Review of a “small ILD” option

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Introduction

Si-W ECAL and Yoke are cost drivers of ILD → re-optimisation ?
impact on ⇒ TPC, ECAL ($\propto R^2$), HCAL, Coil, Yoke, Cavern, (Tunnel)

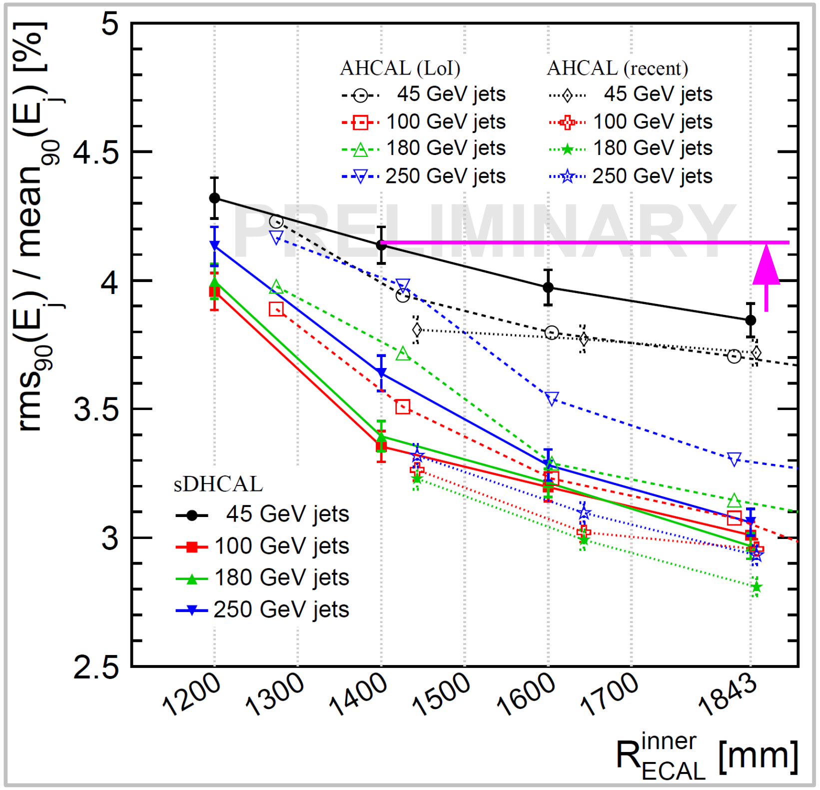
- ILD dimensions had to be fixed early (LoI: cost, etc.)
- LoI results already showed a limited loss of performances when TPC radius is reduced (same for TPC length)
- Performance might depend on granularity
  ⇒ higher granularity compensation for smaller dimensions ?
- What does it give all together ?
  - 2 main parameters to be optimised:
    R_{TPC} ($\propto$ L_{TPC}) & N_{Layers} (ECAL, HCAL)
  - ⚠ECAL performance (cell size) depends on:
    - SW (!)
    - HCAL: SDHCAL vs AHCAL, $1\times1 cm^2$ vs $3\times3 \ cm^2$
    - B field; TPC perf.

⇒ Performance results & realistic Geometry for a reduced radius option.

Simulation studies

Shown @ LCWS'13 (work by Trong Hieu Tran)
https://agenda.linearcollider.org/getFile.py/access?contribId=67&sessionId=35&resId=0&materialId=slides&confId=6000

- Evaluation of the JER vs R_{INNER} ($\leftrightarrow R_{TPC}$, @ fixed R/L ratio).
- Using PandoraPFAnew v0.12 and full calibration procedure
  - μ, γ, K^0_L samples ⇒ ECAL/HCAL intercalib + E2H/H2H + angular corr.
- ILD_o1/2_v05(SEcal04, AHCAL/SDHCAL)
  - SiW ECAL: 5×5 mm², AHCAL: 3×3 cm², sDHCAL: 1×1 cm²



Results

- ≤10% for R_{INNER}=1800→1400mm

Variation of N_{Layers}

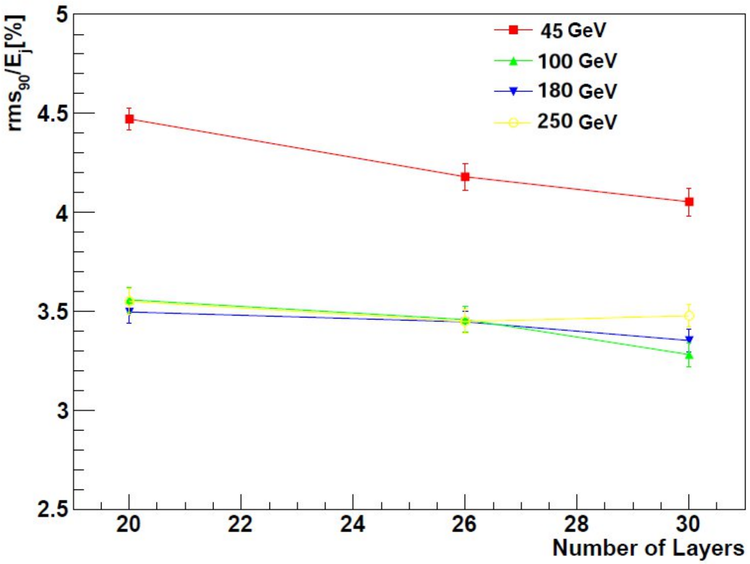
Shown @ 6th ILD Optim meeting (16/07/2014) [Internship work of Dan Yu (LLR)]
https://agenda.linearcollider.org/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=6435

- Variation of ECAL's N_{Layers} for R=1450mm, HZ_{Barrel}=1848mm on ILD_o2_v05
- Exact Same procedure as previous study
  - Non-Linearity ≤ 1%
- For |cosθ| ≤ 0.7

number of Si layers	W layers (1st section)	Thickness (mm)	W layers (2nd section)	Thickness (mm)
20	13	3.15	6	6.3
26	17	2.4	8	4.8
30	20	2.1	9	4.2

Results

- JER + ≤6% @45 GeV



(LLR) plans for the simulation of the SiW ECAL in a reduced version ILD

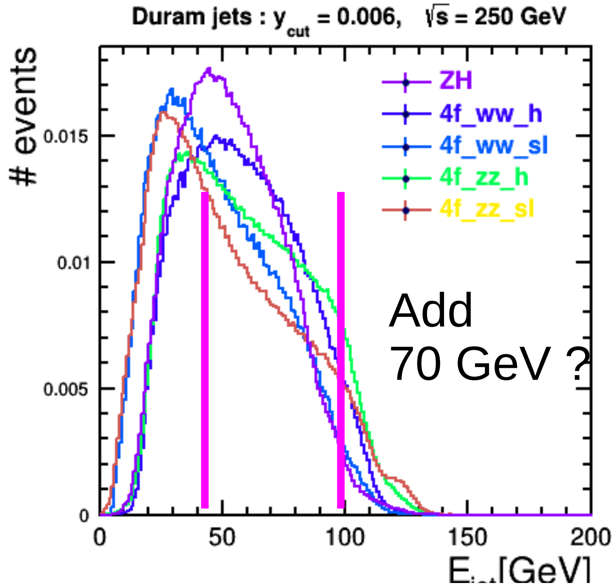
Redution of Radius with fixed R/Z ratio

- R 1800→1400 @ N_{layers}= “30”: JER +≤10 %

Reduction of number of layers

@45GeV

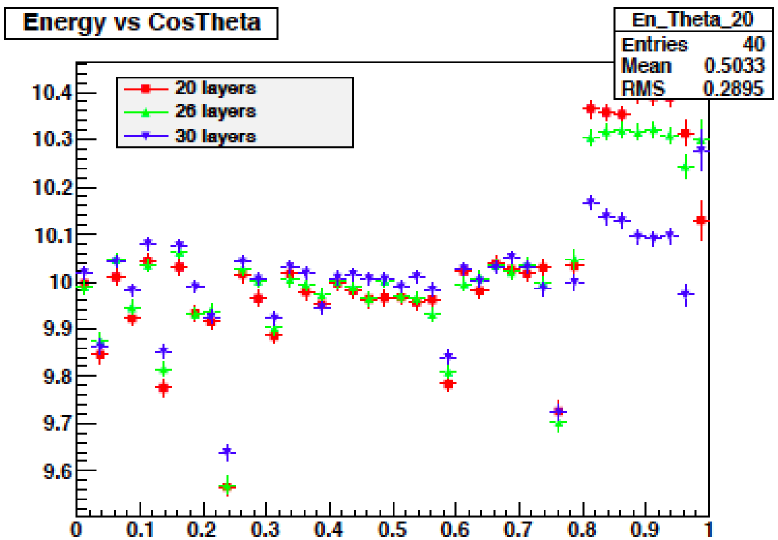
- N_{layers} “30” → “20” @ R=1800: JER + ≤9% (THT @ LCWS'12)
- N_{layers} “30” → “20” @ R=1400: JER + ≤6%



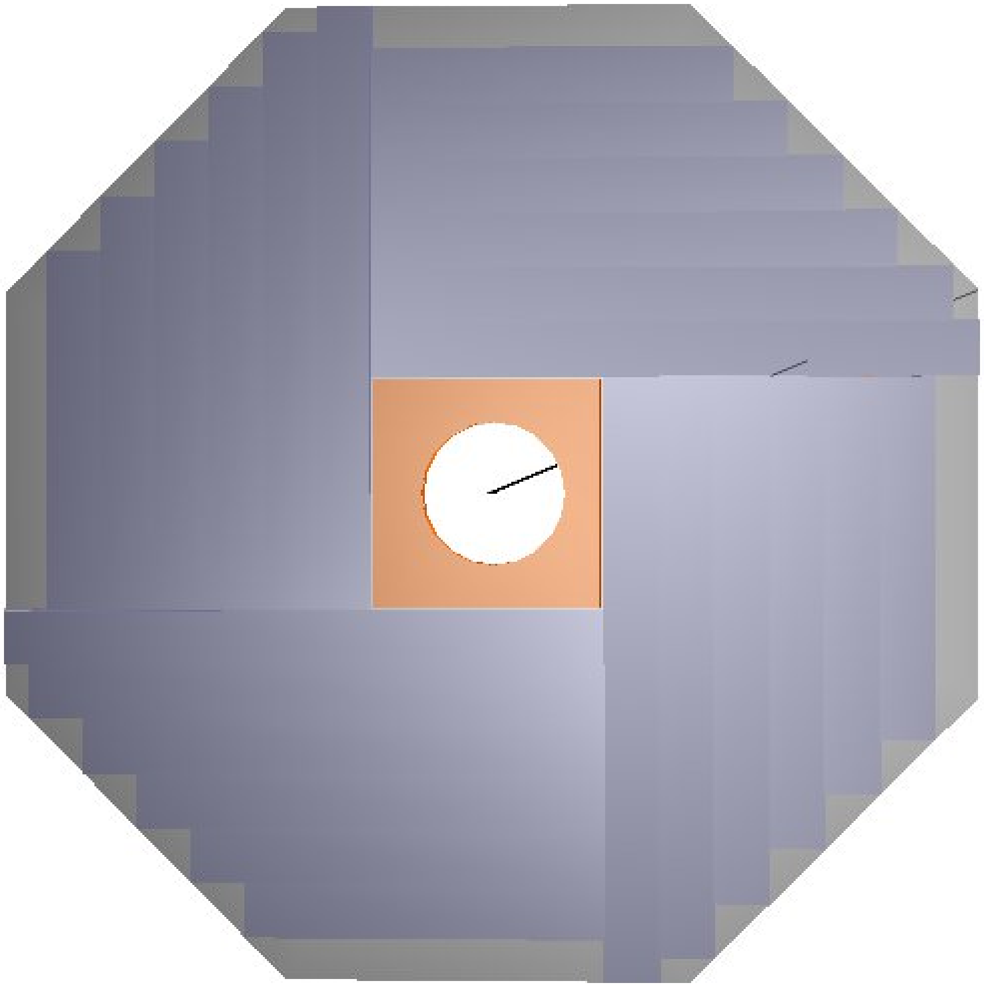
⇒ JER +≤16% wrt “standard” ILD

- **PRELIM:** Barrel ONLY, N_{Layers} handling inclomplete, ≠ Barrel/Endcaps
- Gap between 45 and 100 GeV ⇒ 70 GeV

⇒ Simulation modifications for reduced radius & layers.



Example on “non optimized” geometry



Simulation modifications

Cleaning & adapatation of ECAL Mokka drivers:
[D. Jeans + J. Marshall + E. Becheva + V. Boudry + Dan Yu]

- Many cleaning made by D. Jeans ⇒ SECal05
  - Bugs, improved GEAR output, handling of pre-shower
- Documentation being reviewed
- TBD: Implementation of SEcal05 in DDHEP
  (based on S. Lu implementation of SEcal04 + tests)

New ECAL Driver (SEcal06) to correct defects (mostly in Endcaps).

- Missing dead materials, "corners"
- Consistant treatment of Barrel/Endcaps
- Better handling of Layers, optionnal pre-shower

Realistic parameters

From preliminary mechanical model ⇒ in simulation & cost

Reduced radius **R_{INNER}=1400mm**.

Base unit = Wafer size

- Largers Wafers: 6” → **8”** (OK from HPK, LFoundry); smaller wafers (4”) in 2nd part ?
- Wafer side: ~90 → **126** mm; Alveola ~200mm→ 253,8 mm;

Barrel: **5 modules of 3 alveola**

- L_{Barrel} = 3829mm (Z_{endcap} = 3929mm).

Endcaps: **Quadrants o**f **2 modules of 2 and 3 alveola**

- with R(ECAL Ring) = 40cm + Integer number of Wafers + ½ Wafers

  ⇒ R_{Endcap} = 1676mm

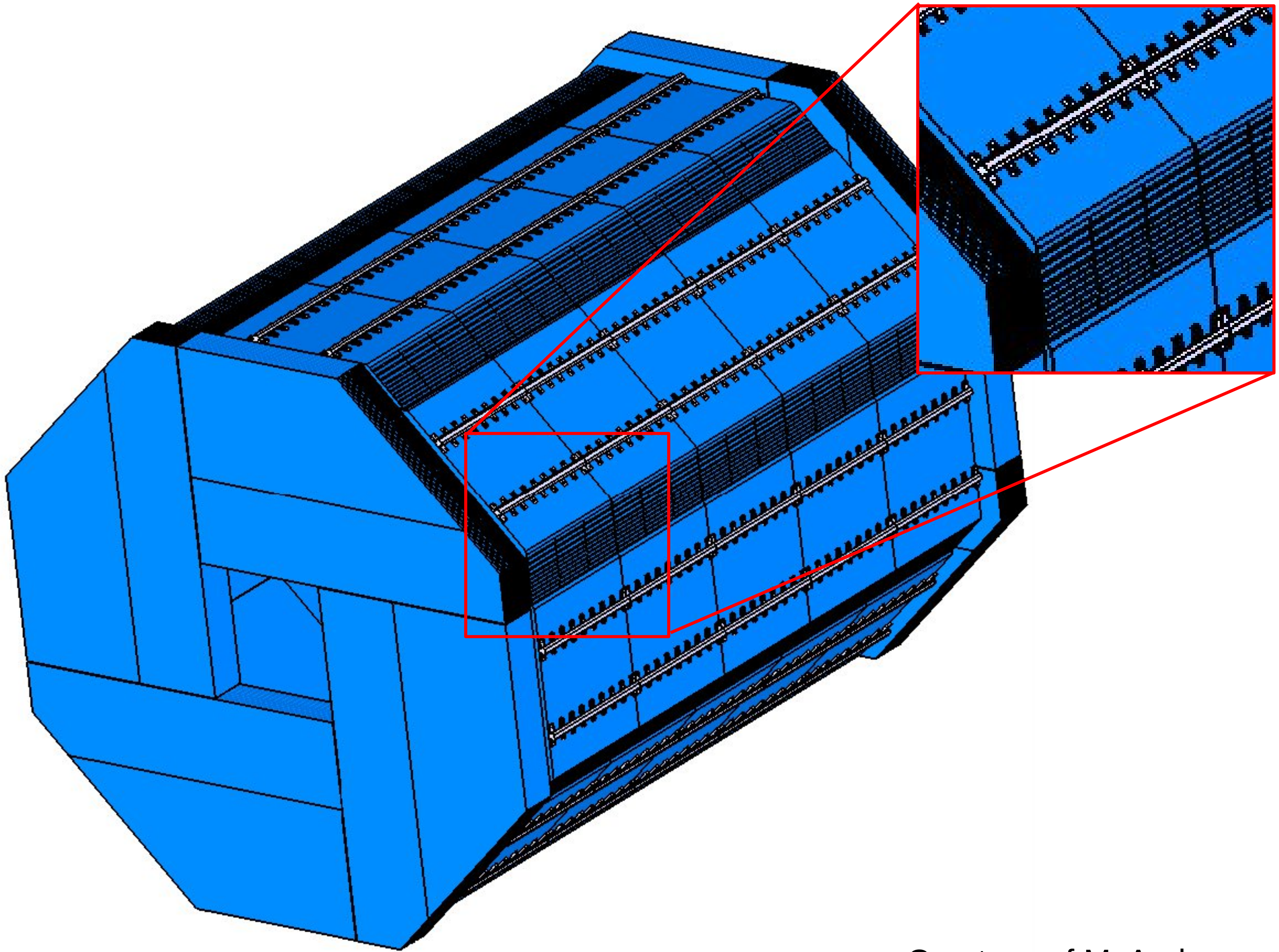
N_{layers} = 22 = **14 + 8** (single and double W thickness)

Wafer thickness 500→ **~725µm**

- Improved $\sigma(E\gamma) \propto \sqrt[5]{t}$ ⇒ ~recovery of N_{layers} effect. ⇒ compensation of N_{Layer} loss.
- ECAL thickness = 223,85 mm

Mechanical model

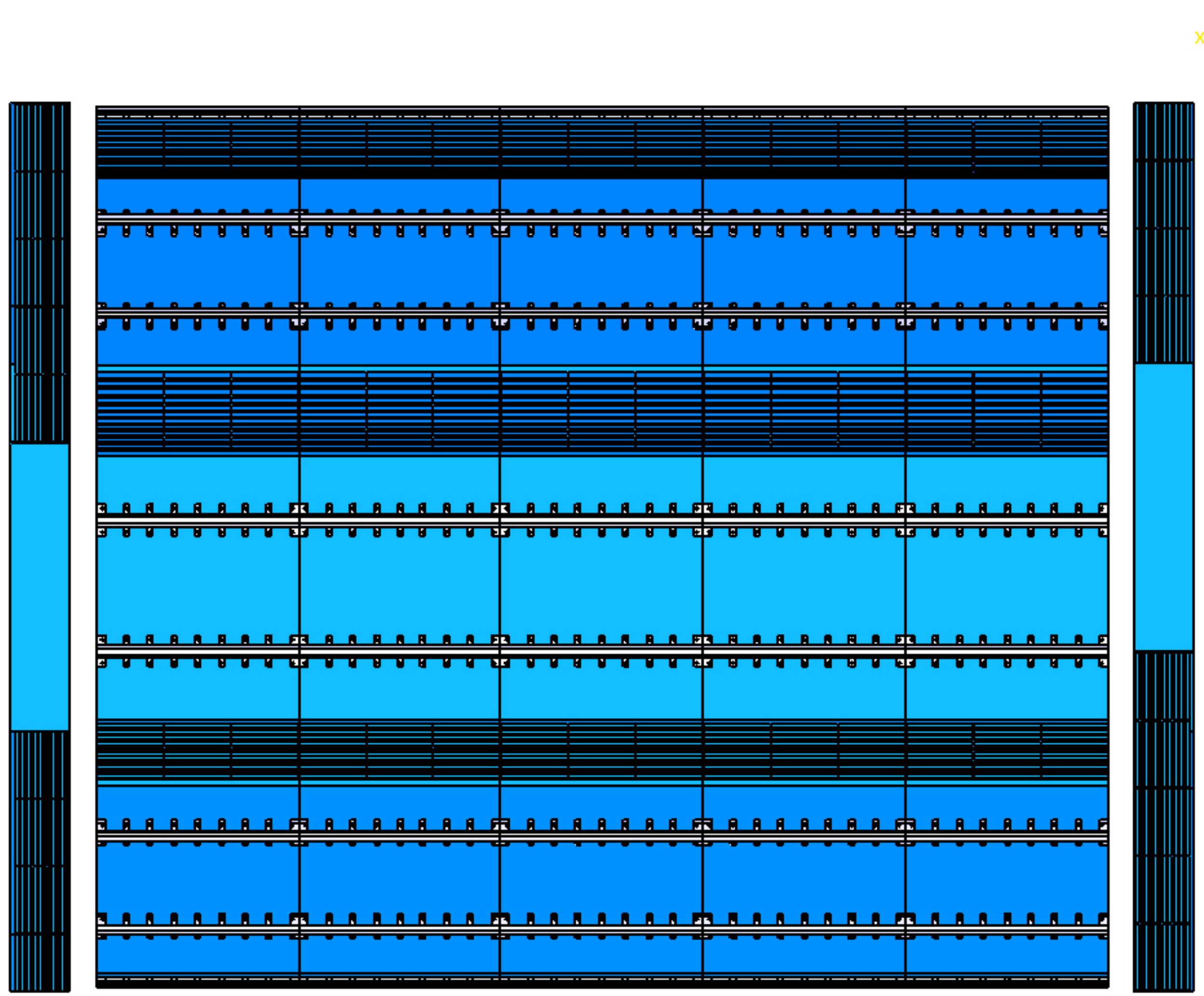
Paramètres
- `Matériau`=Tungstène
- `largeur-alveole`=253,6mm
- ame=1mm
- nombrecolonne=3
- epaisseurW1=2,8mm
- epaisseurW2=2,8mm
- epaisseurW3=5,6mm
- rayonalveole=0,3mm
- jaumontagealv=0,5mm
- couchebasse=2mm
- couchehaute=14,8mm
- epaistoileexterieure=2mm
- jeumodule=5mm
- rayoninterneECAL=1400mm
- jeuintermodule=5mm
- epaisseur_wafer=0,7mm
- epaisseur_colle=0,1mm
- epaisseur_PCB=1,2mm
- epaisseur_BGA=1,7mm
- epaisseur_shielding=0,5mm
- epaisseur_1K=0,15mm
- epaisseur_3K=0,25mm
- epaisseur_kapton=0,05mm
- epaisseur_structil=0,2mm



Courtesy of M. Anduze

Mechanical Model (2)

Paramètres
- `Matériau`=Tungstène
- `largeur-alveole`=253,6mm
- ame=1mm
- nombrecolonne=3
- epaisseurW1=2,8mm
- epaisseurW2=2,8mm
- epaisseurW3=5,6mm
- rayonalveole=0,3mm
- jaumontagealv=0,5mm
- couchebasse=2mm
- couchehaute=14,8mm
- epaistoileexterieure=2mm
- jeumodule=5mm
- rayoninterneECAL=1400mm
- jeuintermodule=5mm
- epaisseur_wafer=0,7mm
- epaisseur_colle=0,1mm
- epaisseur_PCB=1,2mm
- epaisseur_BGA=1,7mm
- epaisseur_shielding=0,5mm
- epaisseur_1K=0,15mm
- epaisseur_3K=0,25mm
- epaisseur_kapton=0,05mm
- epaisseur_structil=0,2mm



Courtesy of M. Anduze

Small ILD ECAL Cost

Complete re-evaluation for the ressource survey in July (PRELIMINARY)

- Number of elements
  - Wafers, ASICs, PCB's, SLABs, structures,
  - moulds, processes, test benches
  - transportation boxes
- Man•Years
  - Reception, Tests, Mounting, Installation
- doubled X-cheked by scaling laws (scripts, excel)
  - But costs ≠ than in TDR

Outcome:

- Cost ratio 1.4m/1.8m of **47,5%**
  - **Used for the ressource survey rescaled to 1.8m.**

Summary

Preliminary* studies hints that reduction of R_{ECAL} 1,8m ➘ 1,4m (-22%) and reduction of layers have limited effect on performances for JER:

- **JER +≤10%** from radius
- JER +≤6% from N_{layers} ~compensated by thicker Wafers

* prelim =
non optimised sim models,
non-optimized SW.

Reduced Mechanical model is available

- Used for full costing → **47%** of "standard ILD" SiW ECAL.
  - To be evaluated for TCP, HCAL, Yoke, Coil, Hall, etc. ⇒ **sizeable reduction**!

X-check of feasabilty:

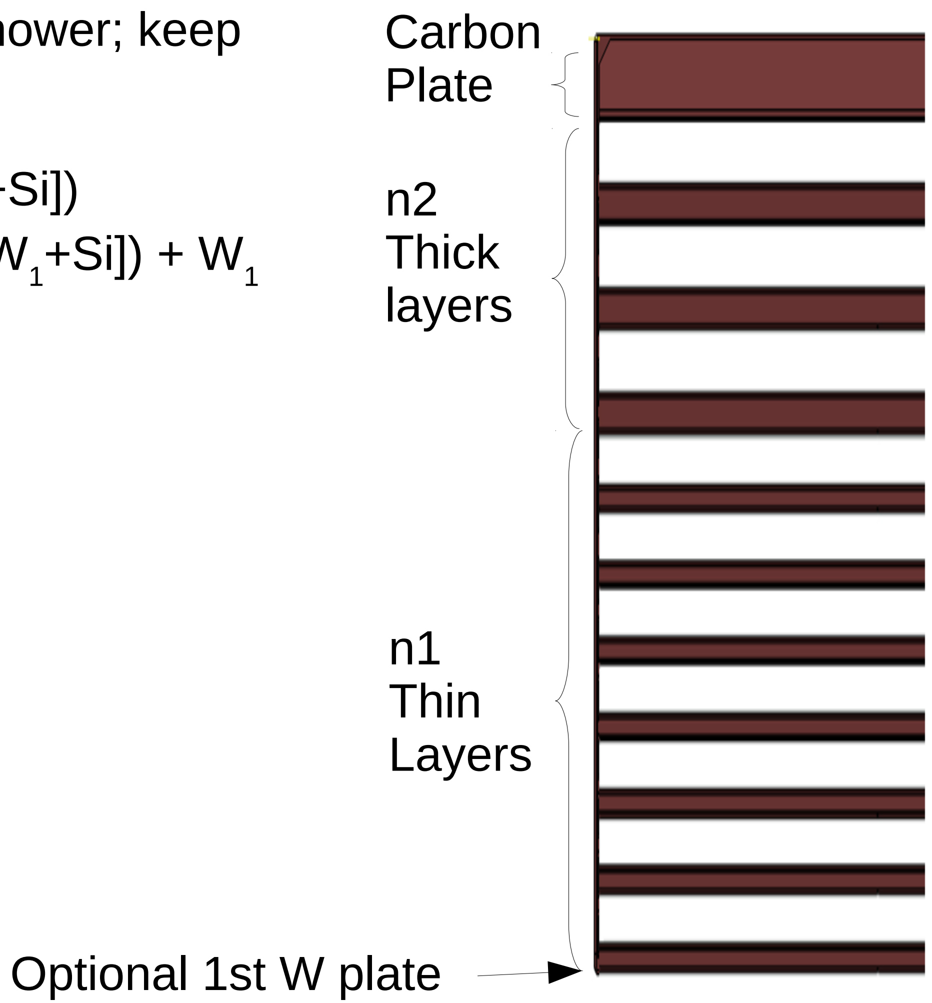
- Larger & thicker wafers to be tested (ordered)
- (Mechanical) PCB design to be updated

Simulation is being prepared, with improvement
⇒ perf: single JER for all cosθ, on tau's, ...

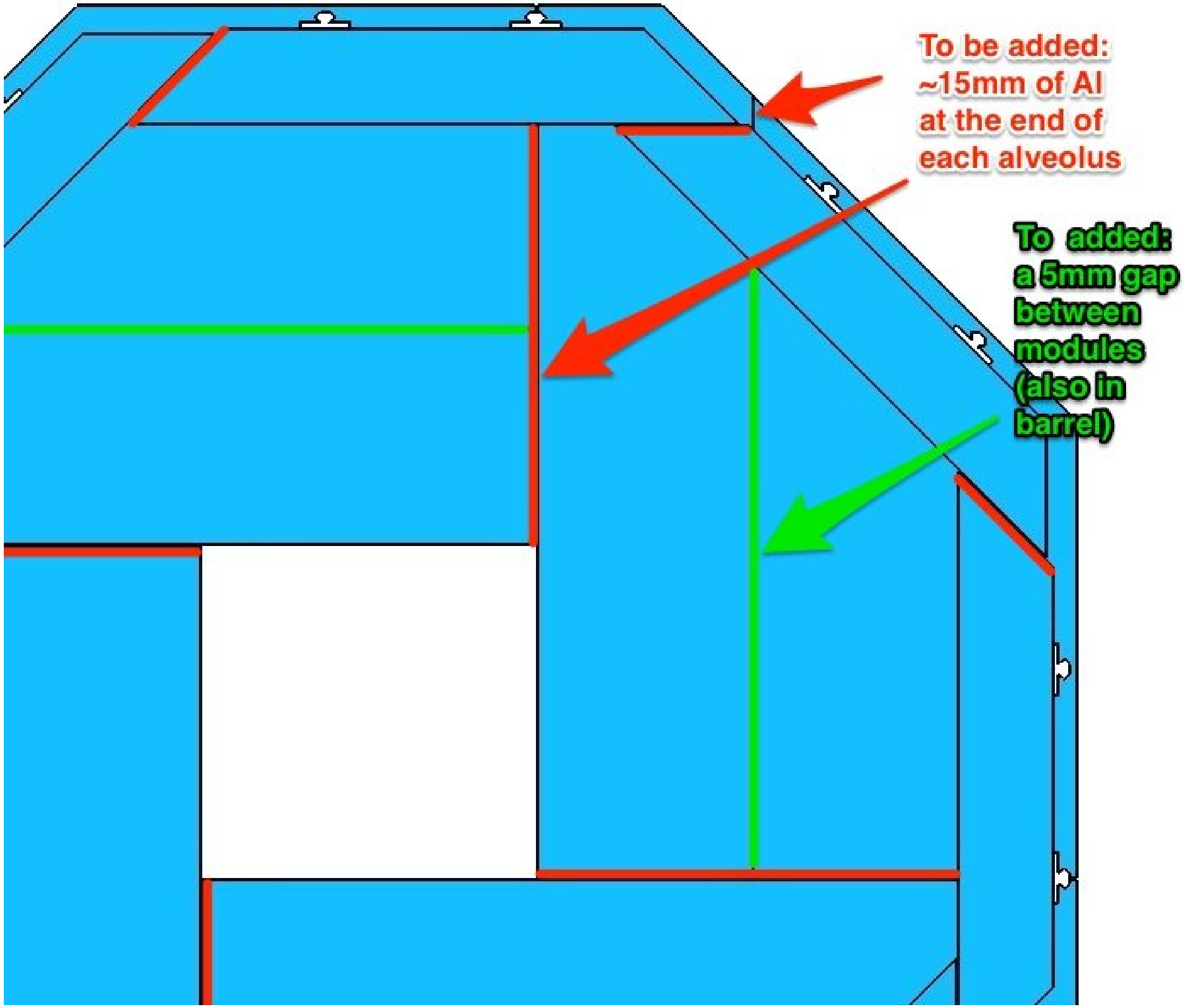
Extras

New ECAL layout & SEcal06 driver

- Option to render the 1st Si layer standard ⇒ 1 layer of W in front 1st alveola ⇒ no preshower; keep option to ***not*** have it.
- more regular structure: $n_1/2\times(W_1+[Si+W_1+Si]) + n_2/2\times(W_2+[Si+W_2+Si])$
  - Now : $[Si+W_1+Si] + (n_1-1)/2\times(W_1+[Si+W_1+Si]) + W_1 + n_2/2\times([Si+W_2+Si] + W_2)$
- For hybrid: alternate Si and Sc alveola [*]
- Unite Barrel and Endcaps drivers



Missing in Simulation



Cost / performance optimisation (review by V. Balagura)

Global geometric parameters

- (W thickness ≡ constant); cell size = 5×5mm^2
- R_{TPC} — single JER — [Trong Hieu Tran, LLR]
  - at constant (R/Half-z)
- Number of layers — single JER — [Trong Hieu Tran, LLR]
  - @

Construction Parameters

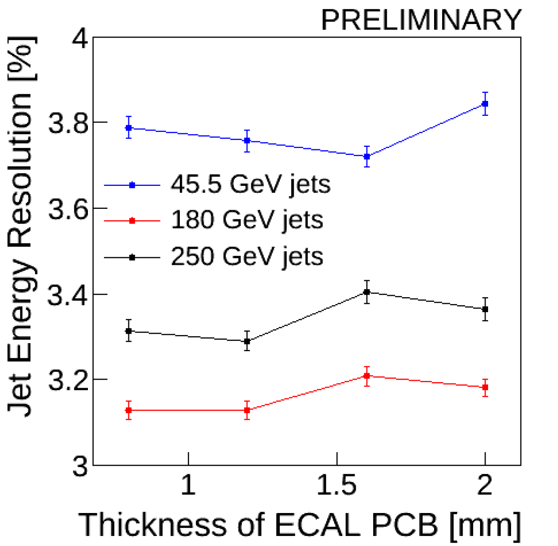
- PCB thickness — single JER — [D. Jeans, Tokyo U.]
  - @ 45.5, 180, 250 GeV
- Si Guard Ring Thickness — (homogeneity) & singe JER — [A. Suhail, LAL]
  - @ constant wafer size; unique global correction

Resilience

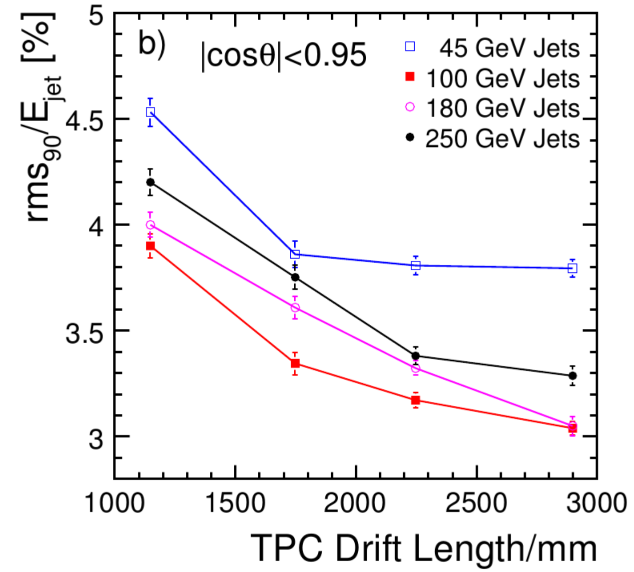
- Amount of dead pixels — single Photons & JER — [D. Jeans, Tokyo U.]
  - random removal of hits ; unique global correction

Optimisation in term of performances.

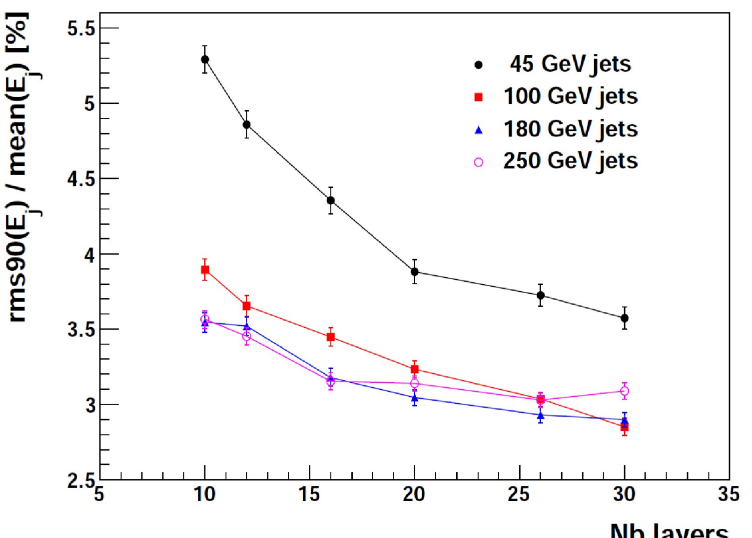
- RMS_{90}
- JER on uds events @ …
- Single γ (3, 10, 100, 500 GeV).



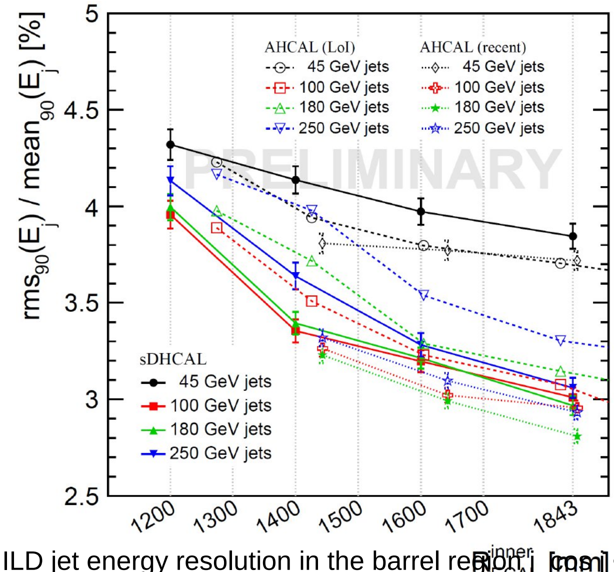
Single jet energy resolution as a function of the thickness of PCB with embedded electronics.



Single photon energy resolution as a function of the number of silicon layers for four photon energies.

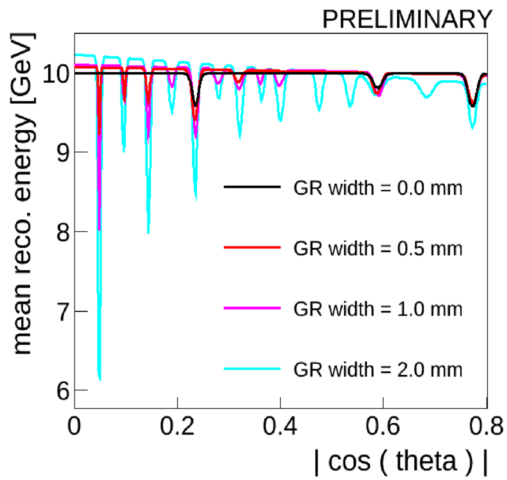


Single jet energy resolution (rms90=E) in the barrel region (j cos j < 0: 7) as a function of the number of ECAL silicon layers in events e+e- → ZX → usd

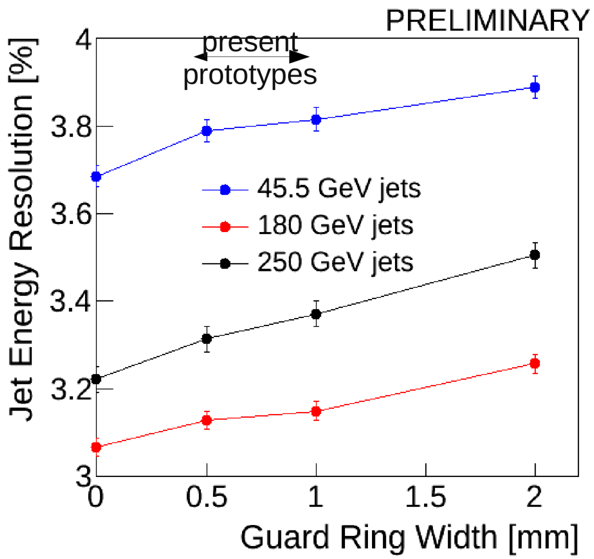


ILD jet energy resolution in the barrel region j cos j < 0: 7 as a function of its radius

Guard Ring studies

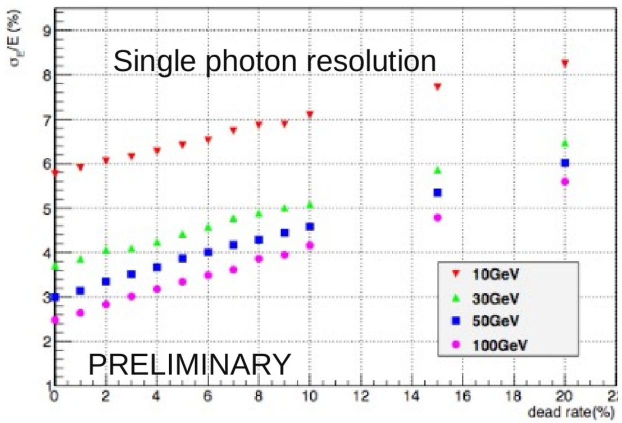


An ECAL average signal versus azimuthal angle. The loss in inter-sensor dead areas is visible (between barrel modules, barrel and endcap
and between the sensors, the latter depends on the guard ring).

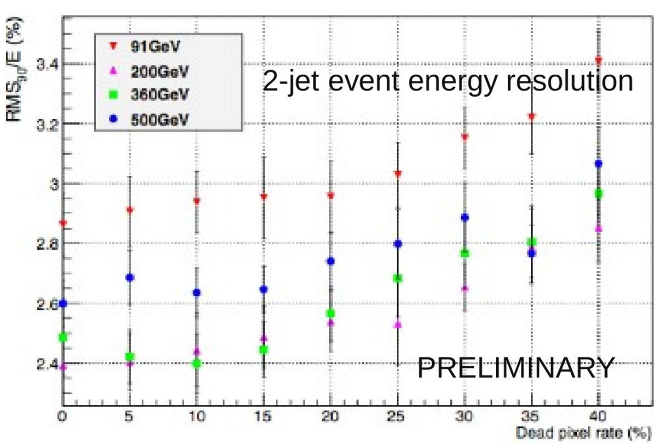


the single jet energy resolution after a simple dependent correction as a function of the guard ring thickness.

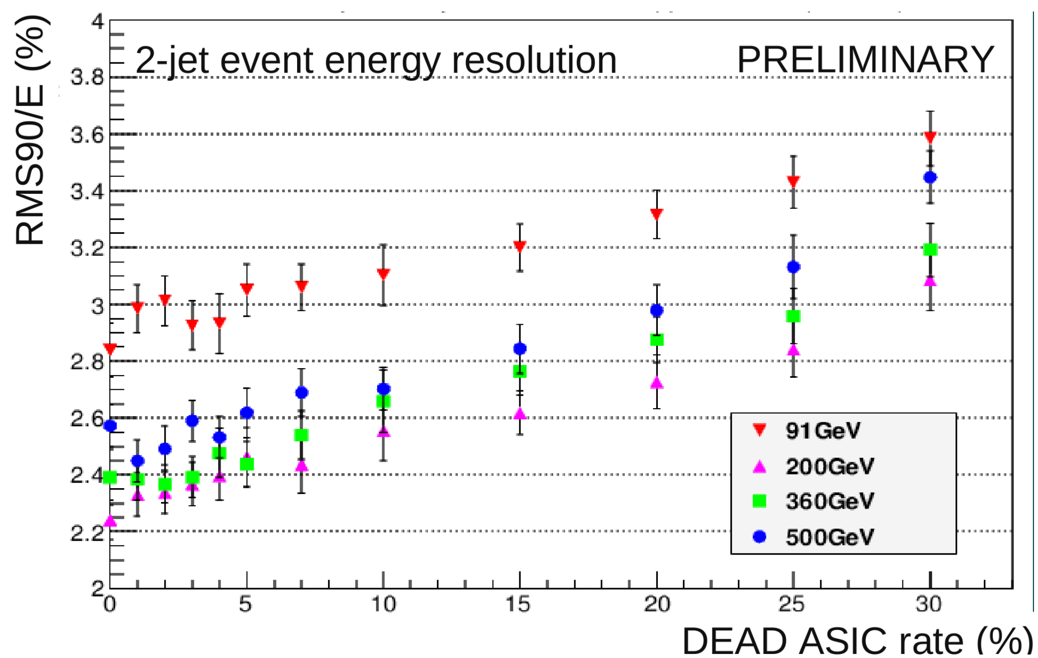
Resilience



Single photon resolution
PRELIMINARY
10GeV
30GeV
50GeV
100GeV
dead rate(%)



2-jet event energy resolution
PRELIMINARY
91GeV
200GeV
360GeV
500GeV
Dead pixel rate (%)



2-jet event energy resolution
PRELIMINARY
RMS90/E (%)
DEAD ASIC rate (%)
91GeV
200GeV
360GeV
500GeV