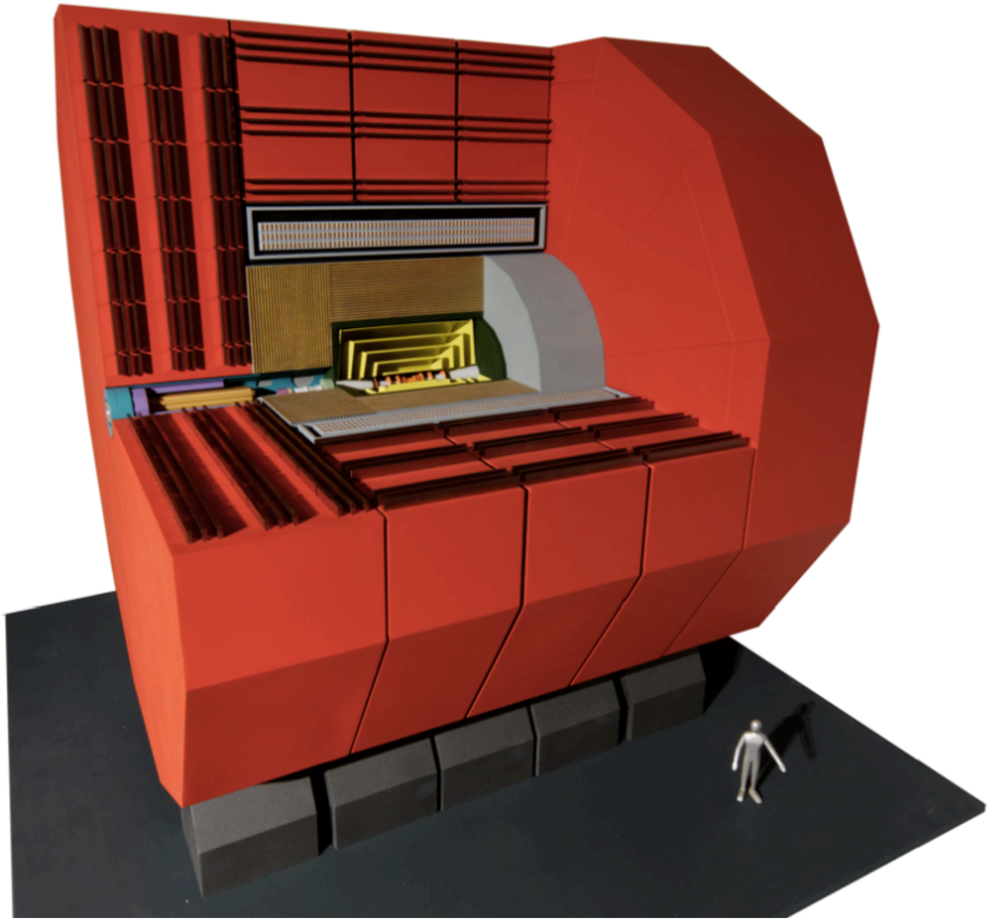
Detector optimisation studies
=>
towards a new CLIC detector model



Motivation

Current CLIC detector models CLIC_ILD and CLIC_SiD:

- Were "fixed" end 2010 for CDR benchmark studies
- Were optimised for 3 TeV (+ vertex det. study for 500 GeV, 1.4 TeV)
- Are still being used for **all** our physics studies

We continue with CLIC_ILD and CLIC_SiD for physics studies, next ~1 year.

In parallel:

Ongoing/upcoming CLICdp (and LC in general) detector optimisation studies:

- Simulation studies on various (sub-detector) areas
- Lessons learned from hardware R&D
- Solve known issues (e.g. high-occupancy regions)

Software development:

- New DD4hep detector geometry package for HEP

time line

CLIC detector optimisation studies

Vertex detector (SiD software)
ECAL study (ILD software)
Forward region (ILD software)
Tracker radius etc. (… software)
…
..

Draw conclusions on combined optimised detector model

DD4Hep development

Incl. pilot implementations
FCAL region CLIC_ILD
Calorimetry CLIC_SiD

DD4Hep validation

Incl. performance comparison for full concept

2013

2014

NEW CLIC detector model

Only one concept
Implemented in DD4hep

Detector optimisation → list

Already ongoing studies:

- Vertex detector optimisation
- ECAL optimisation studies (ILC+CLIC study)
- HCAL studies (ILD study)

Other optimisation studies:

- Reduce occupancies in various regions
- Forward region optimisation (with QD0 in or out)
- Main tracker and forward tracker
- Choice of the B-field (4-5 Tesla)
- Overall aspect ratio, barrel endcap transition

Reconstruction performance improvements:

- Improvements in electron and photon reconstruction in Pandora
- Improved jet/particle reconstruction at the edge of the tracking acceptance

Some references

CLIC CDR detector models:
CLIC_ILD geometry: LCD-note-2011-002
CLIC_SID geometry: LCD-note-2011-009

Occupancy studies for the CDR:
LCD-Note-2011-021 (with CLIC_ILD)
LCD-Note-2011-029, LCD-Note-2013-006 (TPC only)
PhD thesis Christian Grefe (with CLIC_SiD)

Optimisation of vertex and forward tracking layout in view of background:
LCD-Note-2011-031
http://arxiv.org/abs/arXiv:1203.0942

Forward region layout and engineering aspects:
PhD thesis Andre Sailer
Accelerator CDR, physics&detector CDR

PandoraPFA performance with CLIC detectors
LCD-Note-2011-028

Already ongoing studies

Already ongoing studies:

Vertex detector optimisation
https://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=312&confId=6000

ECAL optimisation studies (ILC+CLIC study)
e.g. https://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=68&confId=6000
and several other studies presented at this workshop

HCAL studies (ILD study)

Vertex detector optimisation

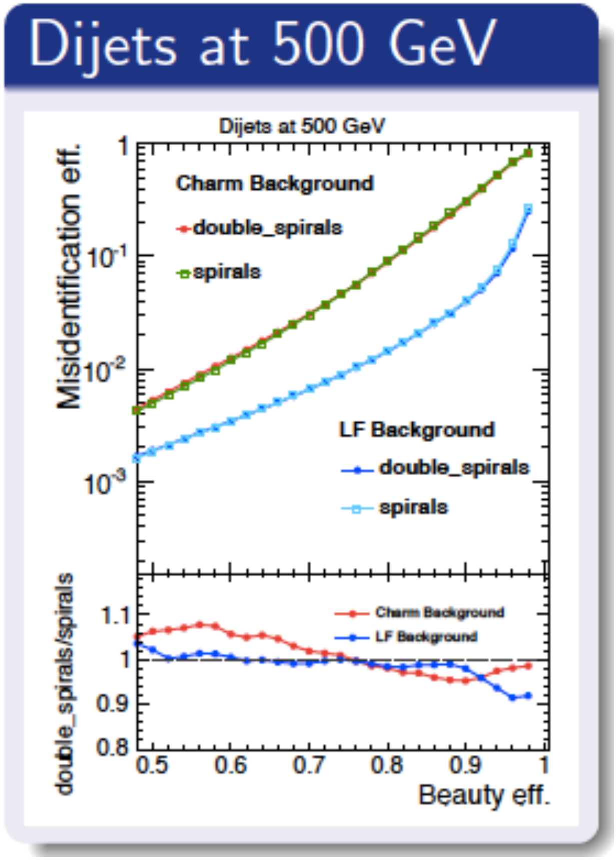
Study flavour tagging performance for different vertex layouts

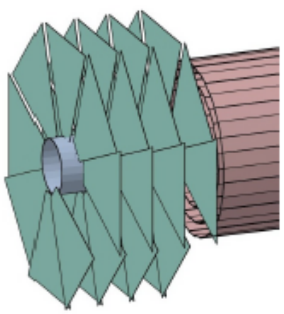
- CDR geometry
- Spiral geometry
- Double-spiral geometry
- .. With more material

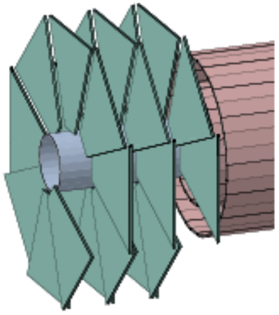
Uses input from hardware R&D

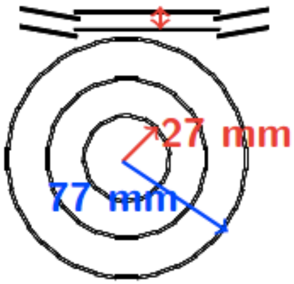
Will impact on:

- Vertex detector layout
- Tracking strategies
- Flavour-tagging strategies









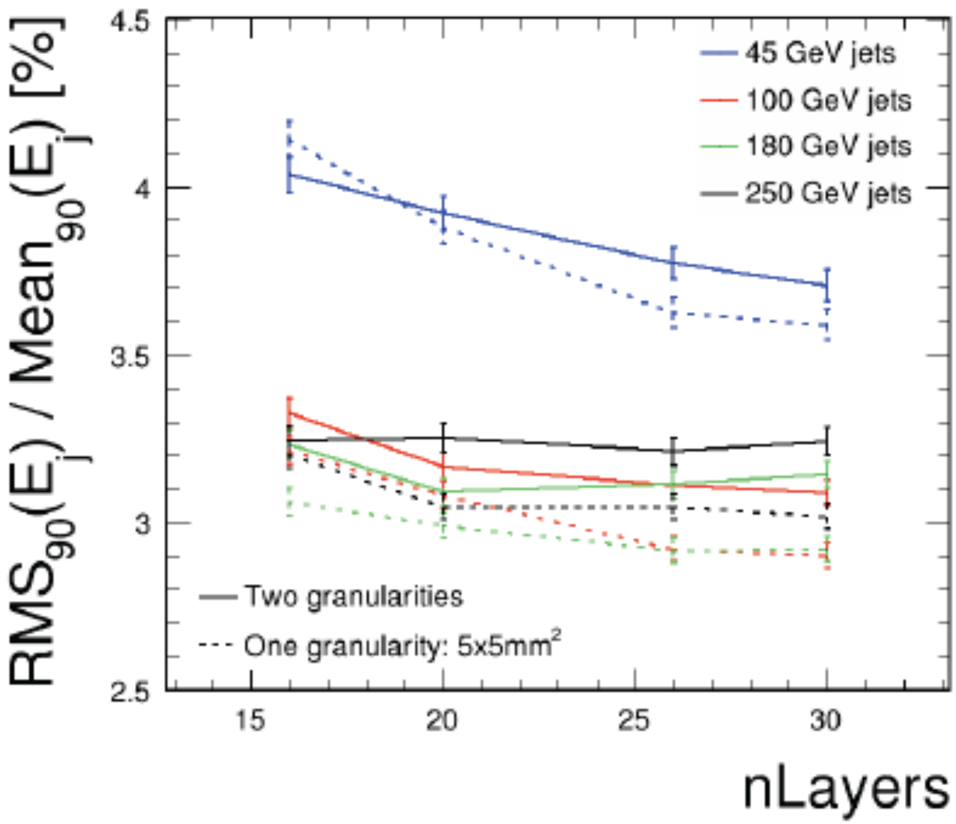
Questions ? Comments ? Ideas ?

ECAL optimisation studies

Study of jet/particle performance, Pandora for different ECAL layouts

- Technology Silicon and Scintillator
- # layers in depth
- Transverse granularity
- Granularity at different depth
- Understanding resolution
- ECAL radius
- Parametrisation of results, incl. cost

Study already very advanced

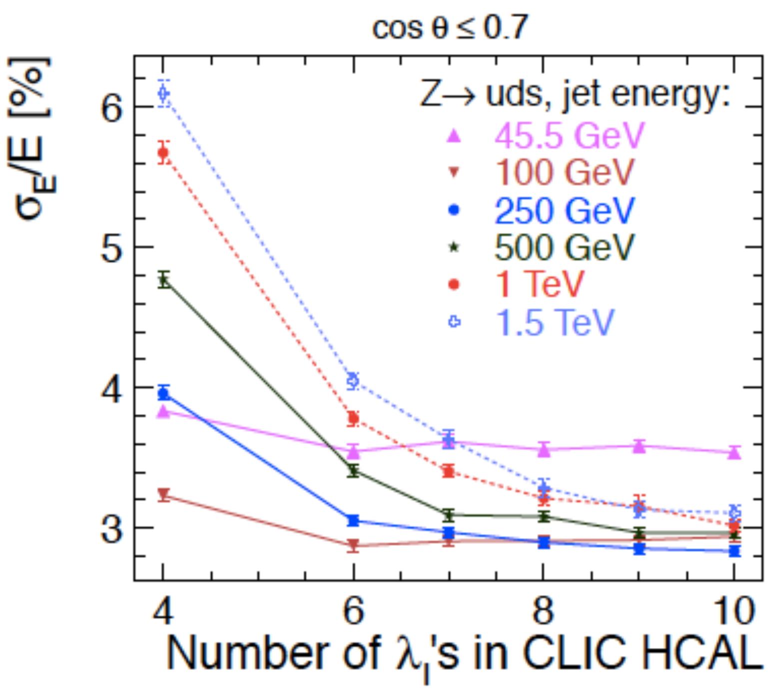


Similar ECAL studies are ongoing in CALICE and ILD

Questions ?
Comments ?
Ideas ?

HCAL studies (ILD study)

A few words by from Mark about the upcoming ILD study (e.g. vary # layers and granularity in HCAL)



HCAL depth was studied for CDR. Can probably be reduced a bit.

Questions ?
Comments ?
Ideas ?

“to do” list (optimisation)

Other optimisation studies:

- Reduce occupancies in various regions
- Forward region optimisation (with QD0 in or out)
- Main tracker and forward tracker
- Choice of the B-field (4-5 Tesla)
- Overall aspect ratio, barrel endcap transition

Questions ?
Comments ?
Ideas ?

Occupancies

Occupancies are (too) high in certain regions of CLIC_ILD and CLIC_SiD

Possible mitigation by careful design:

- E.g. low-angle region of calorimetry endcaps

Detector technologies need to be adapted:

- Inner strip tracking regions
  - => move to pixels or strixels (e.g. look what CMS is doing)

CLIC_ILD FTD occupancies
LCD-Note-2011-021

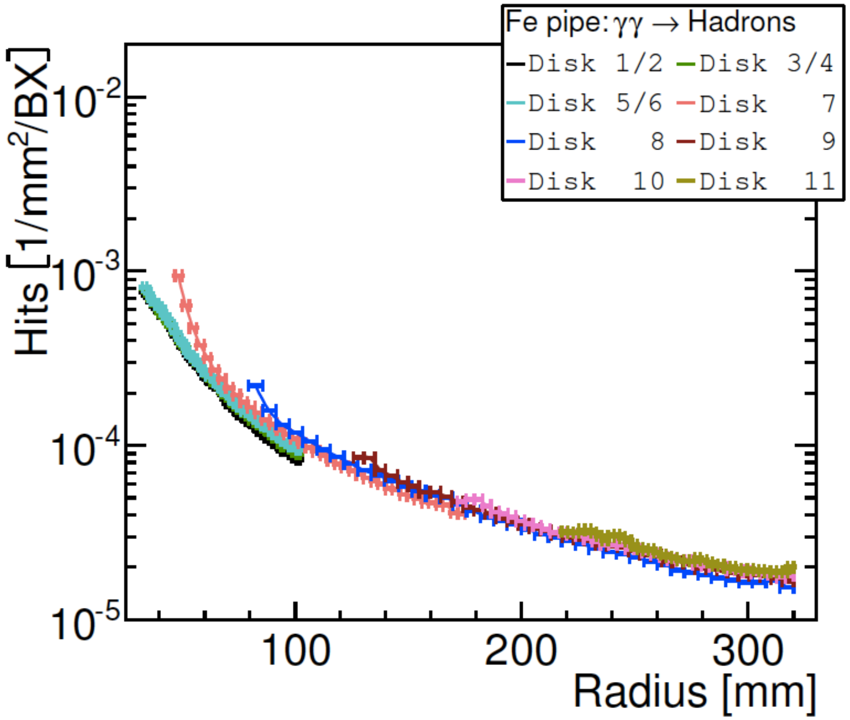


Table 10.1
CDR
Vol. 2

Table 10.1: Overview of readout details for the various subdetectors of the CLIC_ILD detector concept. Occupancies and data volumes are for a full bunch train and include charge sharing between pixels/strips. Safety factors of five and two are applied to the rates of the incoherent pairs and the $\gamma\gamma \rightarrow$ hadrons, respectively; except for the TPC, for which no safety factors have been applied. Occupancies averaged over entire subdetectors are compared to the maximum values obtained for the regions with the highest backgrounds.

	time stamping resolution [ns]	time sampling period [ns]	cell size [mm^2]	number of channels [10^6]	average to maximum occupancy [%]	number of bits per hit [bit]	data volume [Mbyte]
VTX barrel	~ 5	10	0.02×0.02	945	< 1.5 - 1.9	32	56
VTX endcap	~ 5	10	0.02×0.02	895	< 2.0 - 2.8	32	72
FTD pixels	~ 5	10	0.02×0.02	1570	0.1 - 1.0	32	6.3
FTD strips	~ 5	10 - 25	0.05×100	1.6	160 - 290	16	48
SIT	~ 5	10 - 25	0.05×90	1.0	100 - 174	16	30
SET	~ 5	10 - 25	0.05×438	5.0	17 - 17	16	150
ETD	~ 5	10 - 25	0.05×300	4.0	38 - 77	16	120
TPC	–[a]	25	1×6	3[b]	5 - 32	24	500
ECAL barrel	1	25	5×5	69.5	< 3	16	2090
ECAL endcap	1	25	5×5	43.2	60 - 150	16	1300
HCAL barrel	1	25	30×30	6.9	< 5	16	210
HCAL endcap	1	25	30×30	1.8	120 - 5200	16	54
HCAL rings	1	25	30×30	0.2	< 5	16	6.0
LumiCal	5	10	5×5	0.2	600 - 6000	32	28
BeamCal	5	10	8×8	0.1	15600[c]	32	15
MUON barrel	1	25	30×30	1.4	0.01 - 0.05	24	< 0.01
MUON endcap	1	25	30×30	2.4	0.12 - 10	24	< 0.01

[a] By combining with different subdetectors in offline reconstruction 2 ns will be achieved.
[b] The 3D TPC reads out 1000 voxels per channel for each bunch train.
[c] All cells measure a signal for each bunch crossing.

Table 10.1
CDR
Vol. 2

Table 10 ... or concept.
Occupan ... xels/strips.
Safety f ... adrons, re-
spective ... s averaged
over ent ... he highest
backgrounds.

Drives some of the detector optimisation

+

technology development needs

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[a] By combining with different subdetectors in offline reconstruction 2 ns will be achieved.
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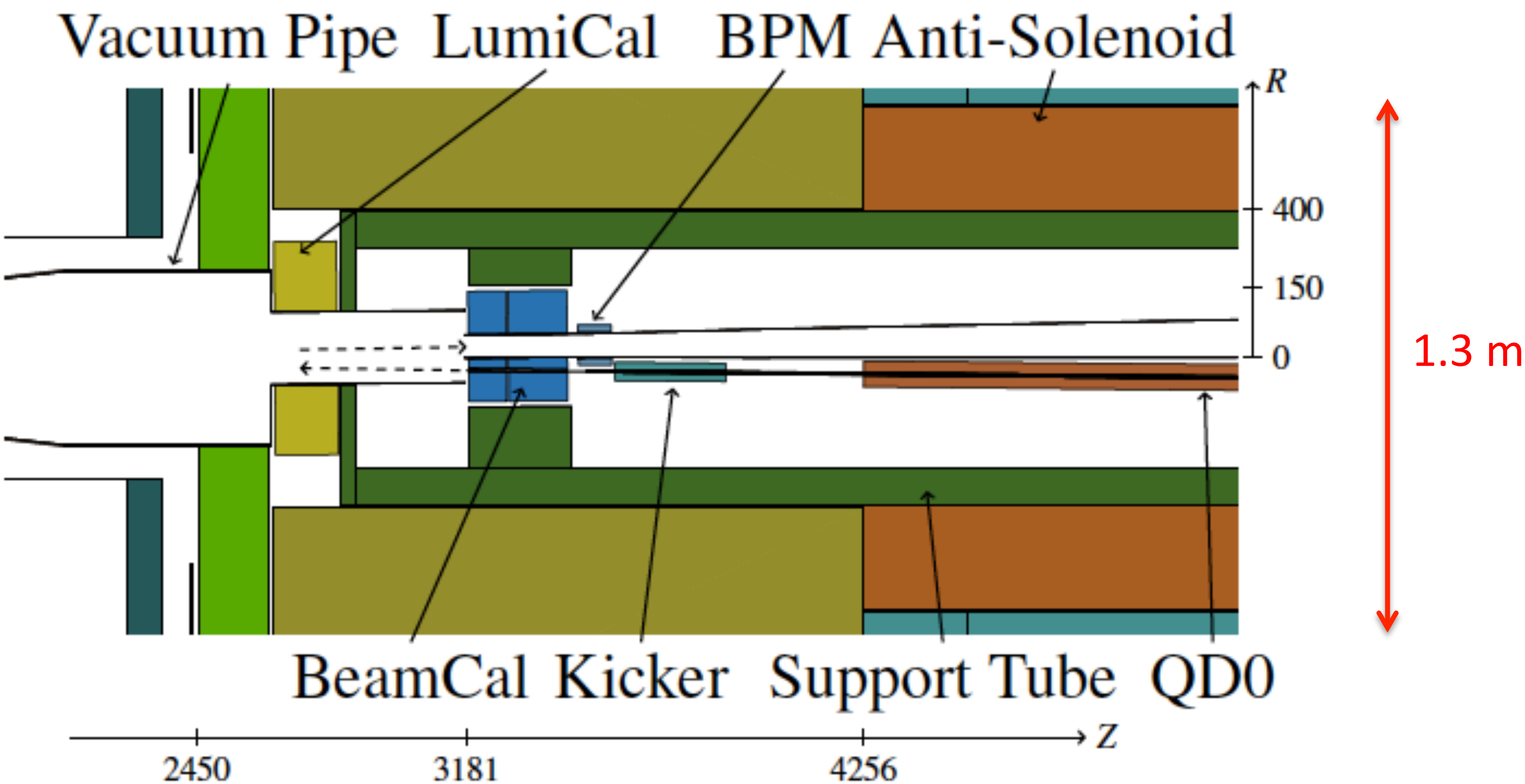
[c] All cells measure a signal for each bunch crossing.

CDR forward region optimisation

For the CDR the forward region was optimised for:

- Placement of QD0 with high mechanical stability and close to the IP
  - ➔ large impact on forward physics coverage
- Good forward coverage for electrons (ECAL + LumiCal + BeamCal)
- Minimise impact of background on vertex and tracker regions



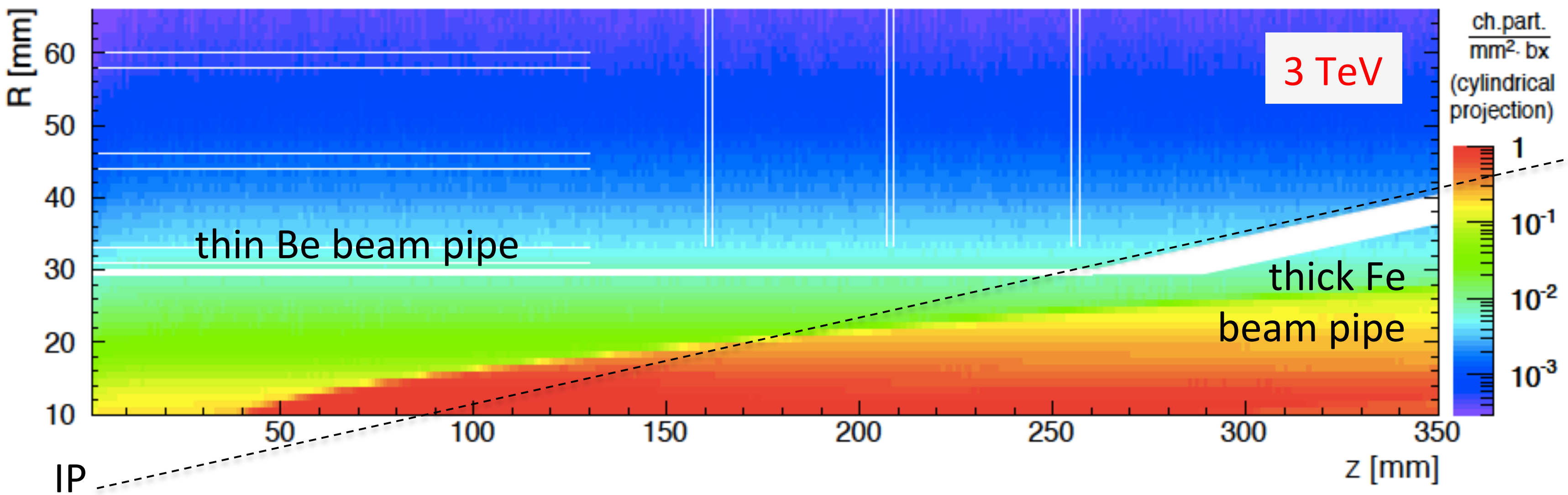
Minimum θ-angle for tracking

Vertex detector layout was adapted to occupancy from beamstrahlung

Conical part of beam-pipe => 4 mm steel

- Pointing to IP
- First measurement point does not have 4 mm steel part in front

This fixes the minimal tracking angle

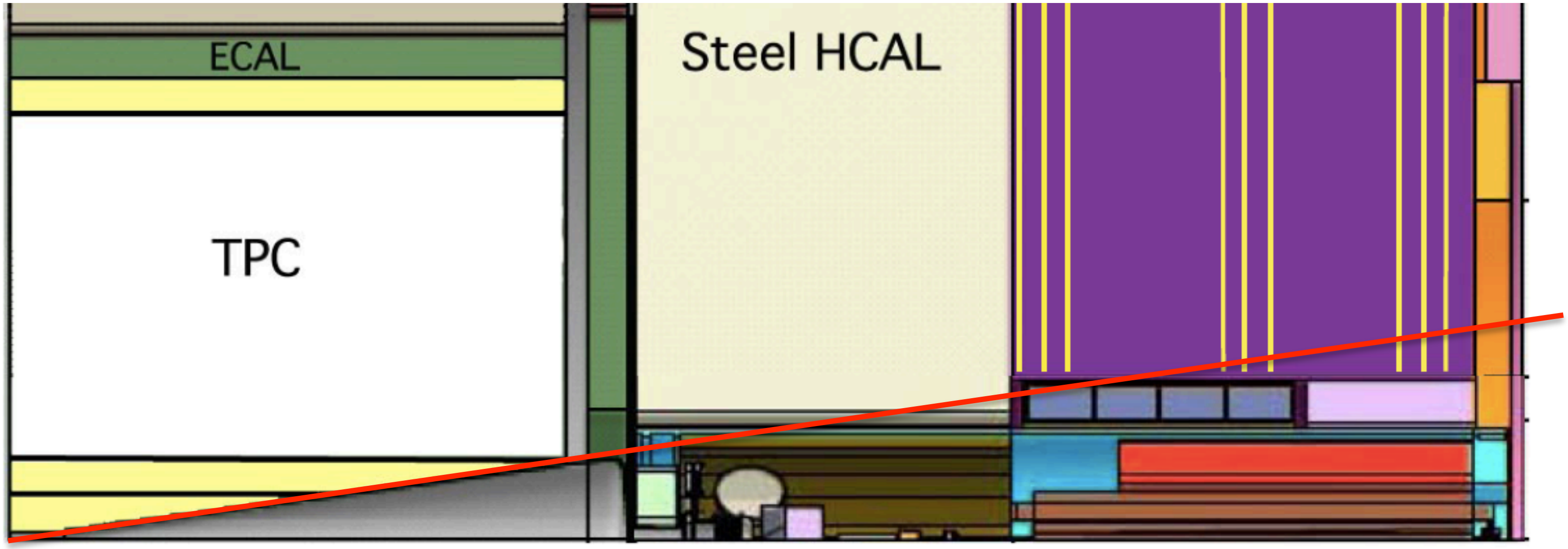


Opening angle of the beam pipe: ~6.5° in both CLIC_ILD and CLIC_SiD

Radius of first vertex layer: 31 mm in CLIC_ILD, 27 mm in CLIC_SiD

Half-length of barrel vertex layers: 130 mm in CLIC_ILD, 98.5 mm in CLIC_SiD

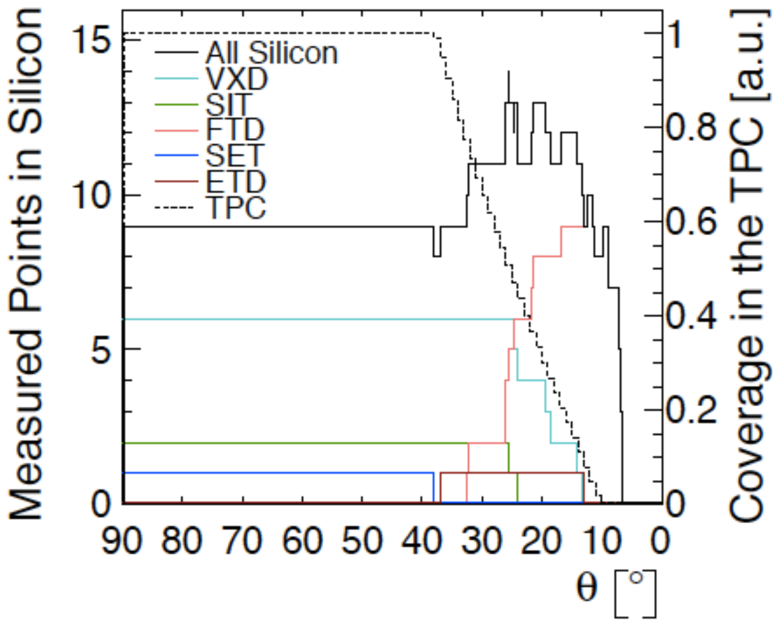
Tracking vs. HCAL and muon coverage



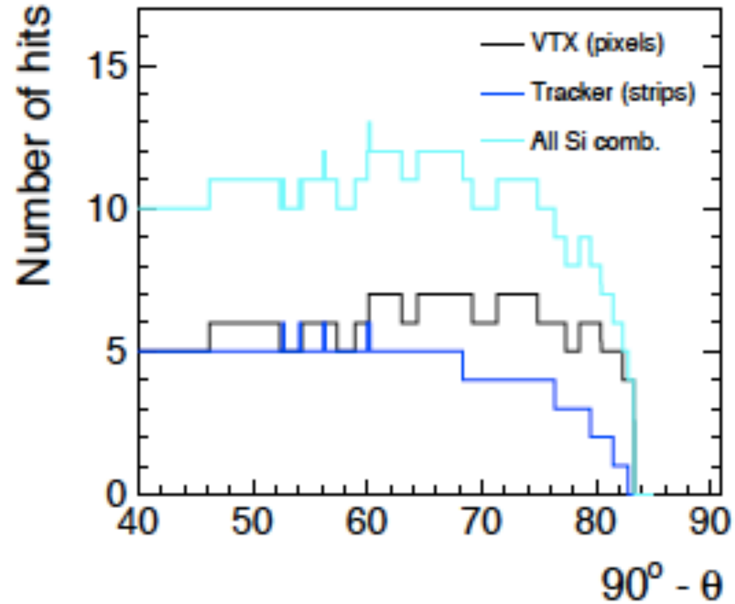
CLIC-ILD

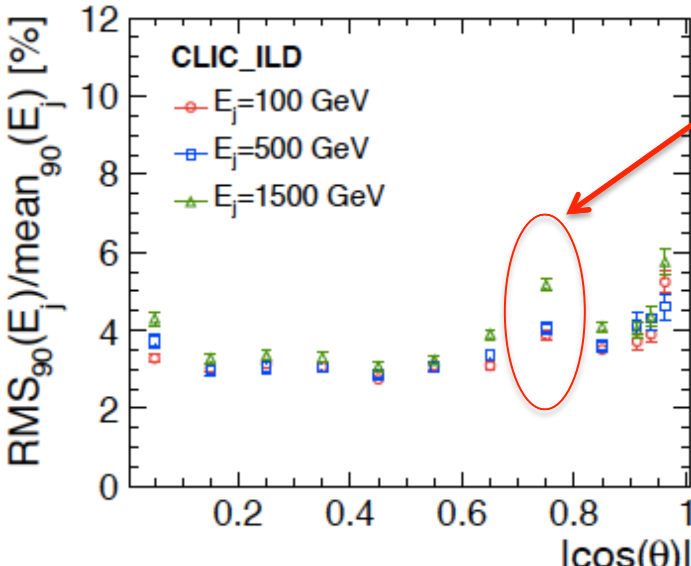
CLIC-SiD

CLIC_ILD tracking/calo coverage



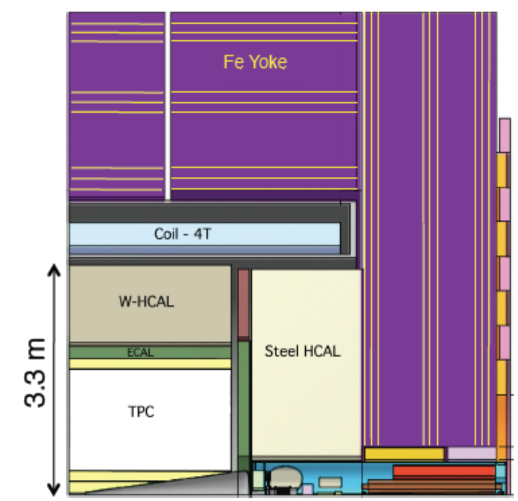
CLIC_ILD silicon only



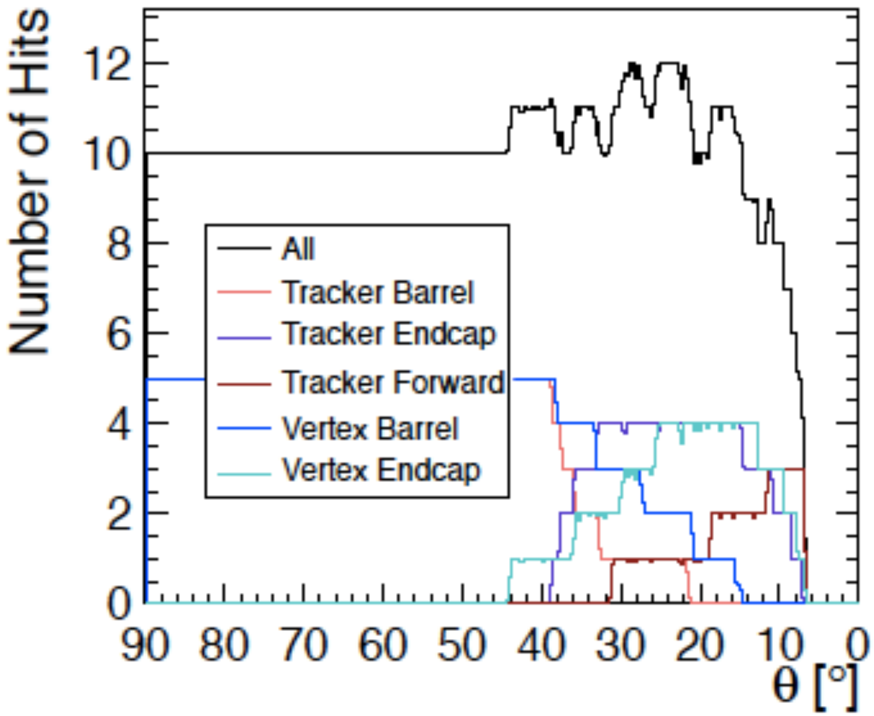


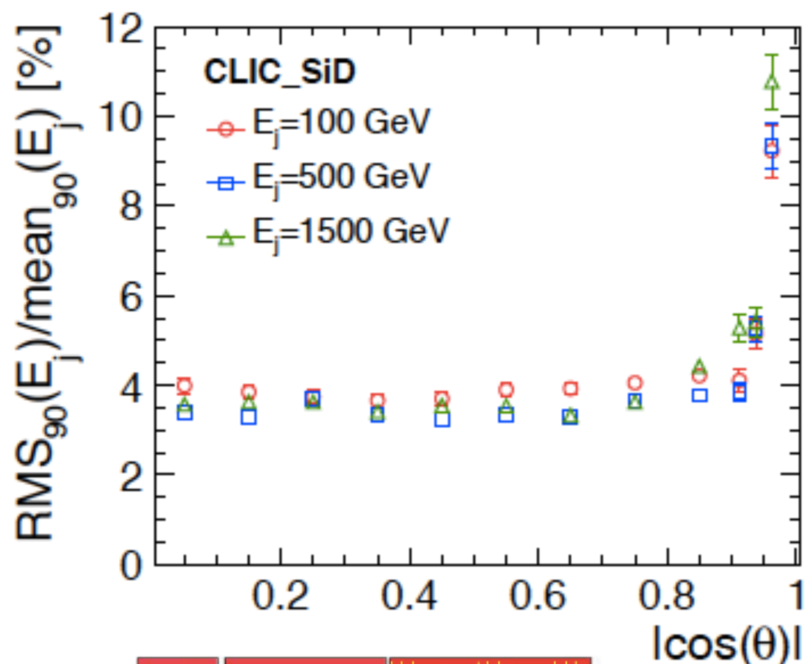
Barrel/endcap transition

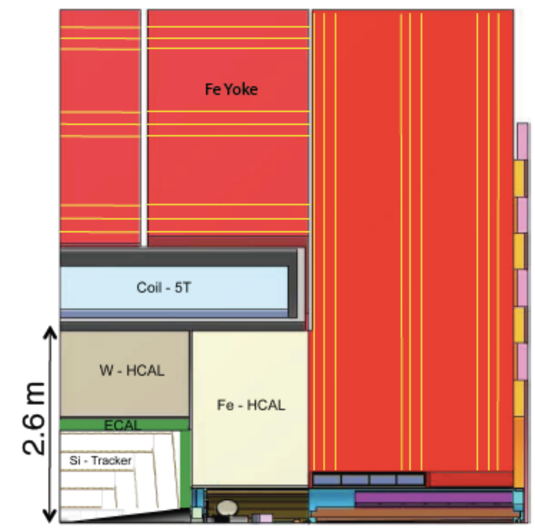
cos(7 degrees) = 0.992



CLIC_SiD tracking/calo coverage







Forward region optimisation (QD0 in or out)

Forward region optimisation

- Final focus QD0 inside or outside the detector ?
  - Trade-off between luminosity and detector acceptance
- Understand physics requirements for forward coverage
  - Triple Higgs study
  - ??
  - ??
- Impact on coverage in endcap calorimetry and muon detection

Questions ?
Comments ?
Ideas ?

Main tracker and forward tracker
Choice of the B-field
Overall aspect ratio, barrel/endcap transition

Possible studies:

- Main tracker radius
- Tracker layout and number of layers
- Cell sizes (pixels / strips / large pixels)
- Trade-off: tracker radius ⇔ B-field ⇔ performance
- Trade-off: B-field ⇔ inner vertex radius ⇔ background ⇔ performance
- Consistent design among: vertex +forward tracker + main tracker

Final focusing QD0 in or out:

- length of experiment in Z is limited
- Opening of the detector on interaction point seems excluded
- Aspect ratio (transition between barrel and endcap) will be determined by tracker radius and yoke depth

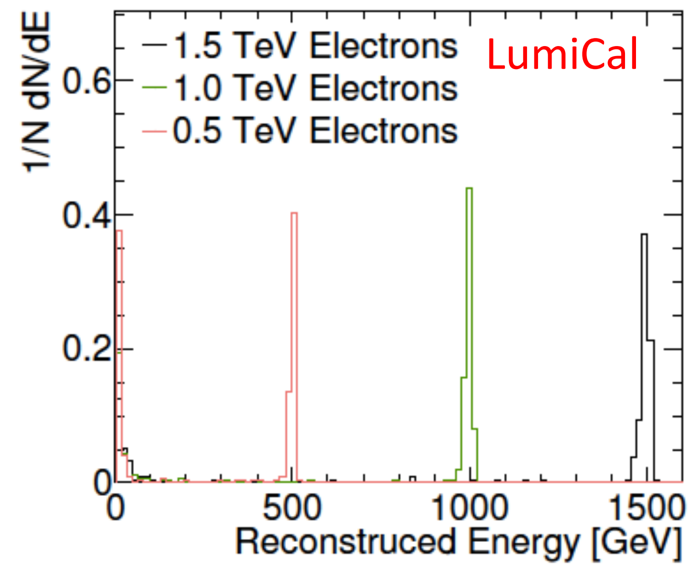
(Collect all existing results/plot of performance across transition region)

Questions ?
Comments ?
Ideas ?

Reconstruction performance

Reconstruction performance improvements:

- Improvements in electron and photon reconstruction in Pandora
- Inclusion of BeamCal/Lumical data in the full-detector reconstruction
- Improved jet/particle reconstruction at the edge of the tracking acceptance

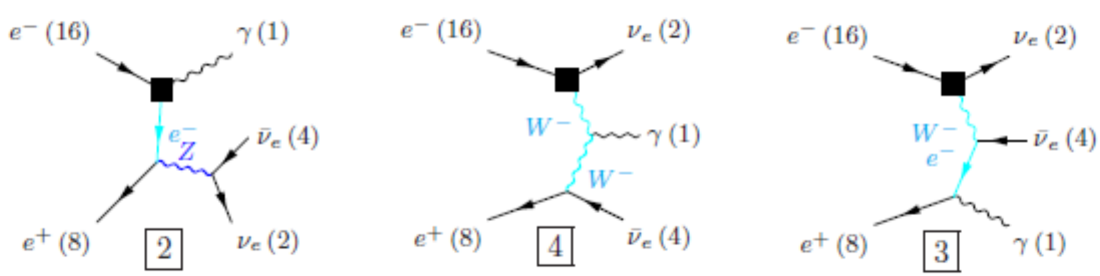


Example: Dark matter search

https://indico.cern.ch/contributionDisplay.py?contribId=36&confId=267137

Signal: e+e- => DM particle + photon from ISR

Background: ↓



Questions ?
Comments ?
Ideas ?

ideas and volunteers are welcome !

In most areas, this work can be done with, and profits of:

Please sign up for the CLIC workshop February 3-5(7)
http://indico.cern.ch/conferenceDisplay.py?confId=275412