Summary of CLICdp Detector optimisation studies

Rosa Simoniello (CERN) on behalf of the CLICdp collaboration

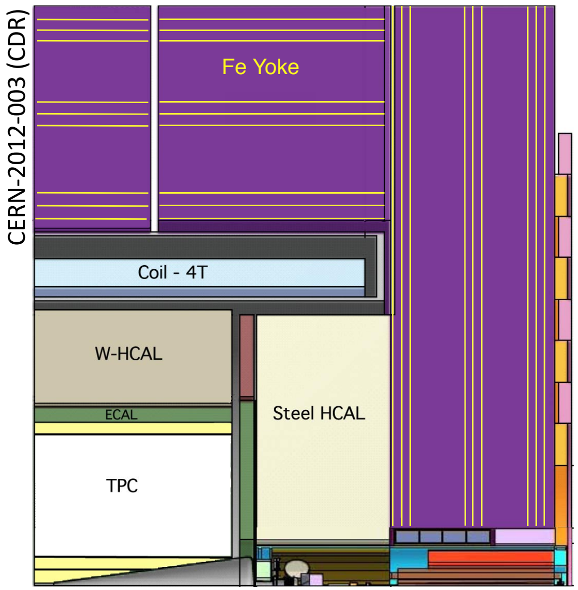
LCWS 2014, Belgrade

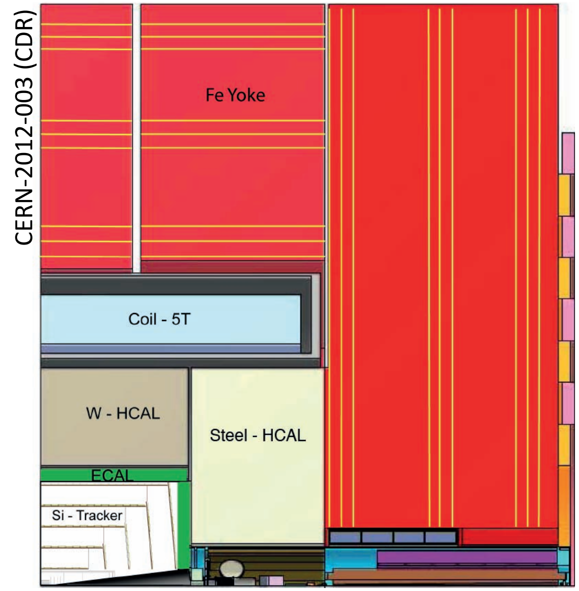
Thanks to everyone who has provided material and discussion!

From CLIC_ILD and CLIC_SiD models…

CLIC_ILD:
- *larger inner tracker and lower B field (4T)*
- *calorimeter and forward region model (and technical implementation) more defined*

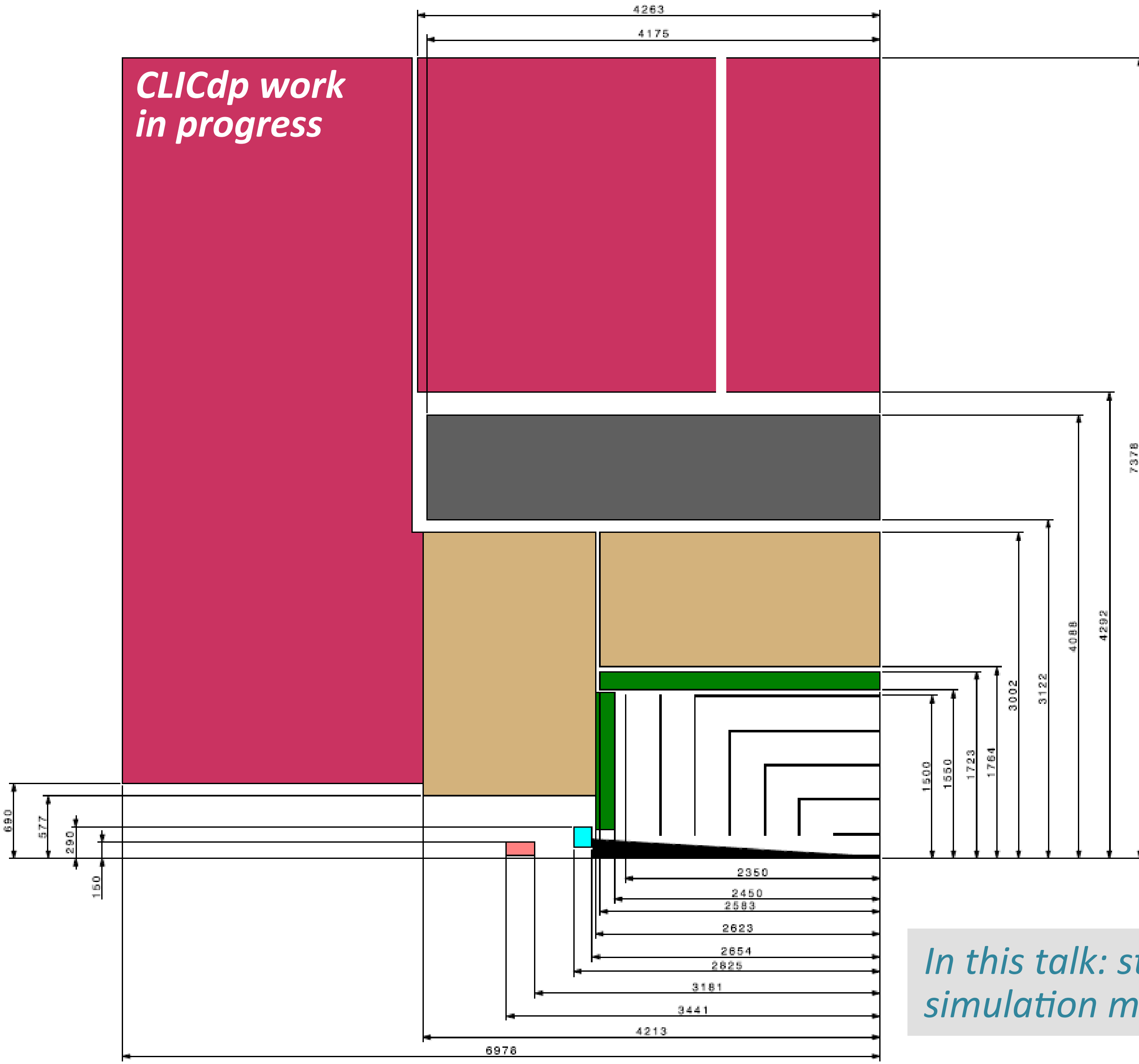
CLIC_SiD:
- *smaller inner tracker and higher B field (5T)*
- *full Si tracker*





	B field [T]	VTX r_{min} [mm]	Trk tech-nology	Trk z_{max} [m]	ECAL r_{min} [m]	ECAL Δr [mm]	HCAL absorber	HCAL λ_I	Overall H [m]	Overall L [m]
CLIC_ILD	4	31	Si+TPC	2.3	1.8	172	W/Fe	7.5	14.0	14.0
CLIC_SiD	5	27	Si	1.6	1.3	135	W/Fe	7.5	12.8	12.8

… towards a new detector model



Simulation model:

- VTX: double layers
- Full Si tracker
- Trk half length 2.3 m
- Trk outer radius 1.5 m
- Ecal and Hcal layout under study
- B field value ~4.5 T (still under discussion for occupancy studies)

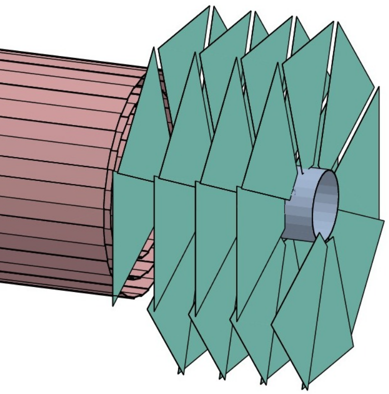
→ *Preliminary model: many parameters still under optimisation!*

→ *Plan to have the defined model at the end of the year*

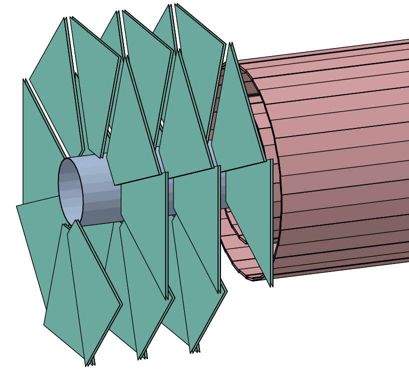
In this talk: studies to define the next simulation model, no choice of technology

See more in N. Alipour's talk

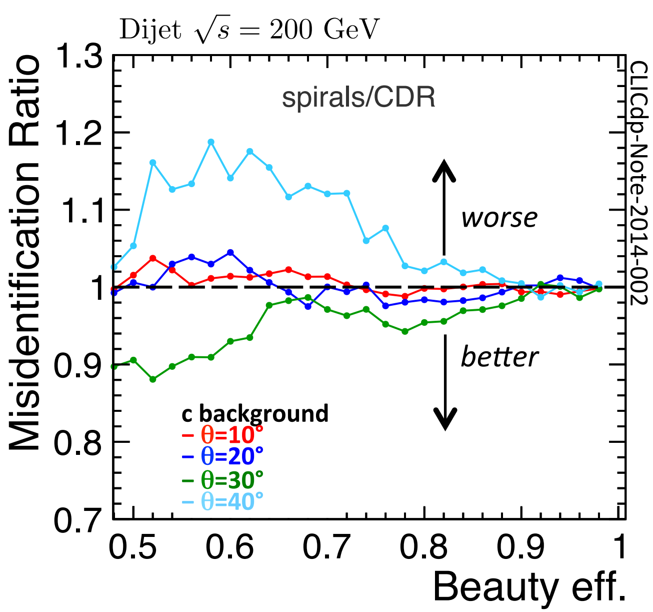
Vertex detector

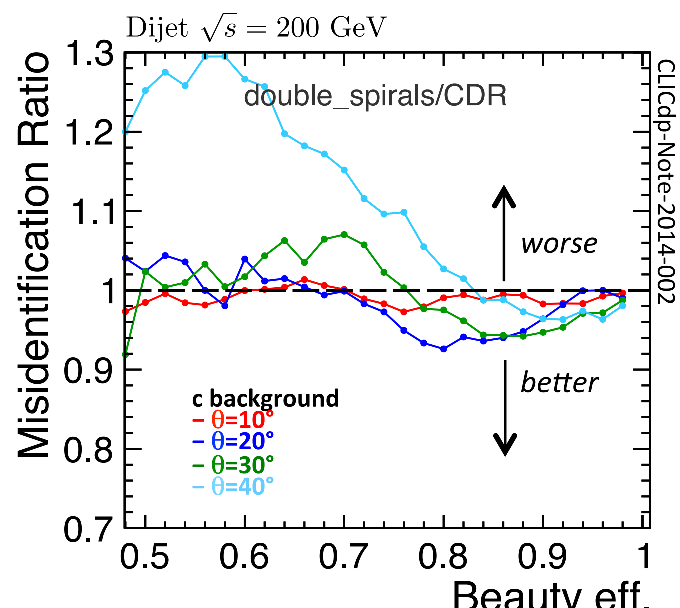


- ***Spiral geometry*** → allows air-flow for cooling
  - 5 single layers in the barrel + 4 in the endcap
- ***Double spiral geometry***→ increases n of measurements with the same material budget
  - 3 double layers in the barrel + 3 in the endcap



Similar result as CDR but for θ~40° → less number of hits

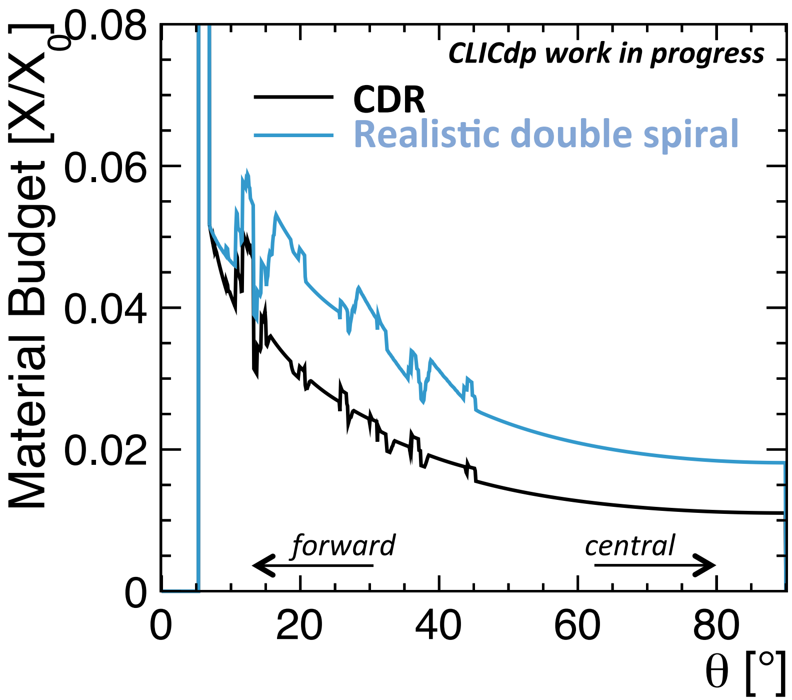


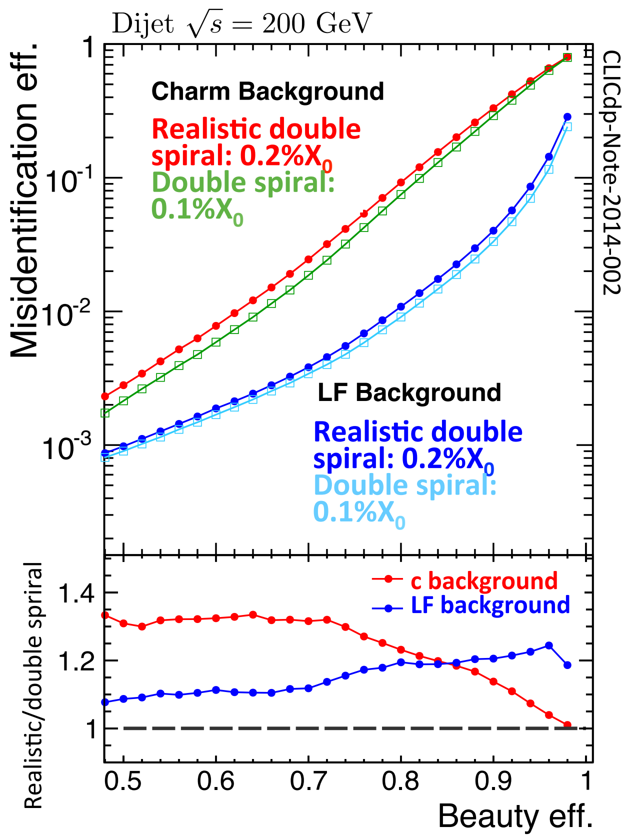


See more in N. Alipour's talk

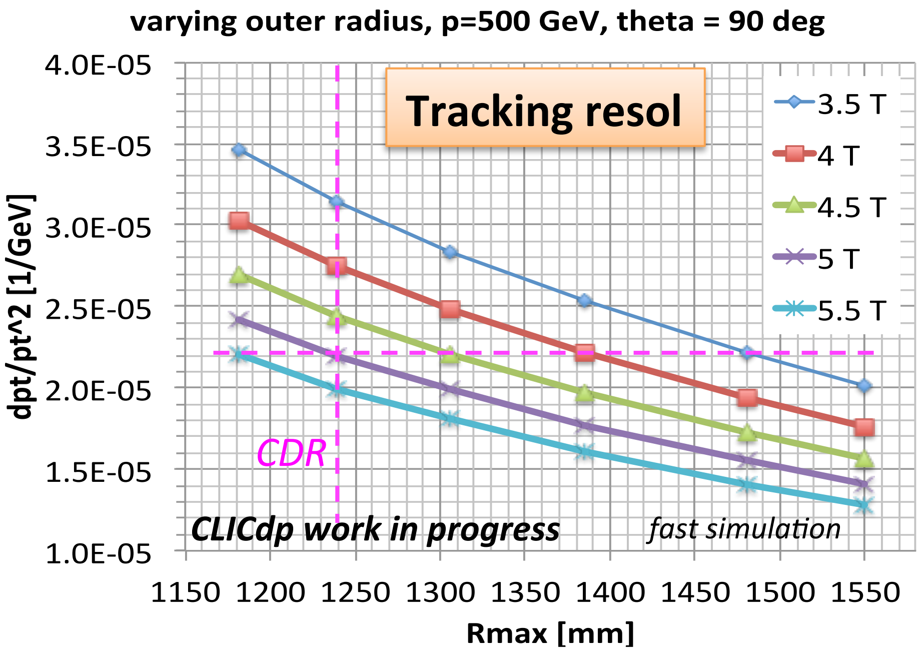
Vertex detector

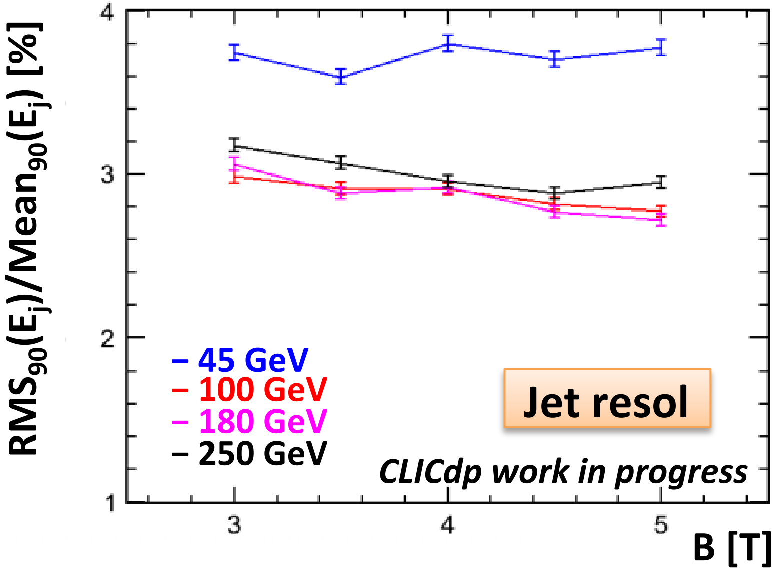
- ***Realistic model for double spiral*** → takes into account material budget for sensors+readout, cabling, electronics and supports
  - *0.2%X_0 per single layer* w.r.t. 0.1%X_0 per single layer
    → important for a fair evaluation of the performance





Magnetic field (B)



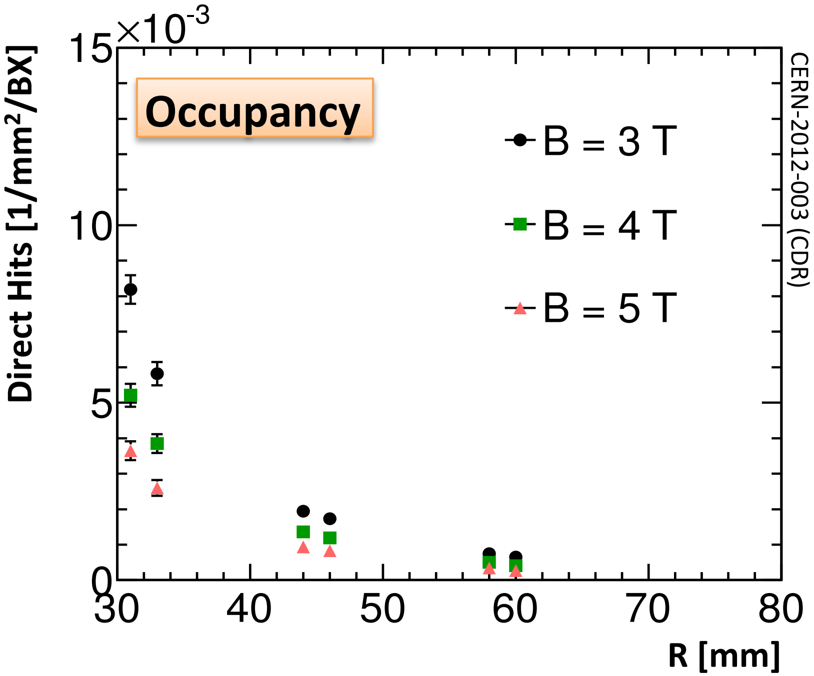


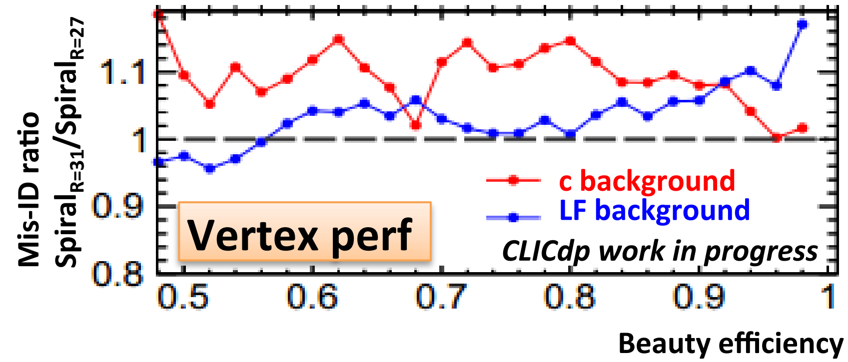
- Track resolution depends stronger on R than on B field

$$\frac{\sigma(p_{\mathrm{T}})}{p_{\mathrm{T}}^2} \propto \frac{\sigma}{\sqrt{N+4}BR^2}$$

- Small effect on particle flow and jet energy resolution
- Effects of inhomogeneous B field is under investigation
  - Working to extend the helical fit

Magnetic field and occupancy





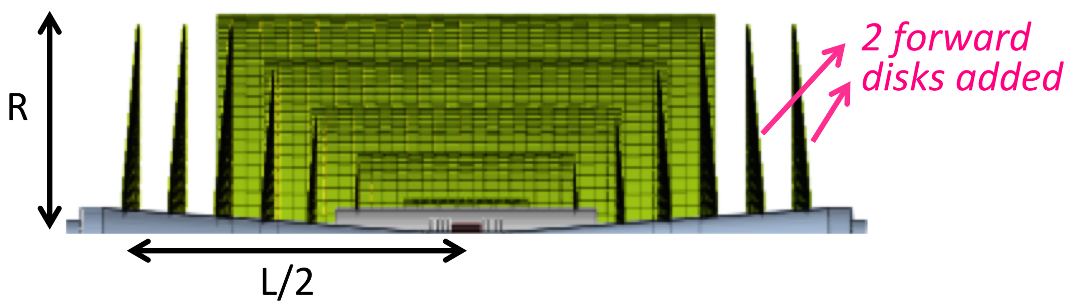
- Lower B gives more occupancy in the vertex detector
  - At 31mm 25% increase from B=5T to B=4T
- Possibility for larger inner radius for the vertex detector is investigated
  - R_{in} from 27mm to 31mm

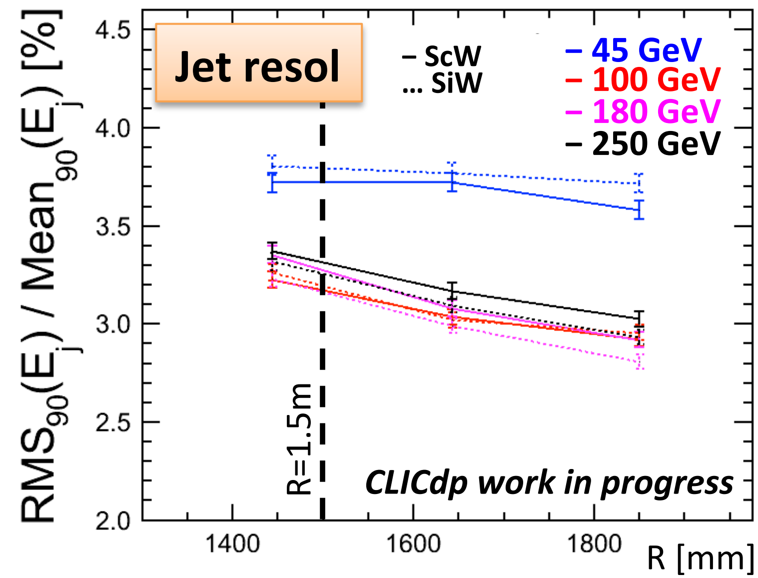
→ Final decision about B field value (4T-4.5T) from HCAL dimensions and vertex/tracking occupancy studies

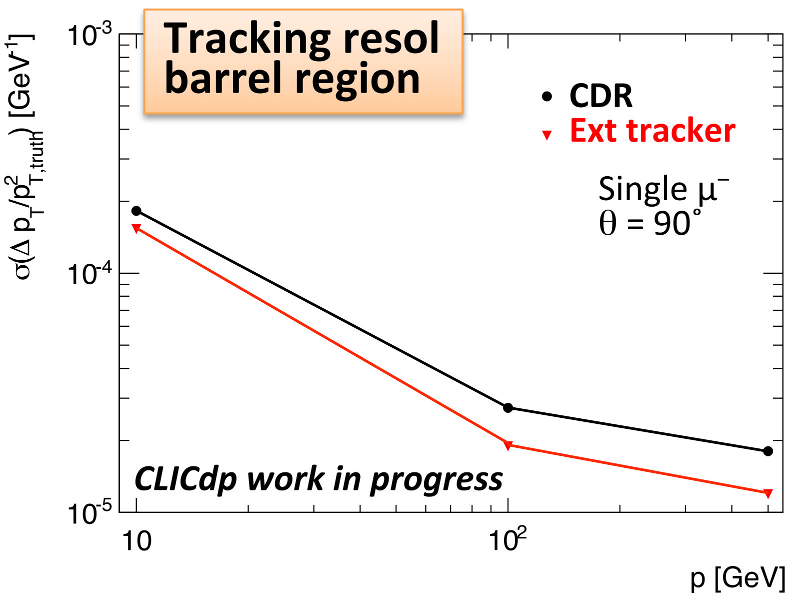
See more in R. Simoniello's talk

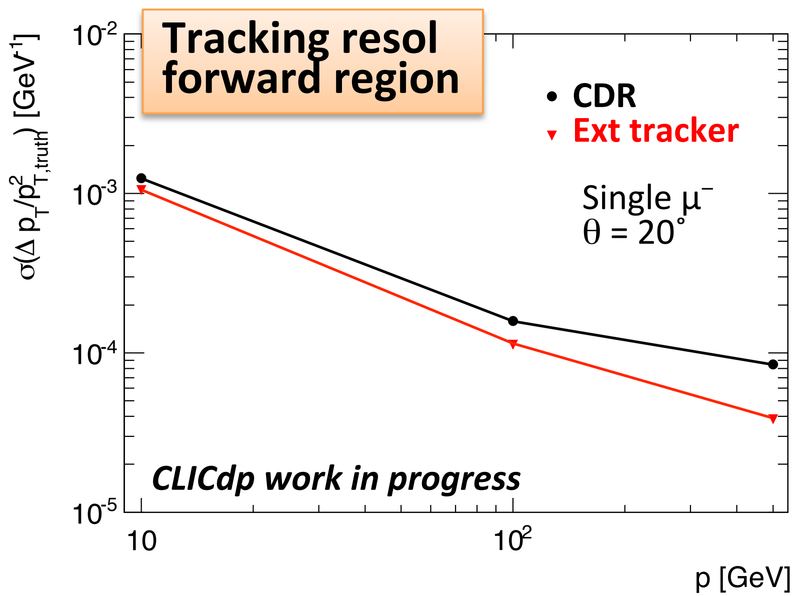
Main tracker

- Improvement in tracking resolution due to larger dimensions according to: $\sigma_{new}=(L_{old}/L_{new})^2\sigma_{old}$
- Extended tracker:
  - *R from 1.25m to 1.5m*
  - *L/2 from 1.6m to 2.3m*







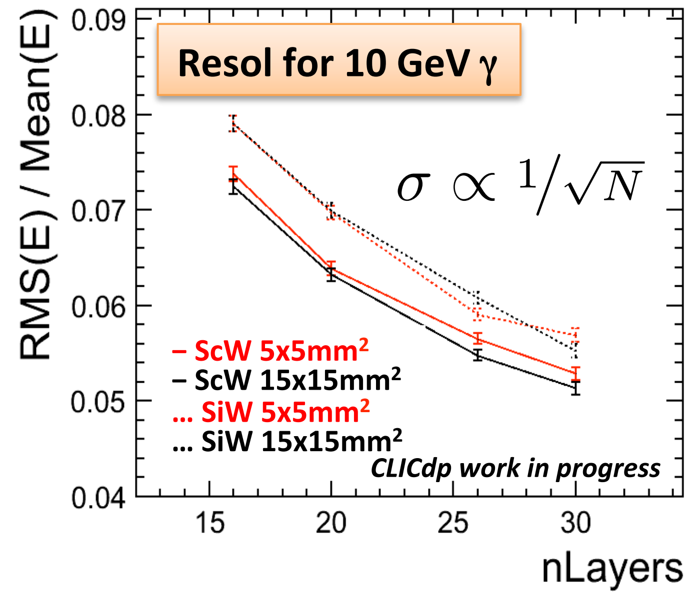


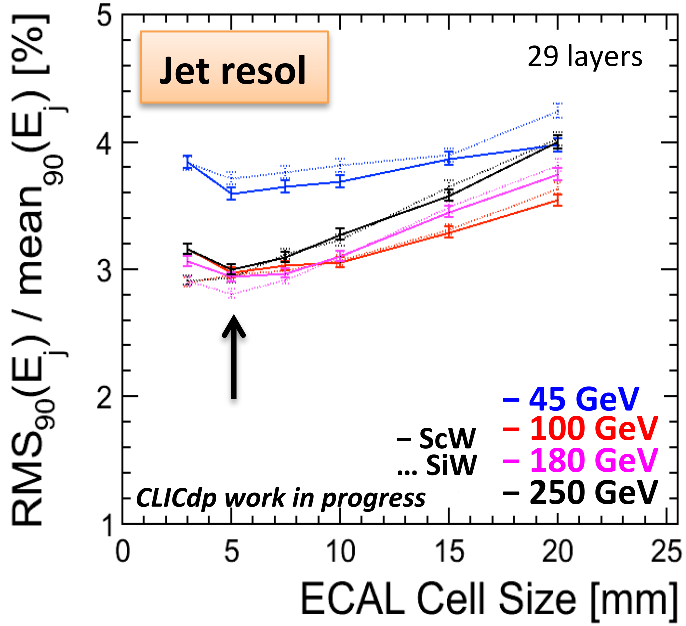
Electromagnetic calorimeter

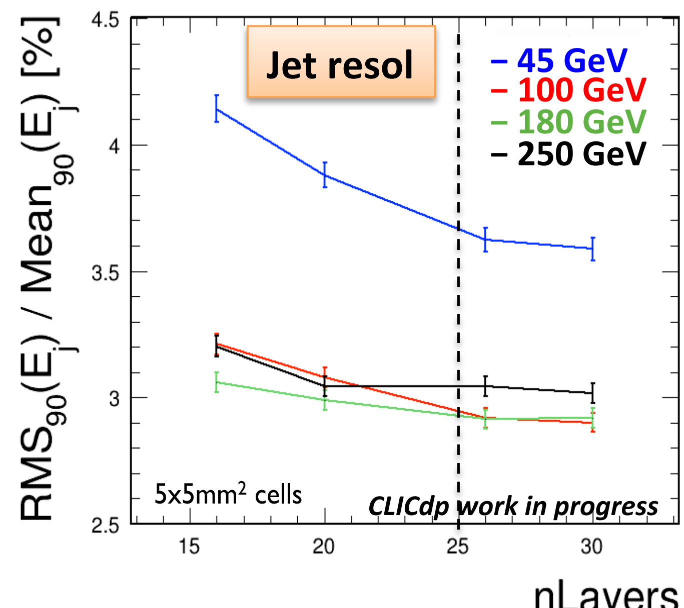
- Material: Sc or Si with W absorber
  → similar performance
- Cell size:
  - High-p_T jet resolution dominated by confusion
    → Best for $5x5mm^2$ ($15x15mm^2$ still ok)
  - Small cell size needed for hadronic τ ID

  → Small cell size more doable with Si w.r.t. Sc
- Number of layers: same jet resolution performance for 25-30 layers

→ Proposal: 25L of SiW with $5x5mm^2$ cell size





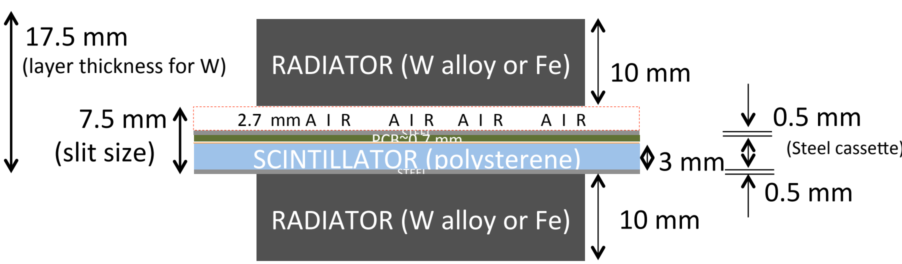


Hadronic calorimeter

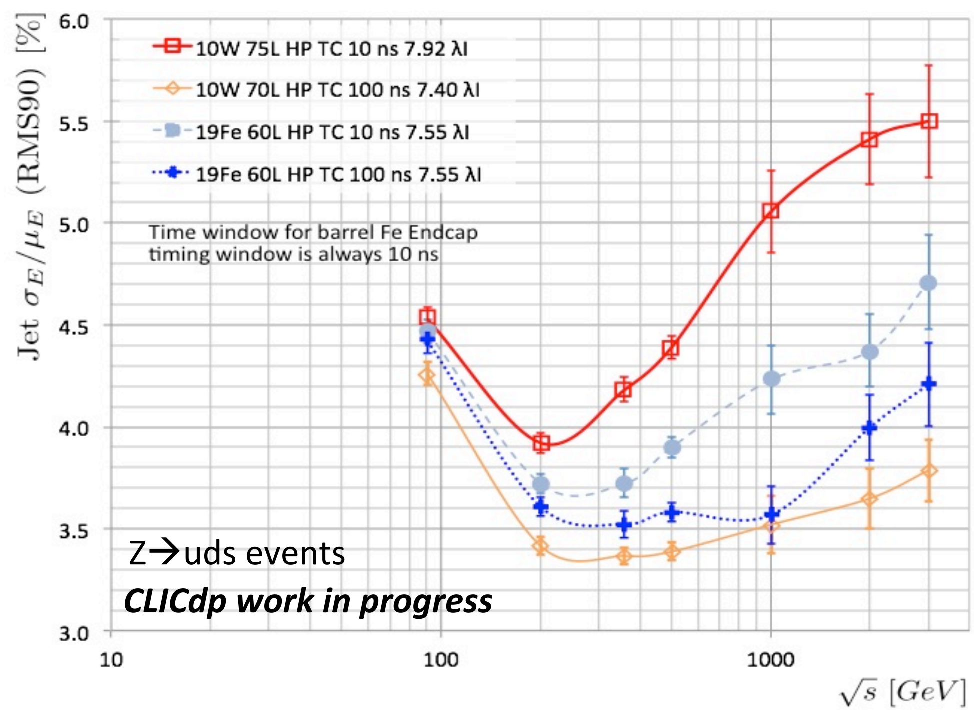
- Hcal endcap: ScFe, 60L, 30x30mm^2
- Hcal barrel layout affects magnet size. Need to optimize:
  - Absorber material: W or Fe
  - Granularity and n of layers
  - Thickness and realistic assembly of active layer → ILD cassette adapted

Detector	# Layers	Abs Thick	Cass. Thick	Air	Total Depth	Total Thickness
		mm	mm	mm	#λI	mm
CDR	75	10	5*	1.5	7.42	1237.5
W + cassette	75	10	4.8	2.7	7.92	1322.5
W + cassette	70	10	4.8	2.7	7.40	1235
Fe + cassette	60	19	4.8	2.7	7.55	1609

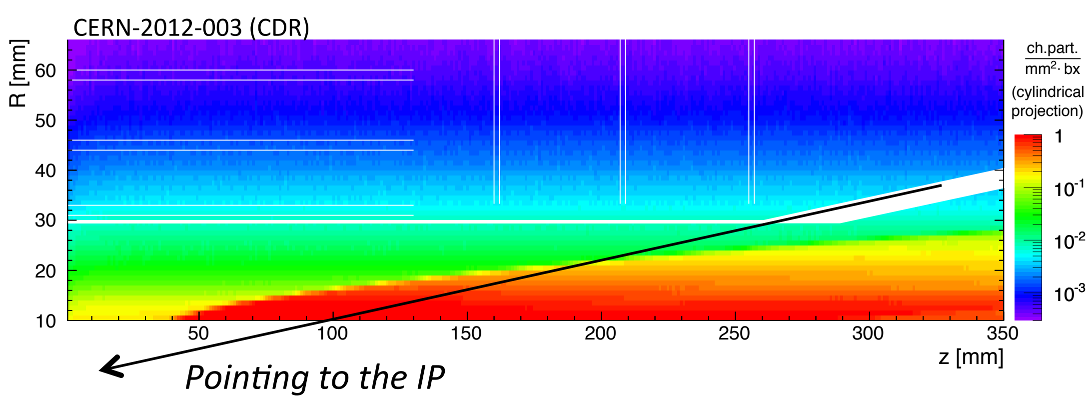
** No cassette model for CDR, just Sc thickness*

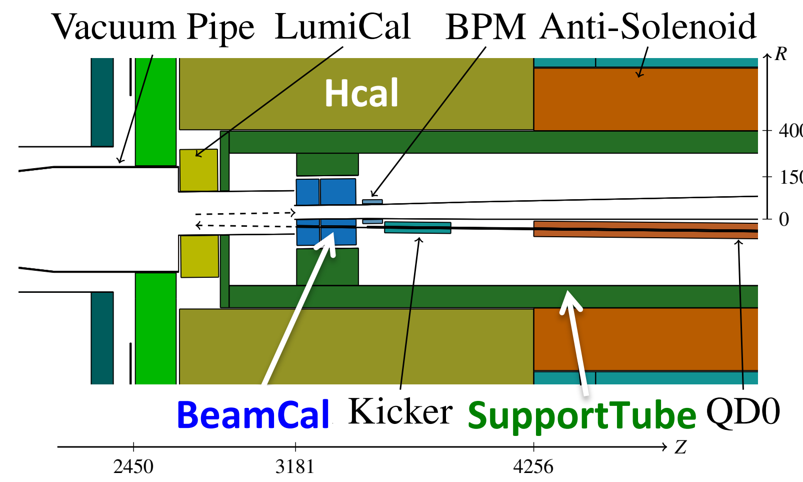


→ JER 6-14% better for W (+ more compact) => impact on physics analysis to be studied → possible improvement for Fe (+ more cheap and handy) correcting for non-compensation



Beam pipe and support tube





- Beam pipe conical shape determined by background occupancy
  - It defines detector acceptance
  - Thick to shield backscattered particles from forward calorimeters/subdetectors
- Forward support tube design:
  - γγ→*hadrons* occupancy in Hcal endcap ~ 8% → direct hits → irreducible with geo changes
  - *Incoherent pairs* occupancy in Hcal endcap ~ 83% → secondary particles from BeamCal

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Material	Occupancy (ϕ average)
Fe (initial) γγ→h	8%
Fe (initial) pairs	83%
W	4%
PE-W	**8%**

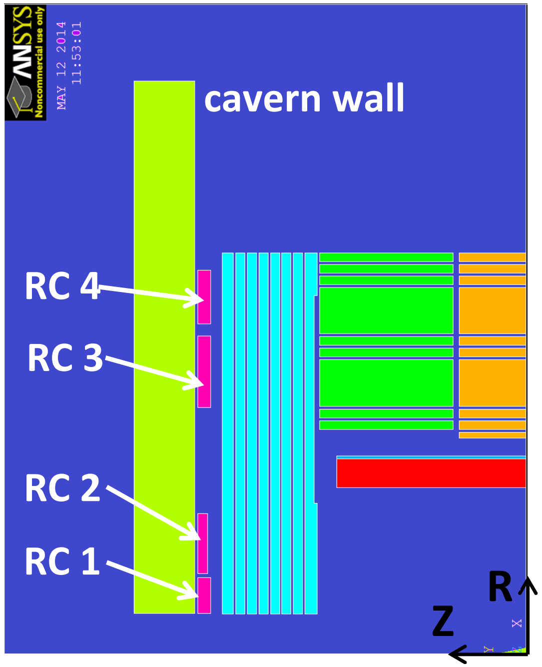
→ *Proposal: PE-W support tube (compromise btw performance and engineering)*
→ *Possible reduction of cell size (<30x30mm^2) in the high-occupancy region*

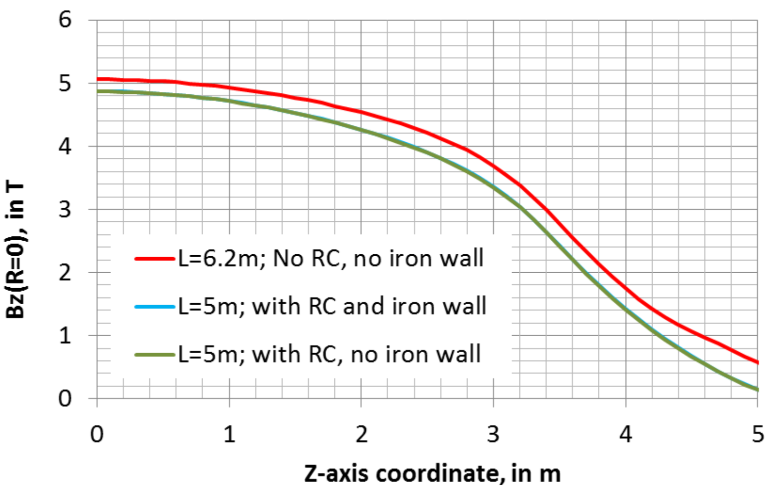
See more in B. Cure's talk

QD0 and Yoke endcap

Two main configurations under study:

- *QD0 out of the detector → L* = 6m*
  - Possibility for better HCAL acceptance → interest in t-channel physics and high energies
  - Loss in luminosity and engineering issues to be studied
  - Make the detector smaller
    → yoke endcap from 2.8m to 1.4m
    → add (copper) ring coils to reduce the stray field
    - 10% of iron in the concrete is assumed
    - Stray field lower than 3.2mT at R=15m
    - Inside the detector region:
      → 4% reduction of the B field
      → 23% increase of the field distortion
    - Power of ring coils: 2 x 2260 kW
- *QD0 partially in the detector → L* = 4.5m*
  - Engineering issues to be studied





On-going studies

- *Detector parameters* to be decided:

Hcal absorber material: W vs Fe → Coil size + B field value → Position of vertex and tracker layers; Hcal endcap cell size; Muon system cell size

QD0 and L* configuration → Forward region / Hcal design and acceptance

- Vertex R&D to match the very *strict material budget requirements* (0.2%X_0)
  - Sensor technology, powering/cabling, supports, integration

See more in F. Duarte Ramos's talk

- Air cooling for main tracker
  - Slow air-flow due to large dimensions
  - *Estimate the main tracker r/o power consumption* to achieve position and time resolution and noise tolerance requirements (S. Kulis)

Summary

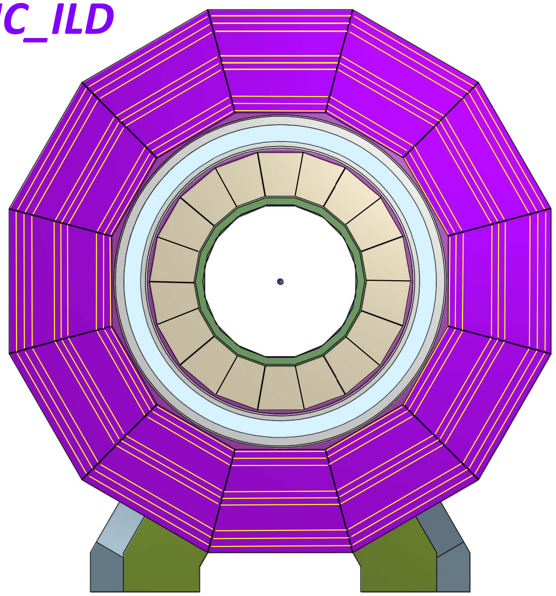
- Finalize the *new CLIC detector* simulation *by the end of the year* → model to be used for next round of physics analyses
- *Current status of simulation detector parameters:*
  - Vertex detector: Si double layers with spiral geometry
  - Main tracker: full Si, R=1.5m, L/2=2.3m
  - Ecal: 25 layers, 5x5mm^2 cell size
  - Hcal barrel: 7.5λ_I, 30x30mm^2 cell size
  - B field ~ 4-4.5T to be decided
- *Software implementation* in DD4hep ongoing → see more in F. Gaede's talk

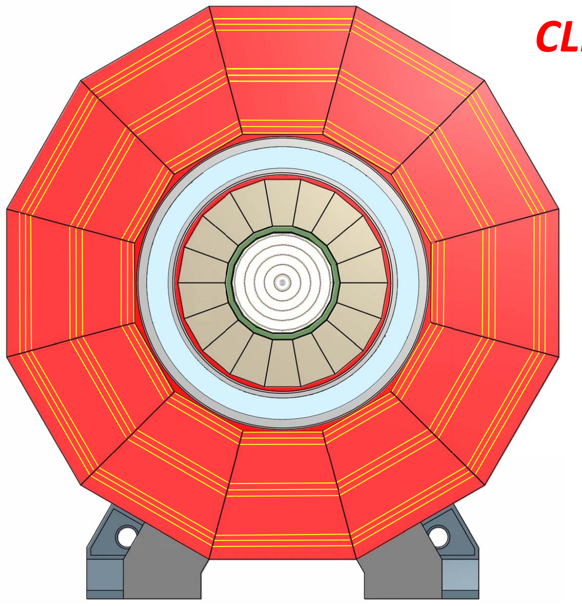
Thanks for your attention!

BACK-UP

ILD and SiD comparison

CLIC_ILD

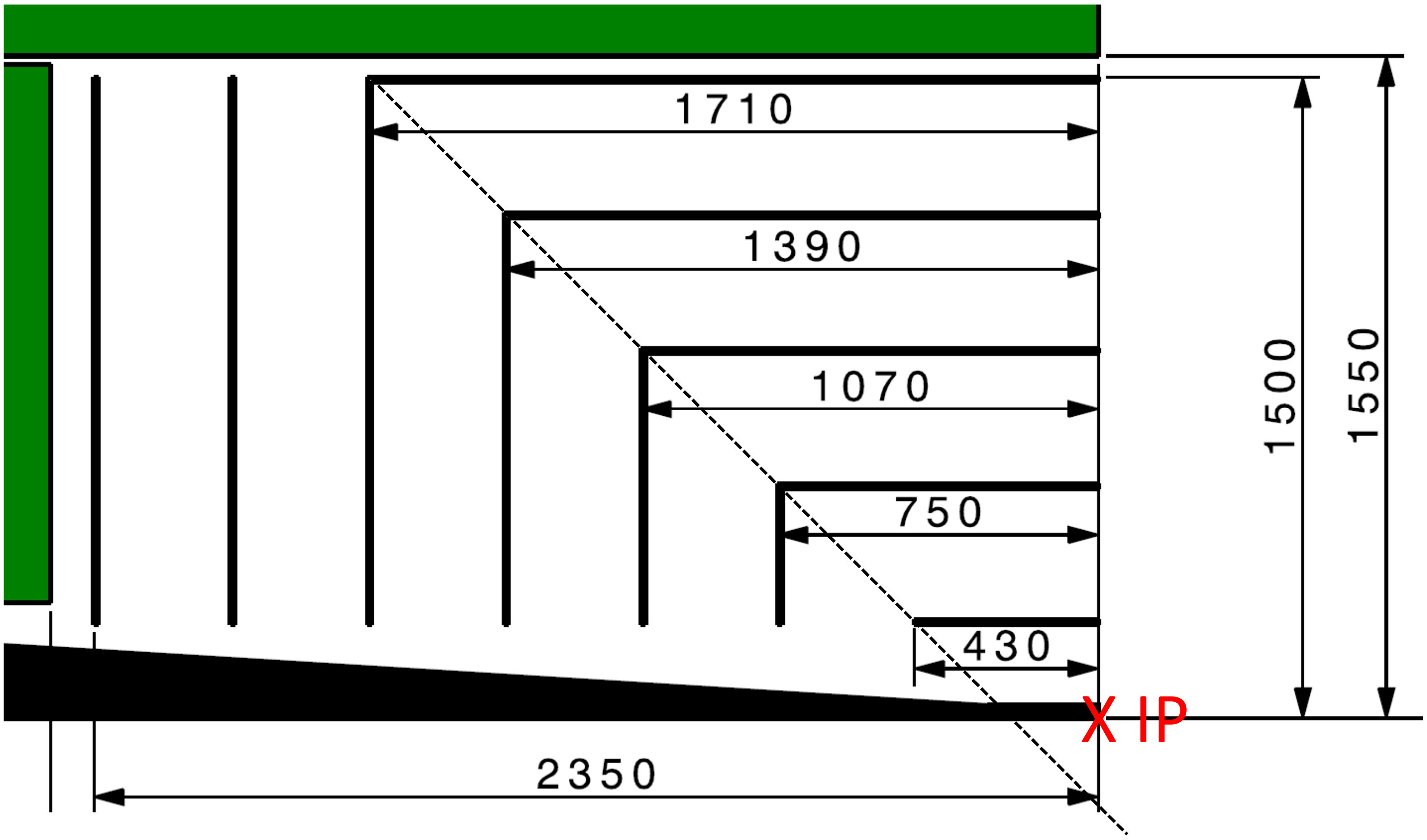




CLIC_SiD

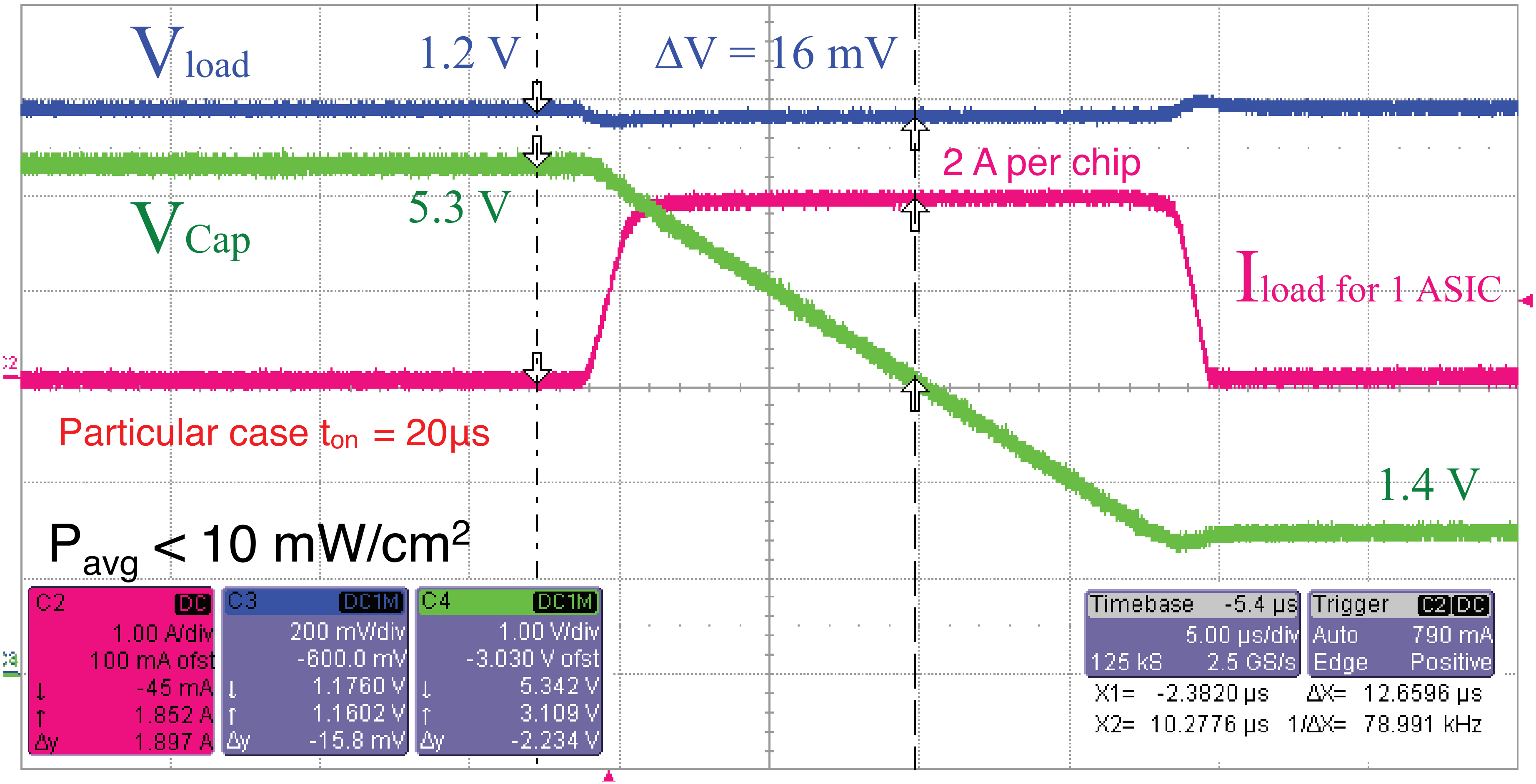
Concept	ILD	CLIC_ILD	SiD	CLIC_SiD
Tracker	TPC/Silicon	TPC/Silicon	Silicon	Silicon
Solenoid Field (T)	3.5	4	5	5
Solenoid Free Bore (m)	3.3	3.4	2.6	2.7
Solenoid Length (m)	8.0	8.3	6.0	6.5
VTX Inner Radius (mm)	16	31	14	27
ECAL r_{min} (m)	1.8	1.8	1.3	1.3
ECAL Δr (mm)	172	172	135	135
HCAL Absorber B / E	Fe	W / Fe	Fe	W / Fe
HCAL λ_{I}	5.5	7.5	4.8	7.5
Overall Height (m)	14.0	14.0	12.0	14.0
Overall Length (m)	13.2	12.8	11.2	12.8

Zoom of the inner detector

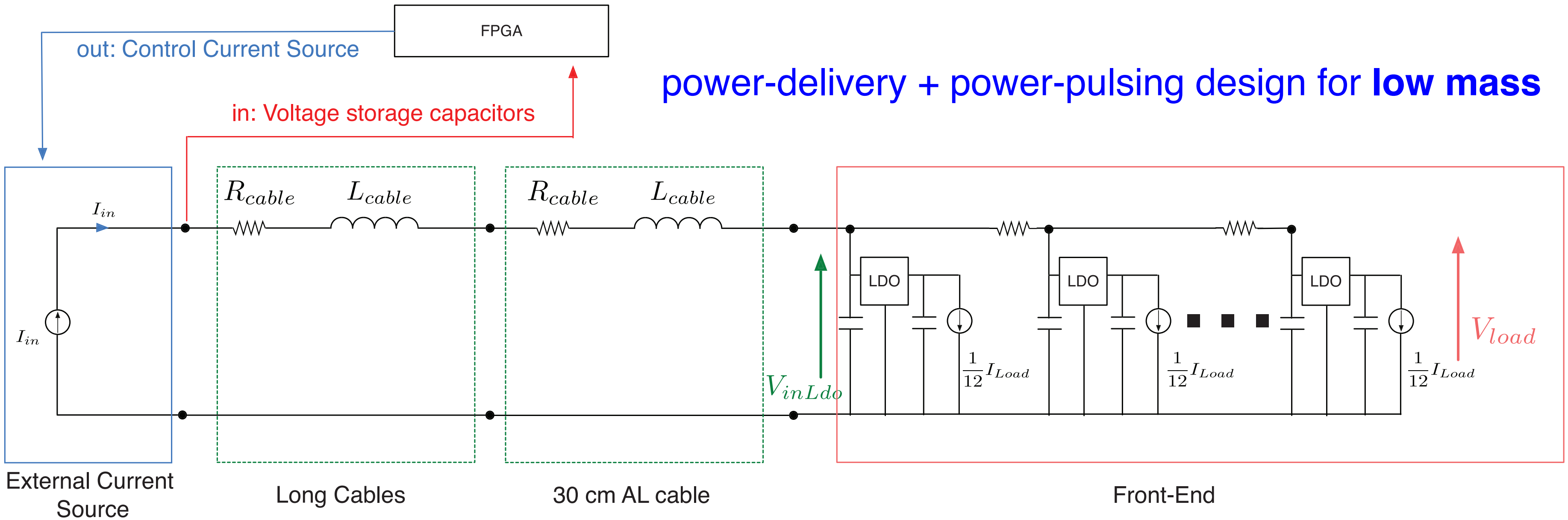


CLICpix power pulsing

analog power



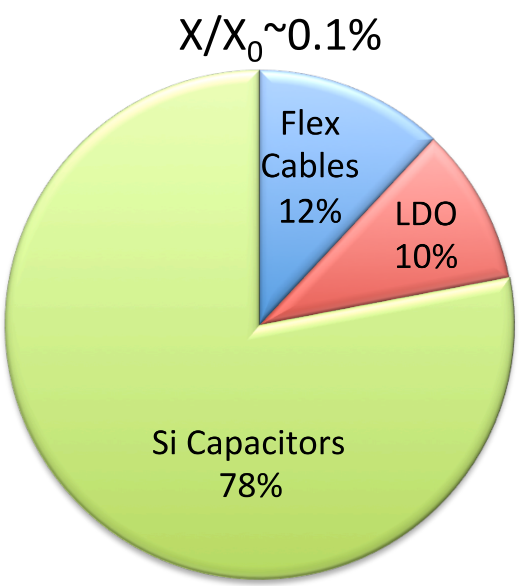
Power pulsing & material budget



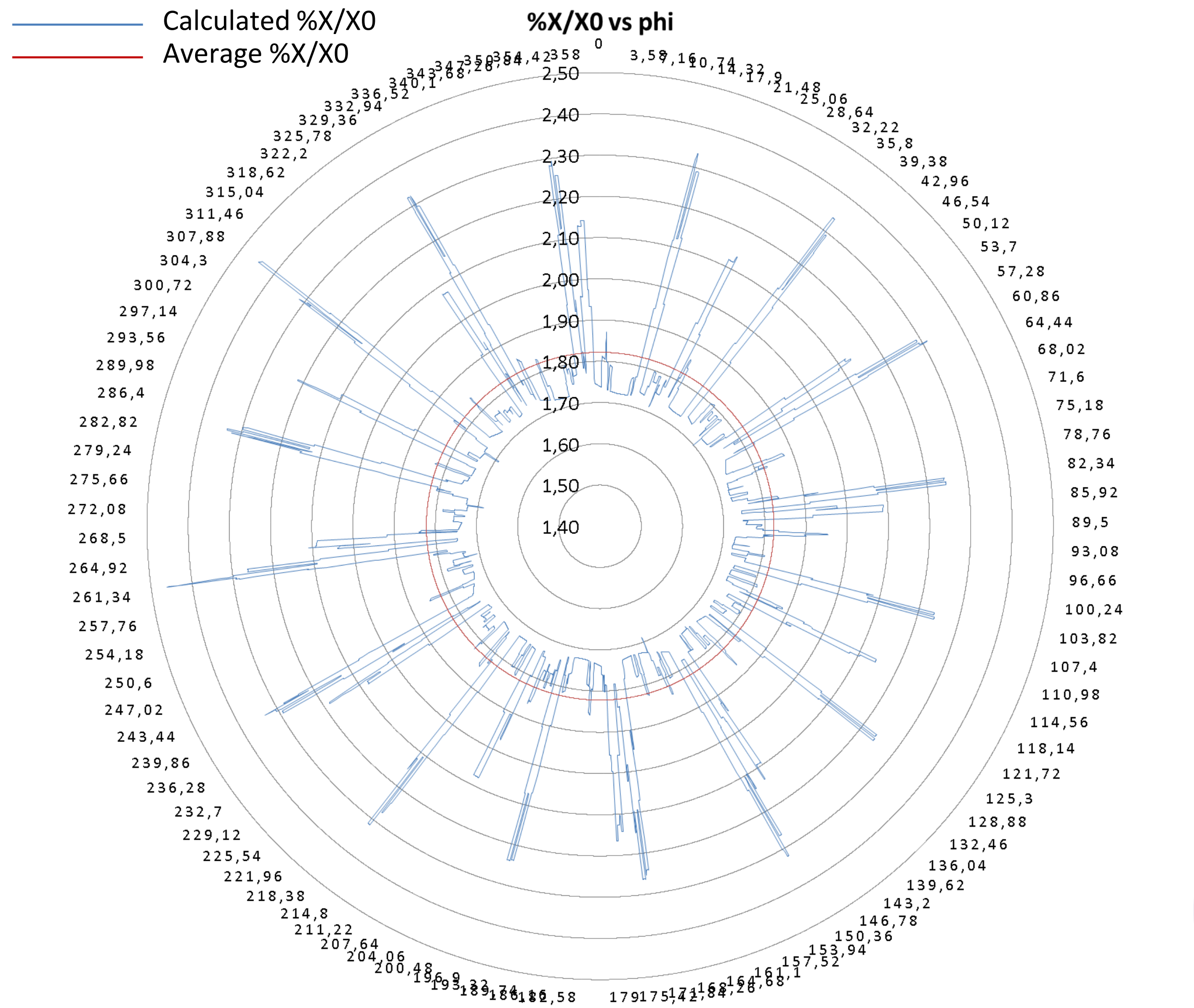
- *Power pulsing* with local energy storage in Si capacitors and voltage regulation with Low-Dropout Regulators (LDO)
- ~0.1% X_0 material contribution dominated by Si capacitors can be reduced to *~0.04% X_0* with evolving Si capacitor technology: 25 µF/cm² → 100 µF/cm²

~0.1% X_0 for sensor + readout
~0.04% X_0 for capacitors
~0.05% X_0 for cablings

Total: ~0.1% X_0 per layer



Material budget



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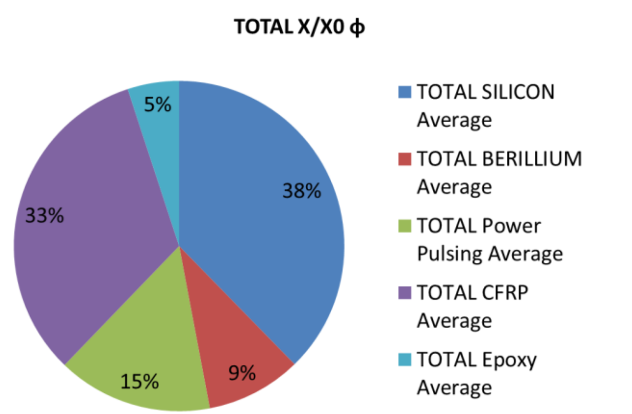
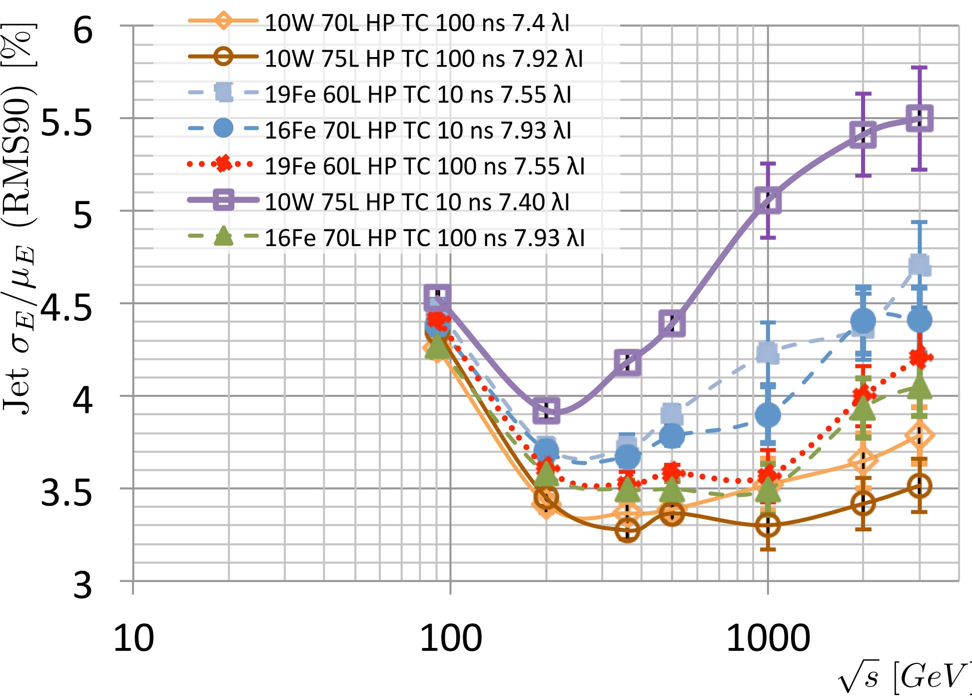
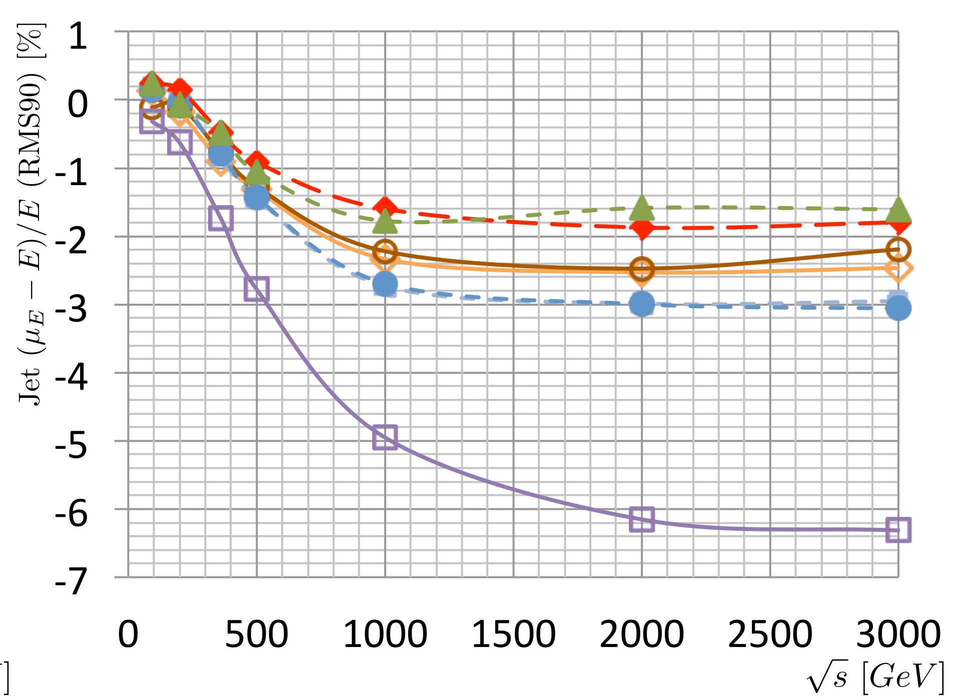


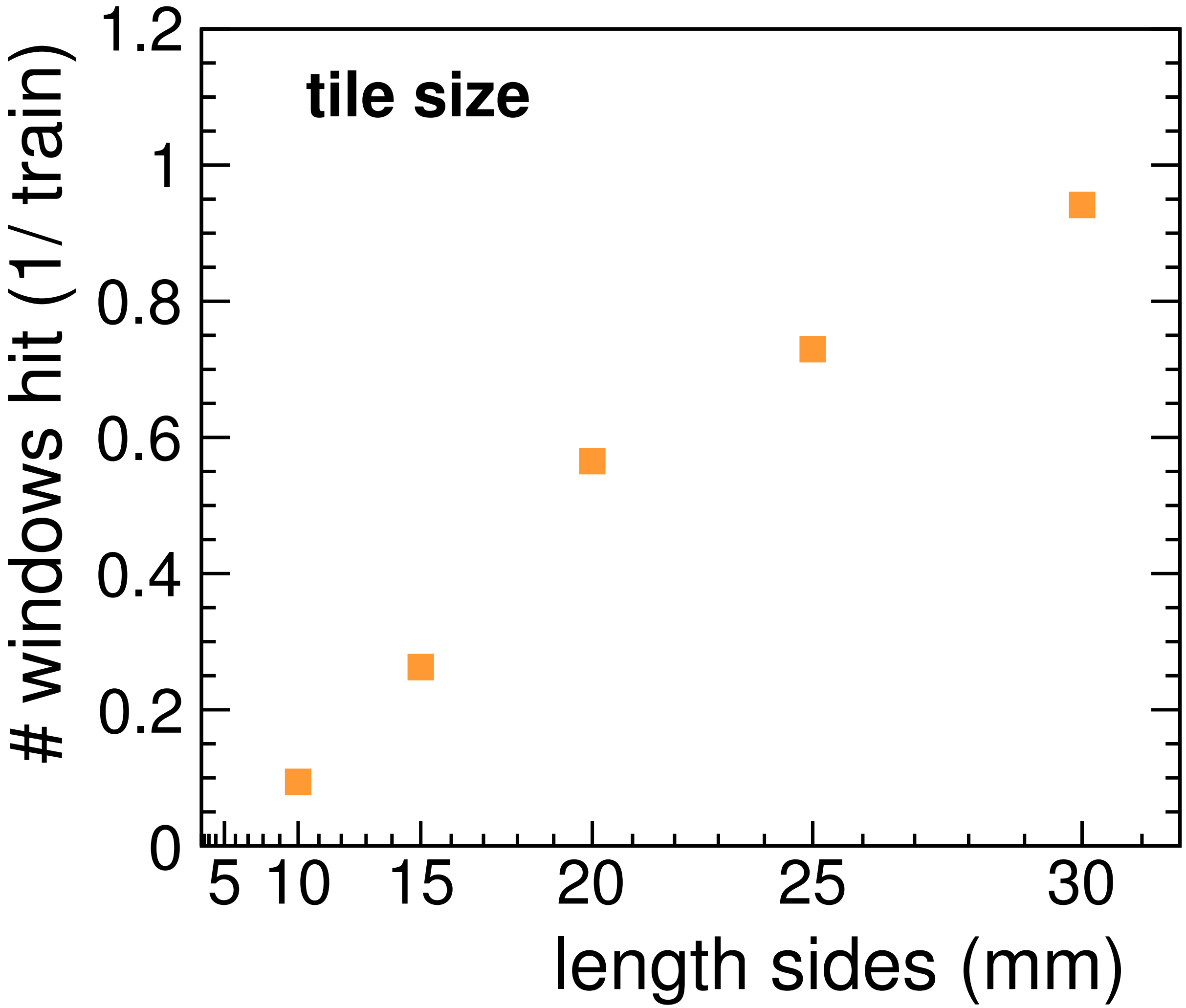
Hadronic calorimeter

Detector	# Layers	Abs Thick	Cass. Thick	Air	Total Depth	Total Thickness	Inner R	Outer Face Position	Outer Radius
		mm	mm	mm	#λI	mm	mm	mm	mm
CLIC_ILD_CDR	75	10	5* (*Scint)	1.5	7.42	1237.5	2058	3295.5	3341.2
CLIC_SID_CDR						1237.5	1447	2684.5	2721.7
W + cassette	75	10	4.8	2.7	7.92	1322.5	1750	3072.5	3115.1
W + cassette	**70**	**10**	**4.8**	**2.7**	**7.40**	**1235**	**1750**	**2985**	**3026.4**
Fe + cassette	**60**	**19**	**4.8**	**2.7**	**7.55**	**1609**	**1750**	**3359**	**3405.6**
Fe + cassette	70	16	4.8	2.7	7.93	1661	1750	3411	3458.3

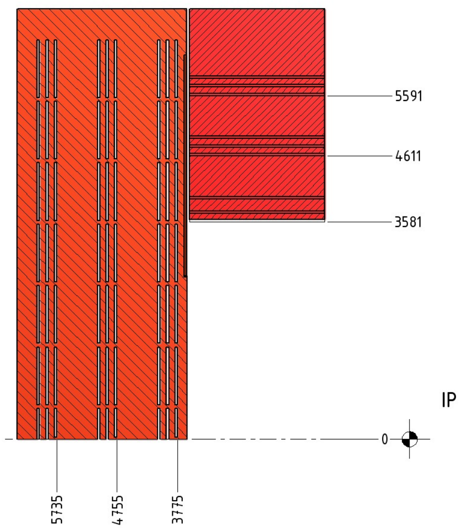


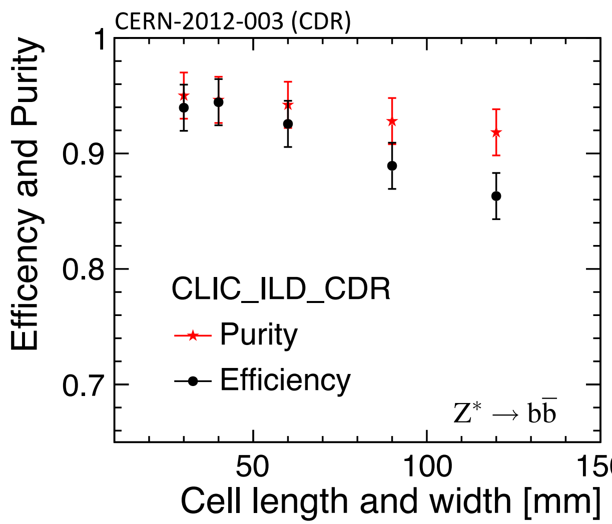


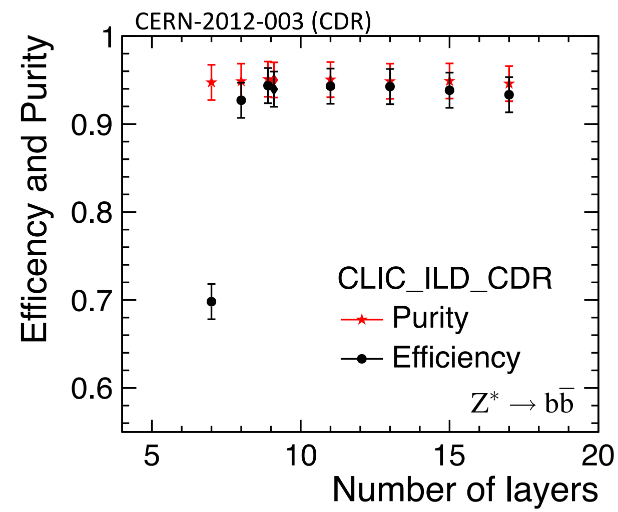
Hcal endcap cell size



Muon system







- Instrumented iron return yoke (thickness plates of at least 10 cm for stability requirements)
- Tail catcher for calorimeter punch trough (first 3 layers)
  - For Hcal of 7.5λ_I and coil of 2λ_I only small improvement for jet resolution
- Identification of beam-halo muons
  - Information used to correct calorimeter energy measurement
  - Good time resolution in endcap (<~1 ns)
- Cell size and number of layers optimized looking at muons in jets (Z→bb events)
  - *Cell size 30x30mm²* (to be more carefully study the 40x40mm² option)
  - *9 layers in groups of 3*

→ *re-evaluation needed if coil dimension and B field change*

Characteristics of the ring coils on the cavern wall with L=5m :

- Arbitrary gap from RC to yoke end cap: **192mm** (RC1, RC3 & RC4) and **244mm** (RC2),
- Space available for radiation chicane,
- Same copper conductor for all RCs,
- Total copper weight : **250 tons** (for 2 end caps). Suppressed steel mass wrt. L=6.2m (2 end caps)≈ **2800 tons,**
- Total electrical power of RCs (2 end caps): **2 x 2260 kW**.

Coil	Nb. turns	Copper mass (ton)	Resistance (1e-3 ohm)	Voltage drop (V)	Power (kW)
RC1	4x12	5.6	2.7	16.5	101
RC2	3x20	13.3	6.4	39.1	240
RC3	4x24	54.4	26.2	**160.4**	**984**
RC4	4x18	51.7	24.8	**152.2**	**934**

Water cooling system characteristics:

- Estimated temperature increase ≈ **45°C**,
- Total water flow (2 end caps): **2 x 57 m^3/hour**.