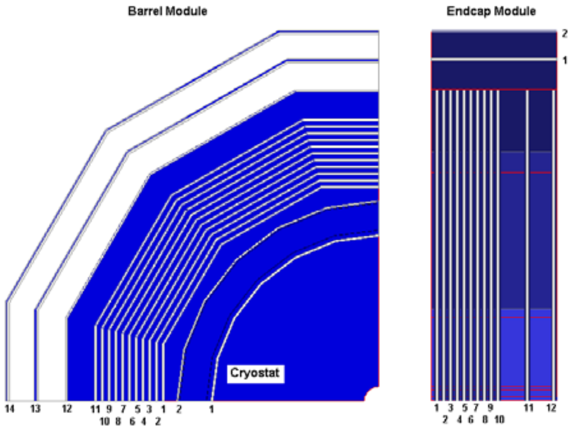




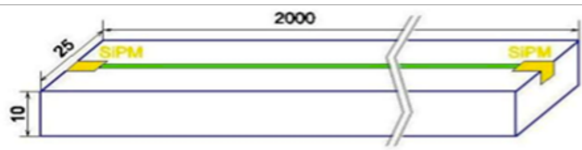
Structure of LUMICAL/BEAMCAL/LHCAL sensors



Iron instrumentation: sensitive layers in yoke baseline design



Sensor structure with scintillator strip option



4.2. SUBDETECTOR TECHNOLOGY STATUS

Proposed main editors: Subdetector technical conveners corresponding to each subsection

This section is one of the main technical added values of the IDR. It should summarize all technological progress since the DBD, including beam tests of technological prototypes and ongoing spinoffs. It should also indicate the remaining steps to fulfil the ILD requirements, with a focus of critical aspects associated to each technology choice. For conciseness only the highlights should be illustrated, with all details to be referenced in technical publications. As regards illustrations it is proposed to stick to o(1-2) photo and o(1-2) plot for each technology.

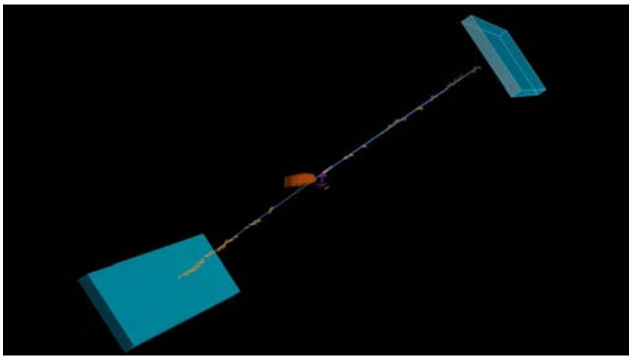
4.2.1. <u>Vertex</u> *(~3 pages of plain text)*

<u>CMOS</u>
Spin-offs: ALPIDE (ALICE upgrade) and MIMOSIS (CBM)
New PSIRA chip for ILD

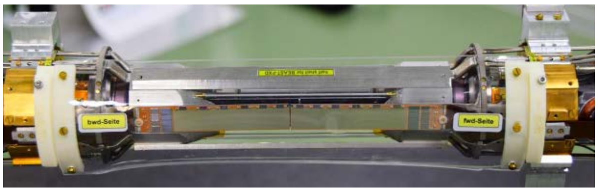
Any photo of a recent ALPIDE chip and performance plot ?

STAR CMOS detector

<u>DEPFET</u>

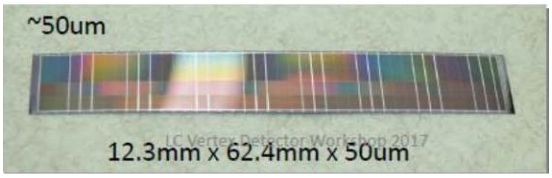


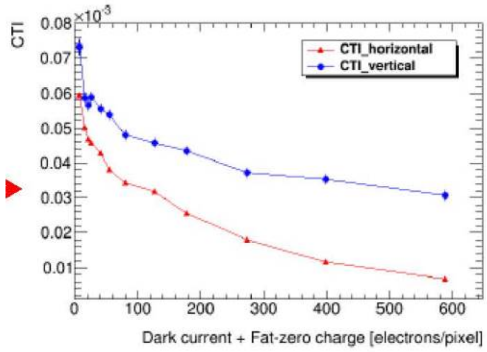
Any ILC-oriented prototype ?
Spin-offs: BELLE-2
BEAST and 1st cosmic event



<u>FPCCD</u>

Long prototype and irradiation test





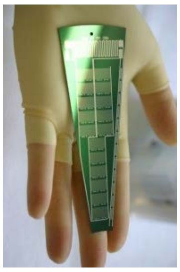
<u>Other options</u>: SOI, … (short mention)

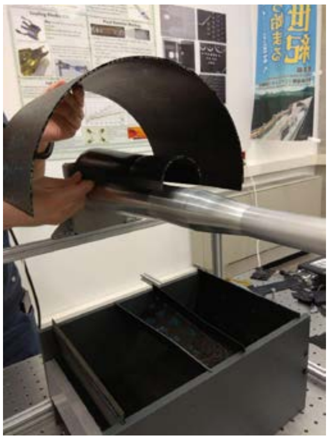
Low material support developments (PLUME ladder) and cooling studies

4.2.2. <u>Forward&Central Inner SiliconTrackers</u>

(~1 page of plain text)

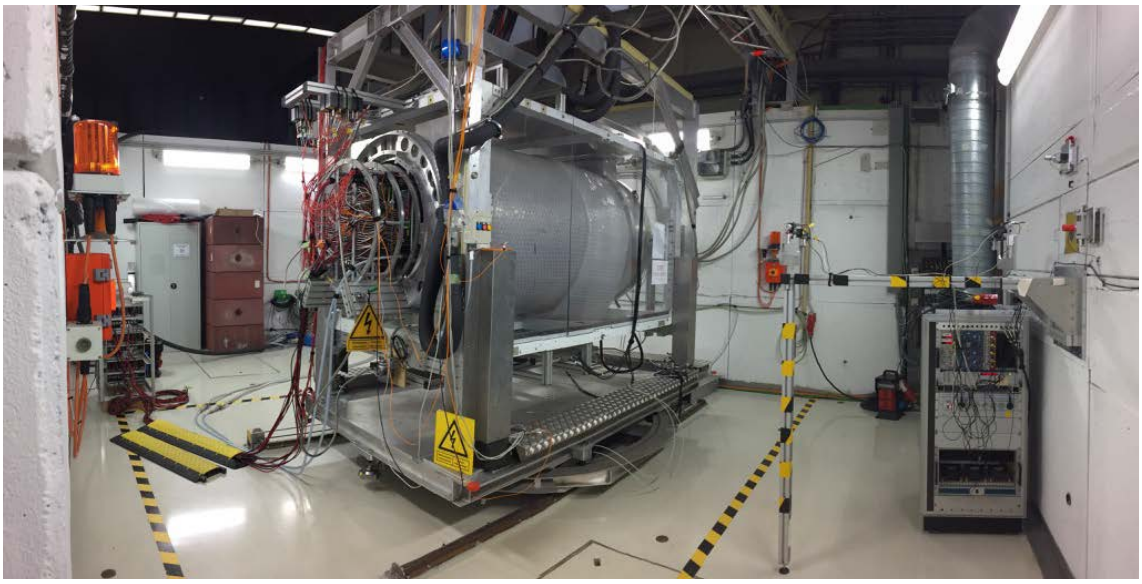
Above DEPFET developments
+ FTD thermo-mechanical mockup



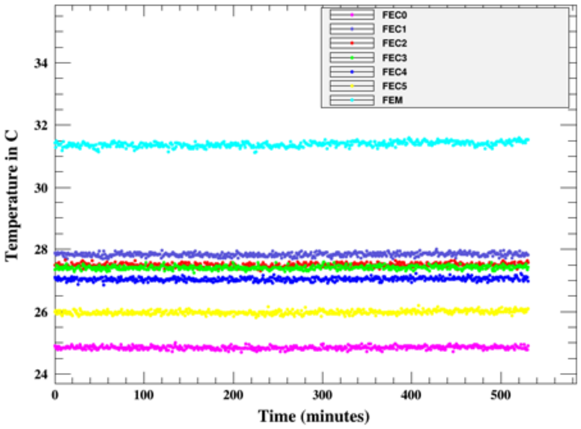


4.2.3. <u>TPC</u> *(~3 pages of plain text)*

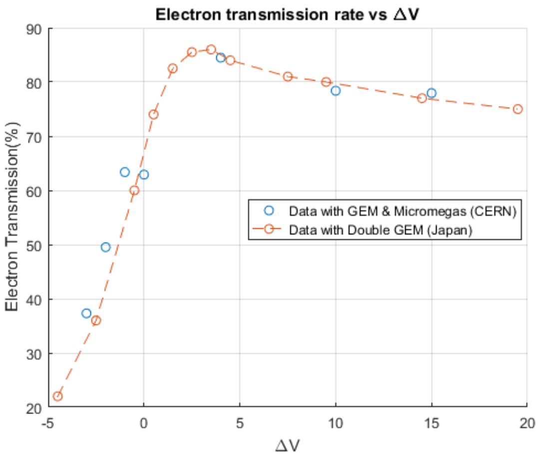
TPC prototype for generic beam tests of all readout options, the gating scheme and cooling. Mention AIDA silicon telescope and new field cage in construction.



CO2 Cooling measurements

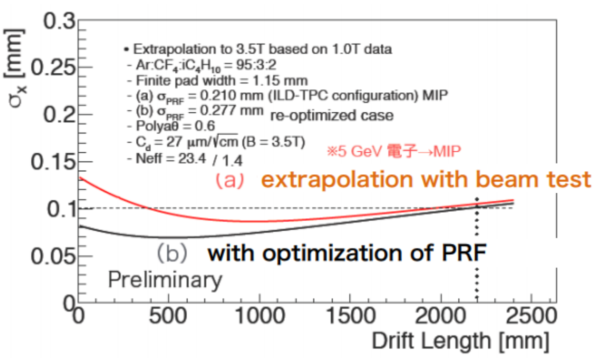


Successful gating achieved with GEM

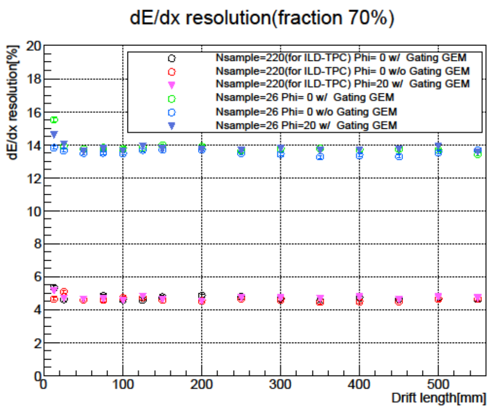


Achieved resolutions:

100 μ spatial



5% dE/dx



Mention ongoing technological developments: improved module planarity, GRIDPIX RO options, etc… Any chance to have results from the November 2018 micromegas beam test ?

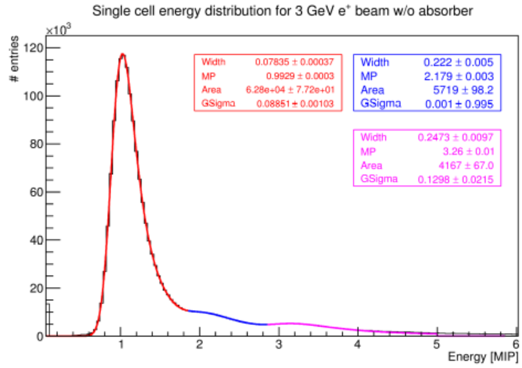
4.2.4. **Calorimeters** *(~5 pages of plain text)*

Si-ECAL

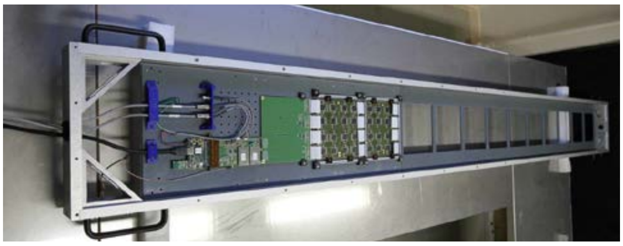
Technological prototype beamtest results

(to be updated with 2018 test)

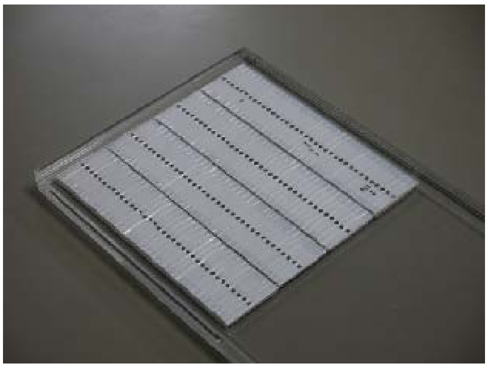
Mention CMS HGCAL spinoff

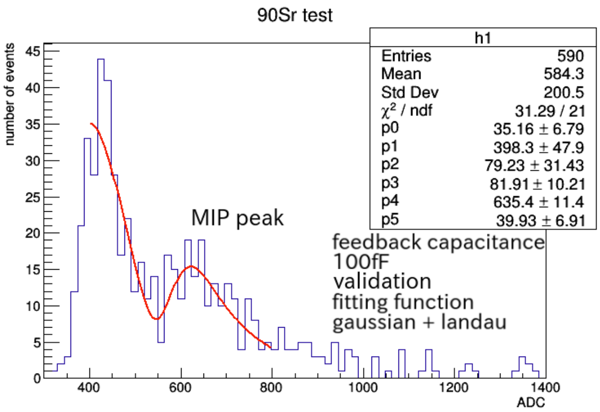


Long slab under test at LLR

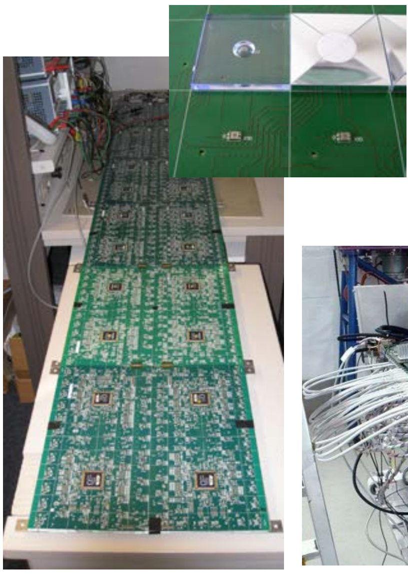


Sc-ECAL (results from new detector unit expected in 2018)





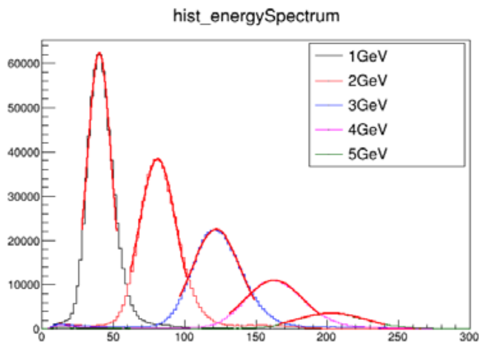
AHCAL



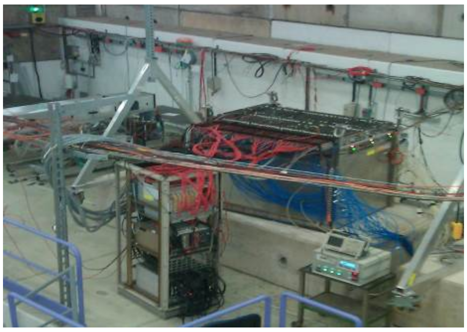
Photos and beamtest results from technological prototypes

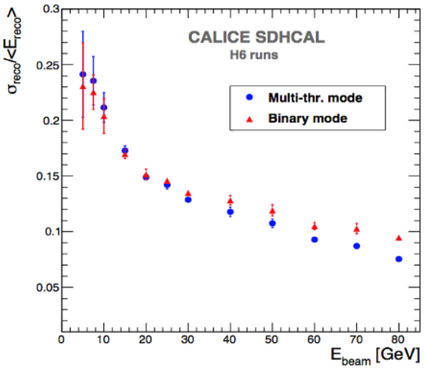
Expect results from large proto at CERN in 2018

Mention CMS HGCAL spinoff



<u>SDHCAL</u>



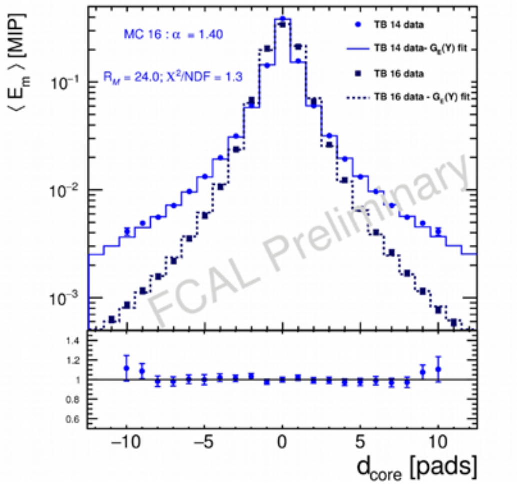


Results of beamtest of large technological prototype at CERN

Ongoing development of large RO board

4.2.5. <u>Very Forward System</u> *(~2 pages of plain text)*

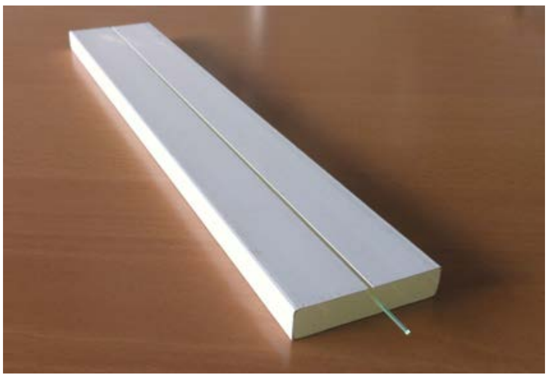
LUMICAL sensors: Beam test of thinner prototypes shows improved transverse resolution of e-showers

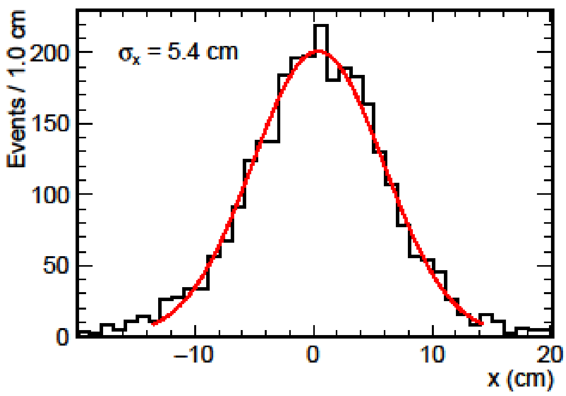


Mention also BEAMCAL and LHCAL developments: results expected from W-Sapphire tests in 2018?

4.2.6. <u>Iron Instrumentatlon</u> *(~1 page of plain text)*

Fermilab Scintillator detectors prototypes and performance tests





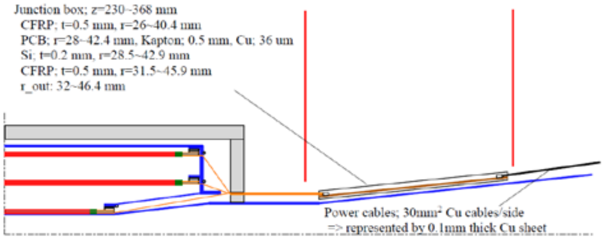
5. ILD GLOBAL INTEGRATION

5.1. INTERNAL INTEGRATION

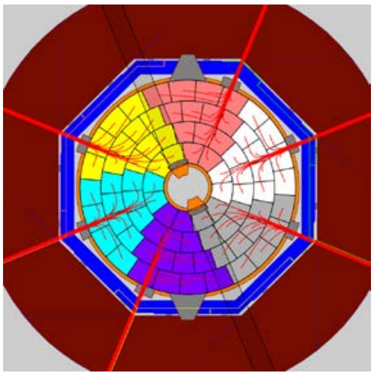
Proposed main editors: CDI conveners (~3 pages of plain text)

Subdetector interfaces and integration scheme including services. Short reminder of the overall ILD integration scheme (unchanged). Technical drawings (ideally from CAD files) showing interfaces (pipes, cables, supports) for each subdetector within ILD. New input is expected from the recently setup dedicated working group chaired by Roman to update the service paths based on subdetector Interface and Control Documents.

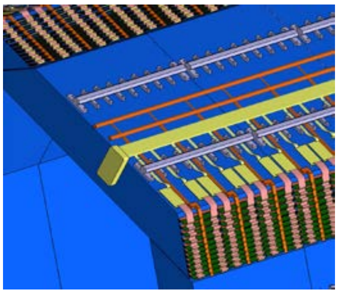
Inner tracker services



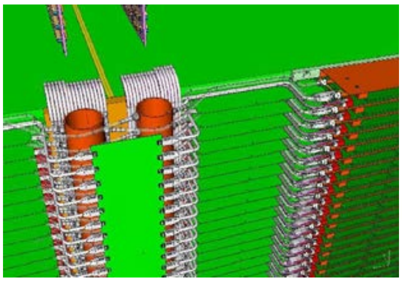
TPC services

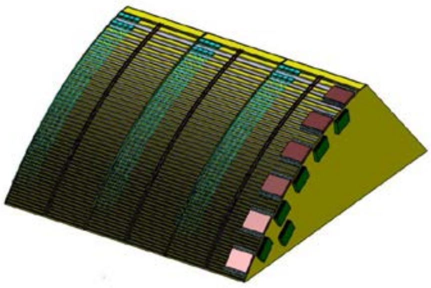


ECAL electrical interfaces

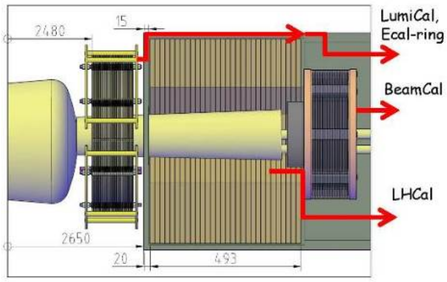


HCAL interfaces in TESLA option (AHCAL example) and Videau option (SDHCAL example)

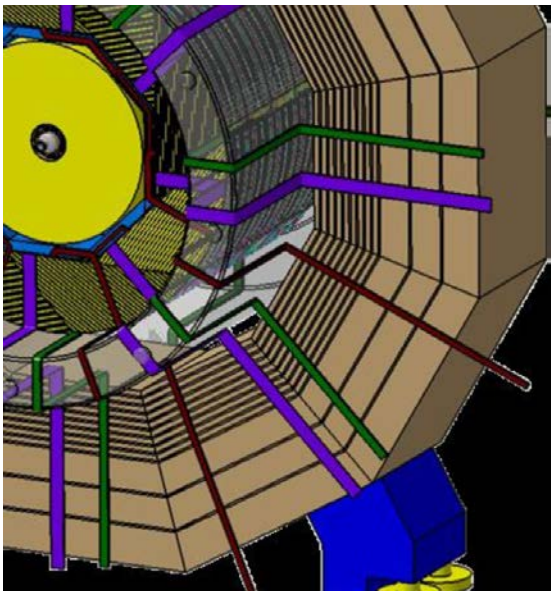




VFS cables



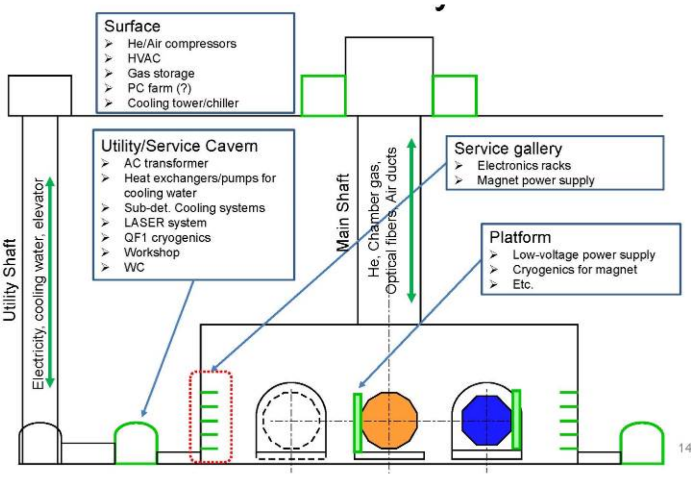
Global scheme for cable paths



5.2. EXTERNAL INTEGRATION

Proposed main editor: Yasuhiro Sugimoto
(~1 page of plain text)

Generic layout of the cavern, mentioning the current options for its configuration (TDR, Tohoku, YS…).



5.2.1. Cavern ancillary services

Proposed main editor: Yasuhiro Sugimoto
(~3 pages of plain text)

Summary of ancillary services from subdetectors in the cavern and on surface, as it will result from subdetector information to be provided in Yasuhiro's excel file.

ILD overall wish for utility space on the platform, the service gallery and the service cavern.

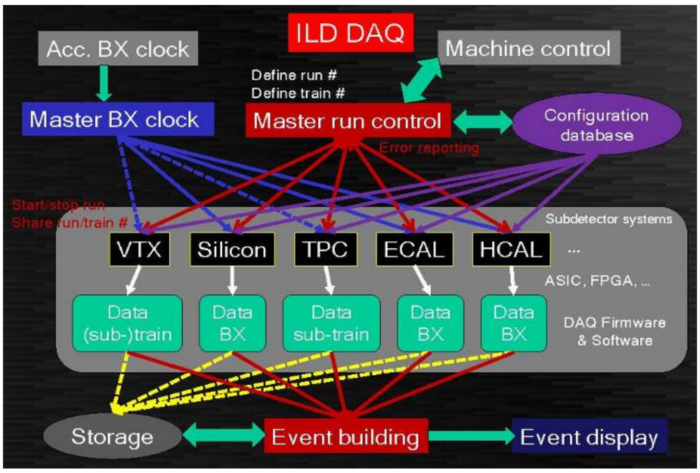
2018/2/23			VTX	SIT
Electronics Racks	Platform	Number		
		AC power (kW)		
		Heat loss (kW)		
	Service gallery	Number		
		AC power (kW)		
		Heat loss (kW)		
	U/S cavern	Number		
		AC power (kW)		
		Heat loss (kW)		
	Surface	Number		
		AC power (kW)		
		Heat loss (kW)		
Cables	Detector Hall	Heat loss (kW)		
Sub-detector cooling system	USC	Floor		
		WxDxH (m^3)	5x3x2	
		AC power (kW)		
	Cooling water	Type	Chilled	
		Heat load (kW)	1	
Gas system	Platform	WxD (m^2)		
	Service gallery	WxD (m^2)		
	U/S cavern	WxD (m^2)		
	Surface	WxD (m^2)		
Laser system	Space requirement	Location		
		WxD (m^2)		

5.2.2. Data Acquisition

Proposed main editors:
Matthew Wing and Taikan Suehara
(~2 pages of plain text)

Expected principles and sketch of the DAQ.

Summary of characteristics of subdetector data including data throughput and local filtering, based on DAQ information recently requested to all subdetectors.

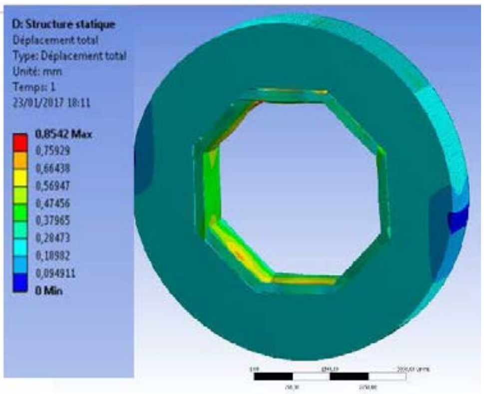


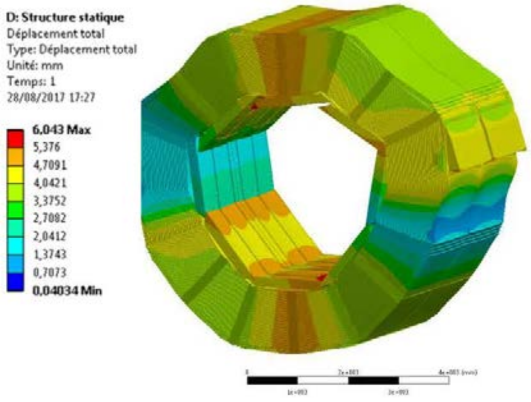
EUDAQ developments towards combined DAQ systems for beamtests

5.3. MECHANICAL STRUCTURE STUDIES

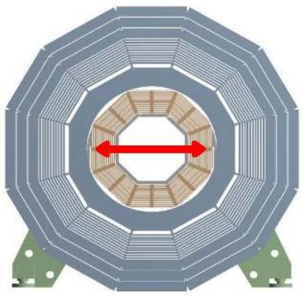
Proposed main editors: Henri Videau, Felix Sefkow and CDI conveners (~3 pages of plain text)

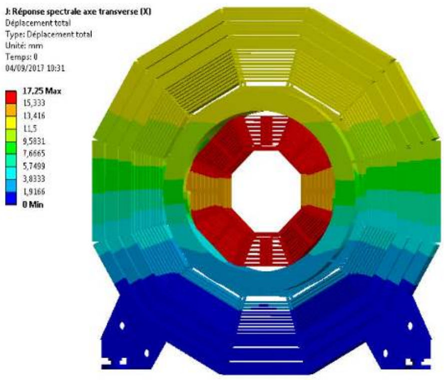
Static deformations of both structure options (TESLA/Videau) including LLR-DESY crosscheck





Dynamic behaviour of both structure options under reference earthquake spectra, including LLR-DESY crosscheck.



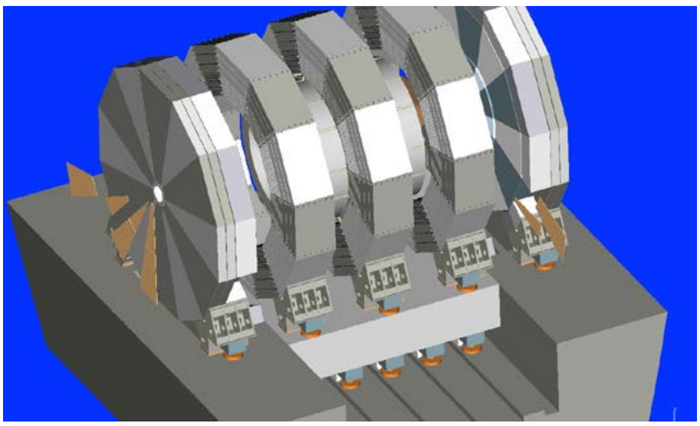


NB: new insights on the above issues are expected from the dedicated group steered by Henri, Felix, Roman and Karsten. Crosschecks between DESY and LLR will most likely restrict to the barrel. A discussion of the endcap structure may also be included.

If available, results on the mechanical behaviour of other subdetectors (e.g. TPC) are also welcome.

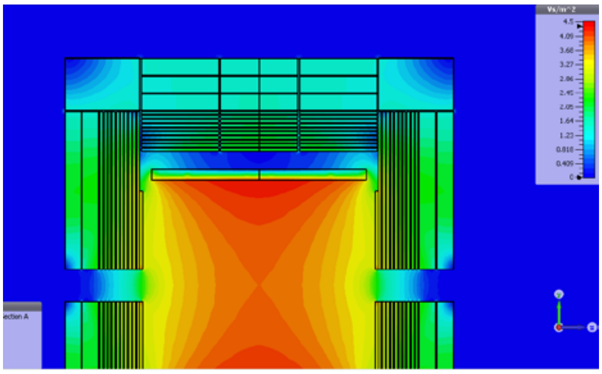
5.4. COIL & YOKE STUDIES

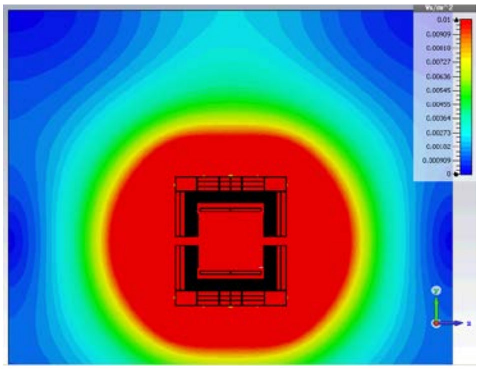
Proposed main editors:
Uwe Schneekloth and Karsten Büsser
(~3 pages of plain text)



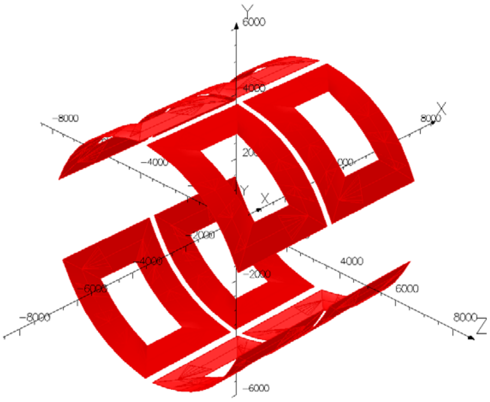
Baseline yoke design and discussion of possible lighter options including separation wall option.

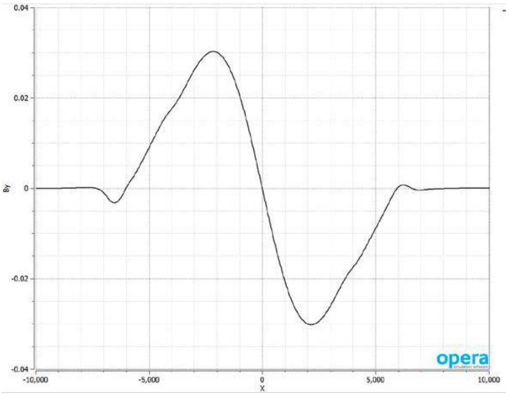
Updated field maps for the baseline yoke design. Table of field maps at various locations (including stray fields) for various yoke options.





Progress on technological design of anti-DID (KEK/Toshiba/Hitachi) and corresponding field map.

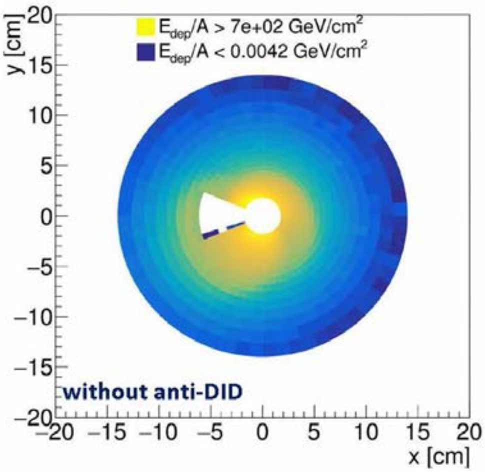


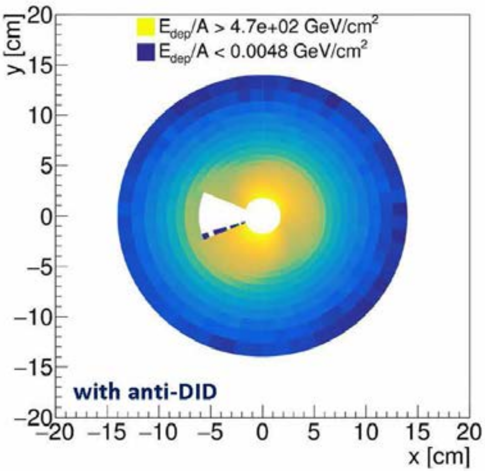


5.5. BEAM BACKGROUND STUDIES

Proposed main editors: Daniel Jeans and VFS conveners (~2 pages of plain text)

Beam-beam BG occupancies with/without anti-DID. New results are expected from Daniel soon to clarify the open points of previous studies and consolidate the estimations. The rates shown in the IDR should if possible be computed for the latest ILC250 beam conditions (input files available from Anne Schütz).





System	Layer #	N_{hit} (cm^{-2} BX^{-1})	N(t>15ns)/N	N(z_{vtx}>3m)/N	Ratio to DBD	Ratio to "noAnti-DID"
VXD	1	3.1 ± 0.5	7.3×10^{-3}	1.7×10^{-3}	1	1
	2	2.0 ± 0.4				
	3	0.14 ± 0.04				
	4	0.11 ± 0.03				
	5	0.032 ± 0.016				
	6	0.027 ± 0.015				
SIT	1	$(3.5 \pm 1.3) \times 10^{-3}$	0.86	0.56	1	0.64
	2	$(2.8 \pm 1.3) \times 10^{-3}$				0.70
	3	$(2.0 \pm 0.5) \times 10^{-3}$			~1.8	0.61
	4	$(1.9 \pm 0.6) \times 10^{-3}$				0.66
FTD	1	0.038 ± 0.011	0.44	0.36	1	1
	2	0.023 ± 0.010				1
	3	0.014 ± 0.004				0.7
	4	0.011 ± 0.002				0.7
	5	0.009 ± 0.003				0.7
	6	0.005 ± 0.002				0.7
	7	0.003 ± 0.002				0.6
System		N_{hit} (BX^{-1})				
TPC	Total	150 ± 440	0.56	0.07	2	1

It would also be good to provide hit maps from backscattered neutrons from the beamdump and from halo muons, using input particle files from Anne Schütz.

5.6. ALIGNMENT/CALIBRATION PROCEDURES

Proposed main editor: Graham Wilson with subdetector conveners (~1 page of plain text)

There was little progress here since the LOI/DBD. Most of the corresponding text of these documents could be recovered and summarized for the IDR, taking into account the latest considerations about in-situ calibration with particles/collisions and subdetector requirements.

6. DETECTOR MODELLING

Content expected mainly from software group

- New DD4HEP framework
- GEANT4 level of details
- Hybrid options for calorimeters
- Digitisation implementation
- Method for BG overlap and anti-DID inclusion

7. DETECTOR PERFORMANCE

Content expected mainly from physics and software groups

Performance quantified at various levels as function of size (2 models) and/or technology (hybrid simulation):

- Updated reconstruction and analysis methods
- Response to individual particles
- Global response including particle flow (ideally using both Pandora and Arbor for mutual cross-checks)
- Performance on a few physics benchmarks

8. COSTING

Proposed main editors: Henri Videau, Karsten Büsser and subdetector costing group members (~2 pages of plain text)

Short reminder of methodology (similar to DBD)

8.1. WBS TABLES

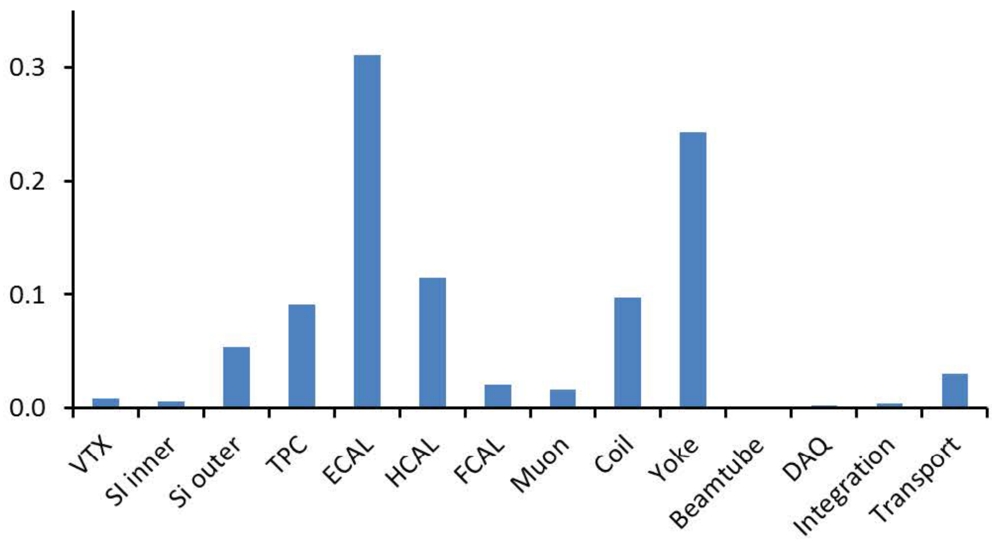
Simplified tables from subdetectors updated using latest info from technological prototypes and spinoffs. WBS tables are expected to be collected from subdetectors until summer.

	Steps/Needs	Quantities	Unit	Tools	Place	Unit cost/time	Cost in k€	M.Y	fraction	
2.	**Electromagnetic calorimeter**						**158159.14**	**115.8**		
2.1	**Barrel**	**1**					**105552.807**	**77.1**	65.7%	
2.1.1	**Module structure construction**	**40**					**14461.54**	**51.1**	13.7%	
2.1.1.1	**Material procurements and operations**						**12209.04**	**5**		
	Tungsten plates (thickness tolerance +- 40 µm) Thickness : 1.05 – 2.1 – 4.2 mm	90.3	ton		Industry Several suppliers	120	10836			
	Dimensional inspection of W plates	24000	plates	3D measurement system	HOME/Industry			5		?? Not a procurement
	Carbon fibres prepreg 1K for H structure	6000	m²		Industry	0.09	540			
	Carbon fibres prepreg 3K for alveolar structure	13000	m²		Industry	0.05	650			
	Thin carbon plate (2mm) with 12K fibres	40	plates		Industry	1	40			
	Thick carbon plate (15mm) with 12K fibres	40	plates		Industry	2	80			
	Rails fabrication (male + female parts)	80	rails		Industry	0.5	40			
	Metal inserts	960	inserts		Industry	0.024	23.04			
2.1.1.2	**Monolayer alveolar structure**	**600**					**1812**	**15**		
	Tools procurements						**342**	**0**		
	Hextool moulds	6	moulds		Industry	50	300			
	Steel ground cores	30	cores		Industry	1	30			
	Storage boxes	40	boxes	Specific boxes	Industry	0.300	12			
	Operations						**1470**	**15**		
	Dimensional inspections (cores & moulds)	all		3D measurement system	Industry					
	Wrapping operations	600	[illegible]	Clean room	Industry	2 days	[illegible]	12		

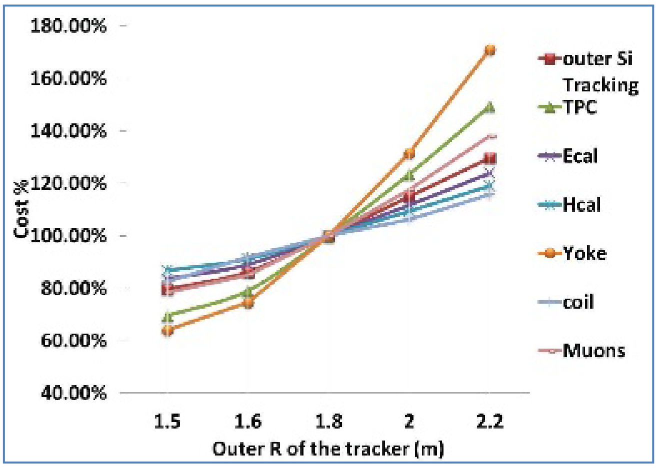
8.2. GLOBAL COSTING

Global plots to be filled from updated WBS by DESY under Karsten's supervision

Costs per subdetector (to be updated)



Variation of costs under various hypotheses (to be updated)



9. SCIENCE WITH ILD

Content expected mainly from physics group

ILD performance for key channels. This should summarise what we consider the relevant ILD performance numbers.

At the time of the IDR no decision on a new ILD baseline will have been done. We need to discuss how to handle this with regard to the physics performance. It is also rather clear that for the relevant analyses we will have a mixture of “old” and “new” simulation and reconstruction. We will not be able to fully re-do all analyses in the new software and improved reconstruction.

Document the ILD performance on key points, as reference for the next couple of years:

- Higgs branching ratios
- BSM physics at 250 GeV
- Top physics at 380 GeV
- SM physics at 500 GeV
- Higgs Self Coupling at 500 GeV and 1 TeV
- BSM reach at 1 TeV
- Rare processes at different energies

10. ILD AS AN ORGANISATION

- ILD membership
- ILD structure and people

11. ABBREVIATIONS

12. REFERENCES

[1] LoI

[2] DBD