Calorimetry/muon session

3 sessions on calorimetry : 10 talks announced, 8.3 presentations

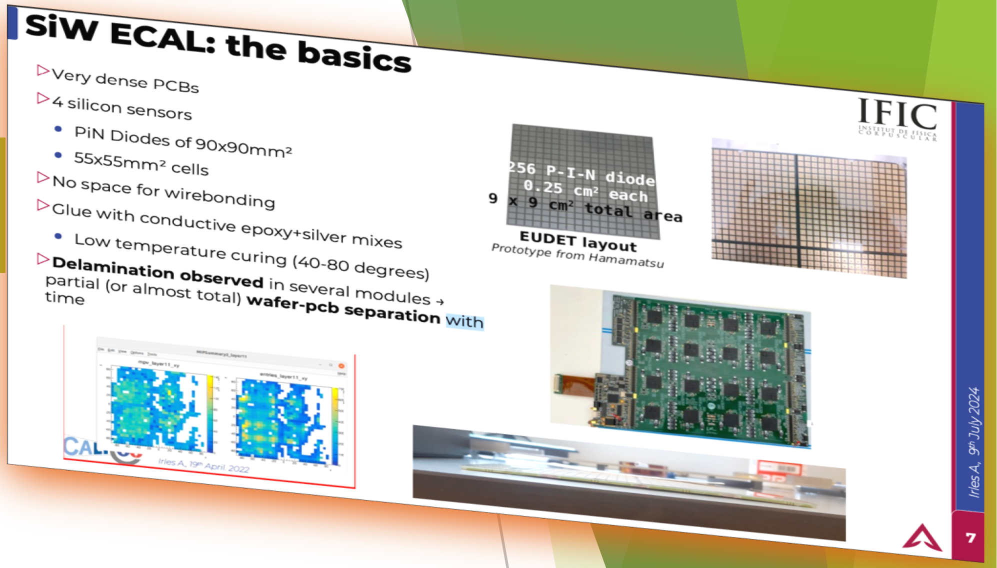
- New ideas / future
- Test beam results
- Simulations

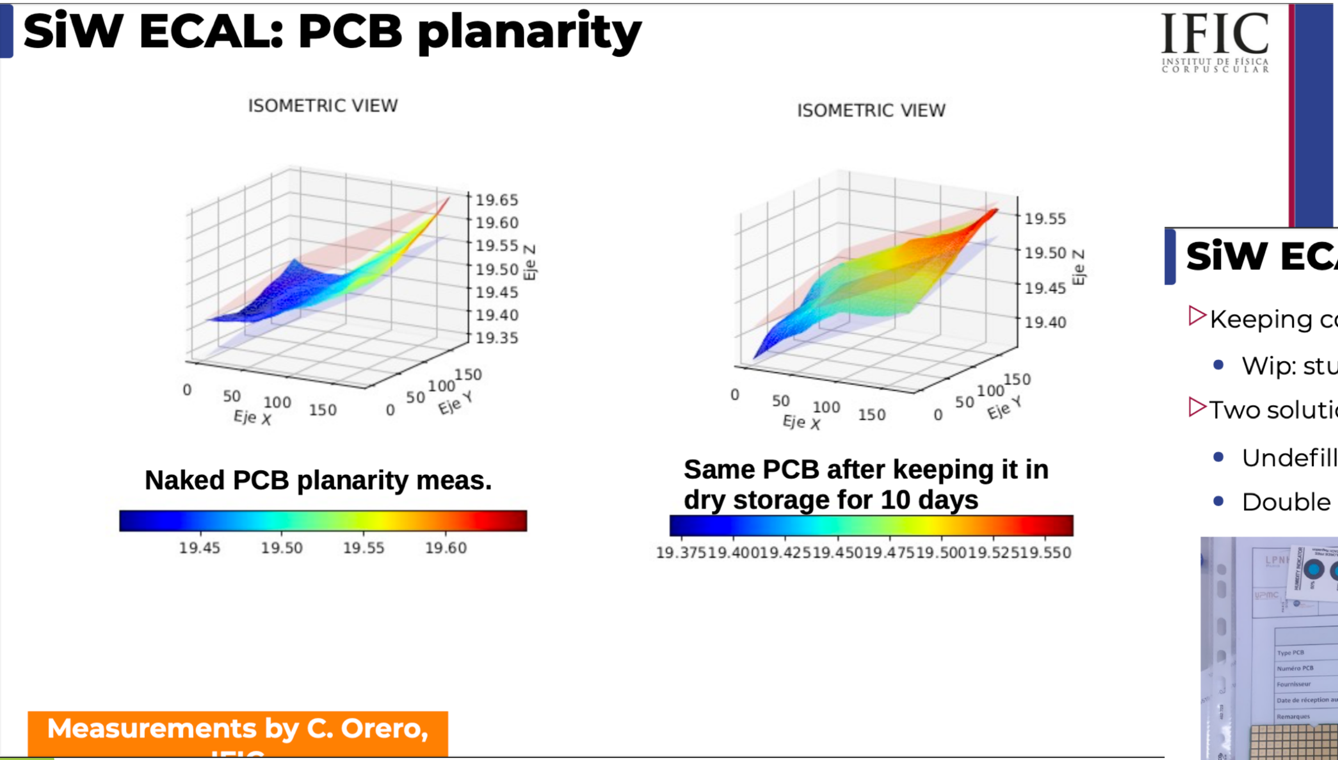
no talk on muon detector …

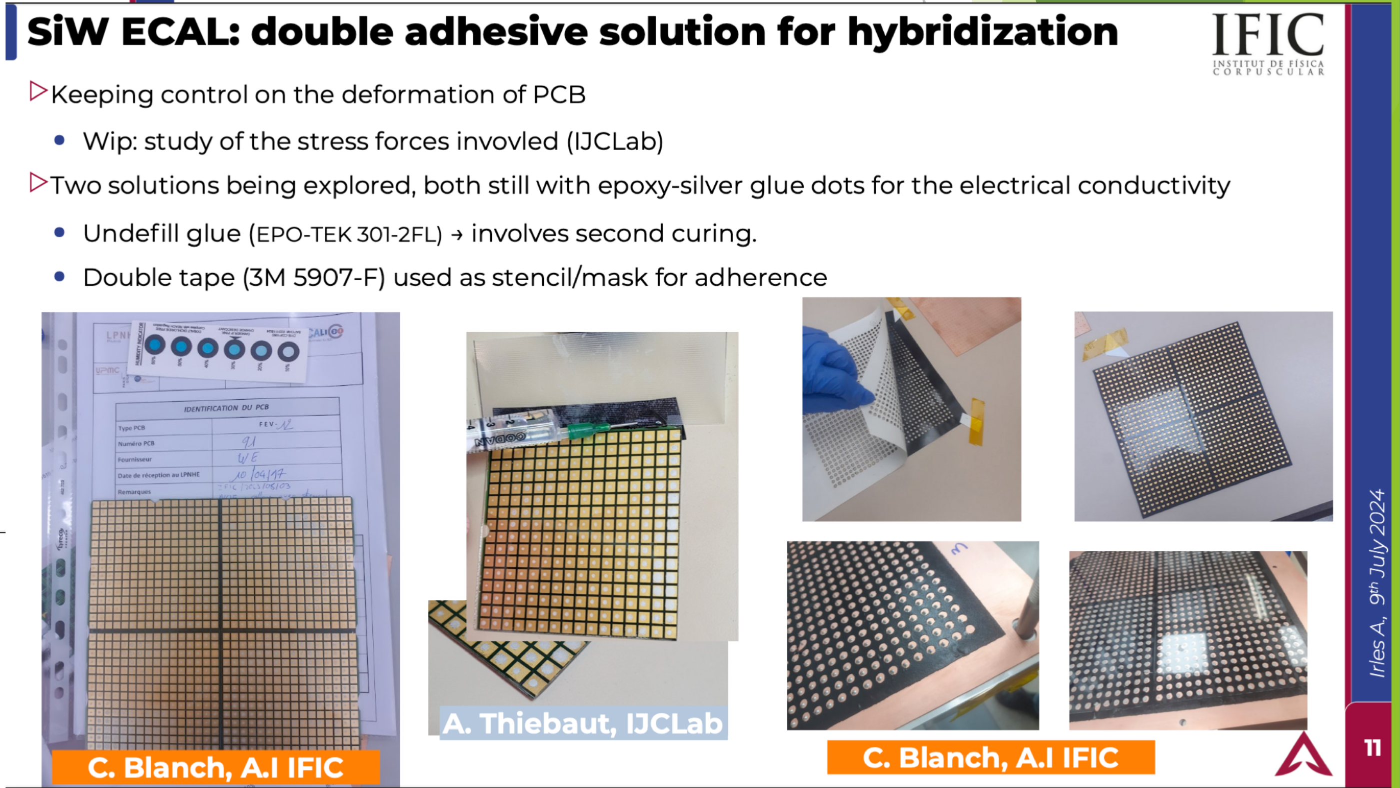
News ideas/future (09/07 morning)

Challenges on sensor-electronics hybridization for compact silicon tungsten electromagnetic calorimeter, Adrian Irles

Studies of sensor-pcb for SiW Ecal (CALICE) and for LUXE Ecal

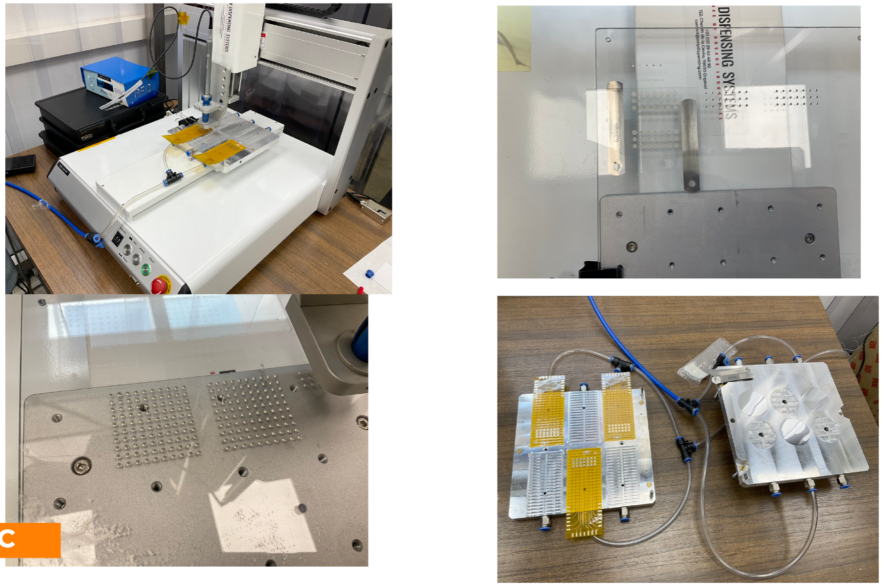






Ultra Compact Calo Hybridization

IFIC

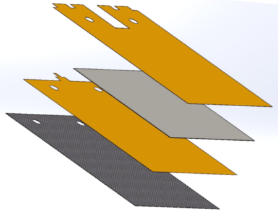


IFIC

Ultra Compact Calo Hybridization

IFIC

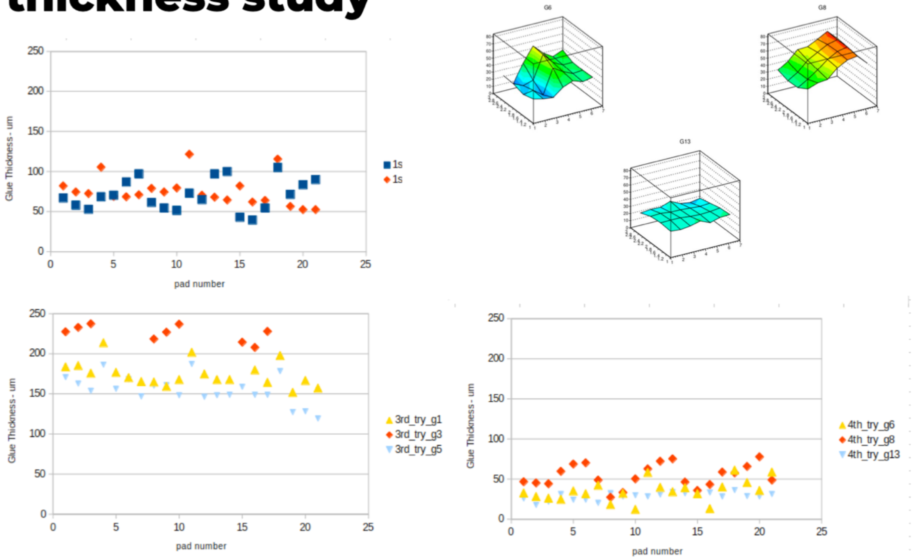
- Large sensors (9x9cm²) and **flexible PCBs (compact calo)**
- **Material budget, thickness:**
  - **Total bellow 1mm**
  - 200um CF + 320um sensor
  - ~500um for fanout + HV kapton + 3 layers of glue/Adhesive
- The main challenge is to obtain a very thin layer of glue, with high repeatability



Glue thickness study

IFIC

Change of dosification needle



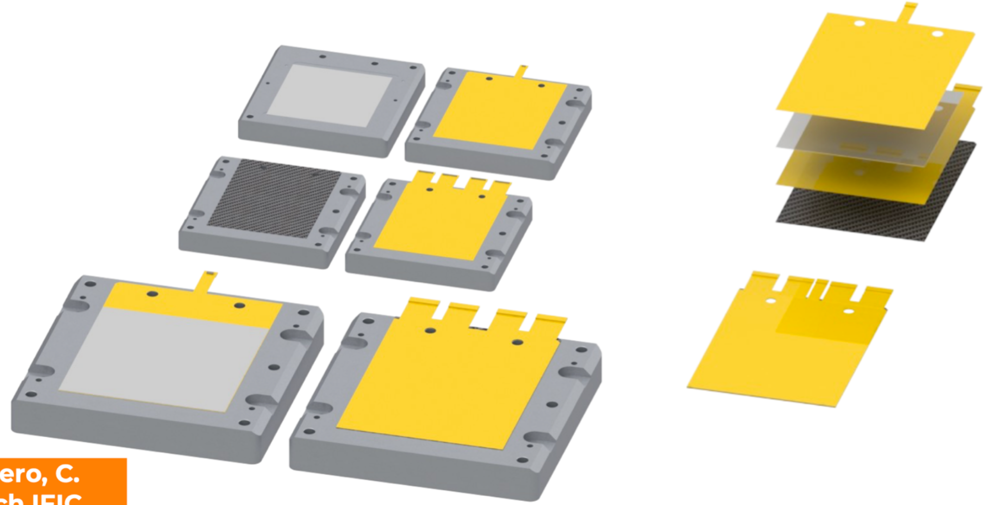
Release of vacuum before curing

IFIC

Tooling for precise hybridization

IFIC

- **Work in progress** – design and optimization of the gluing process



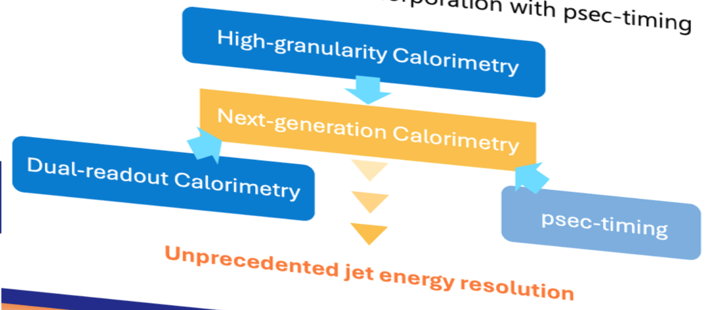
C. Orero, C. Blanch IFIC

News ideas/future (09/07 morning)

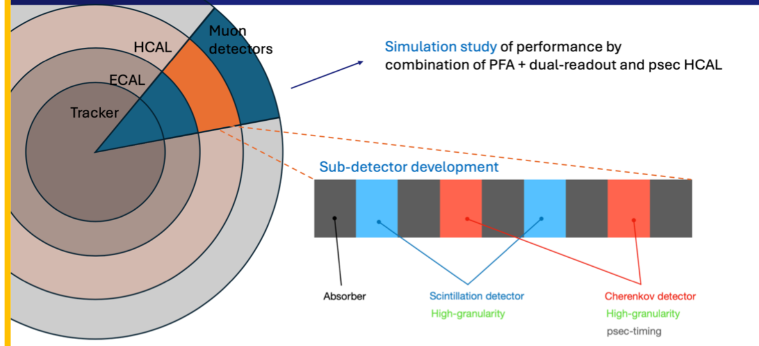
Development of next-generation calorimeter combining high-granularity and dual-readout calorimeter with psec-timing,
Weiyuan Li

Concept of next-generation calorimeter

Combine two calorimeter technology in corporation with psec-timing



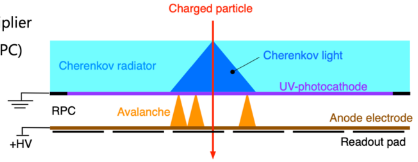
Implementation



Cherenkov detector

- Requires granular readout and psec-timing

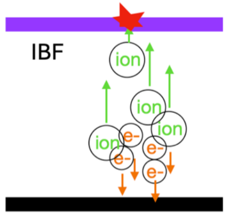
- Cherenkov radiator coupled to Gaseous photomultiplier
- Electron amplification by resistive plate chamber (RPC)
  - ✓ Fast timing
  - ✓ Simple structure → Large area by low cost
  - ✓ Readout segmentation

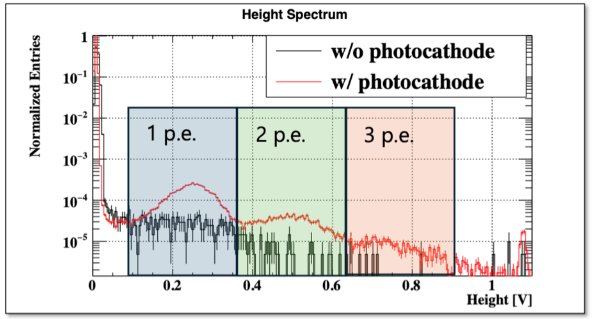


- Diamond-Like Carbon as resistive electrode (DLC-RPC)
  - ✓ High-rate-capability > 1 MHz/cm^2
  - ✓ DLC sputtered on polyimide = "film" electrode

Cherenkov detector

- 👍 Successfully observed Cherenkov light signal!
- 👍 Discrete peaks of #p.e. in height(charge) spectrum = photon counting capability
- 👎 Low #p.e.
  - Ion-backflow (IBF)?
    → robust photocathode required
  - Failure in the handling of photocathode?

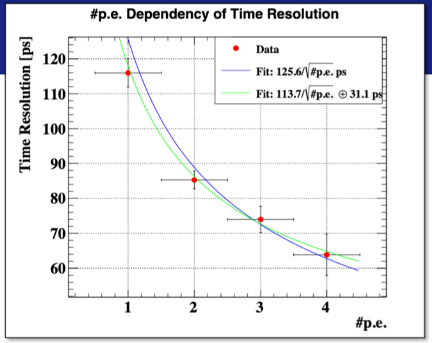




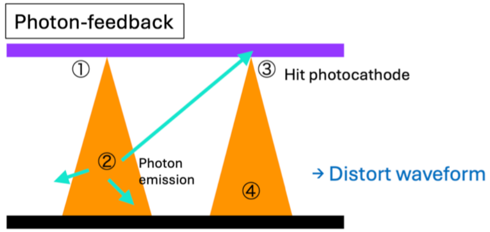
Cherenkov detector

Time resolution depends on #p.e.

- $126/\sqrt{\#p.e.}$ or $114/\sqrt{\#p.e.} \oplus 31.1$ ps
- 40-50 ps for 10 p.e., 30-40 ps for 20 p.e.
- RPC signal contamination (~ 50%), Photon-feedback (PFB)
  → Possible reason of discrepancy to estimated value



- Improvement planned
  - Reduce gap thickness → mitigate RPC contamination
  - Switch to robust photocathode → mitigate PFB



The construction technique been established
→ Moving on to the upgrade of the detector

News ideas/future (09/07 morning)

Development of next-generation calorimeter combining high-granularity and dual-readout calorimeter with psec-timing,
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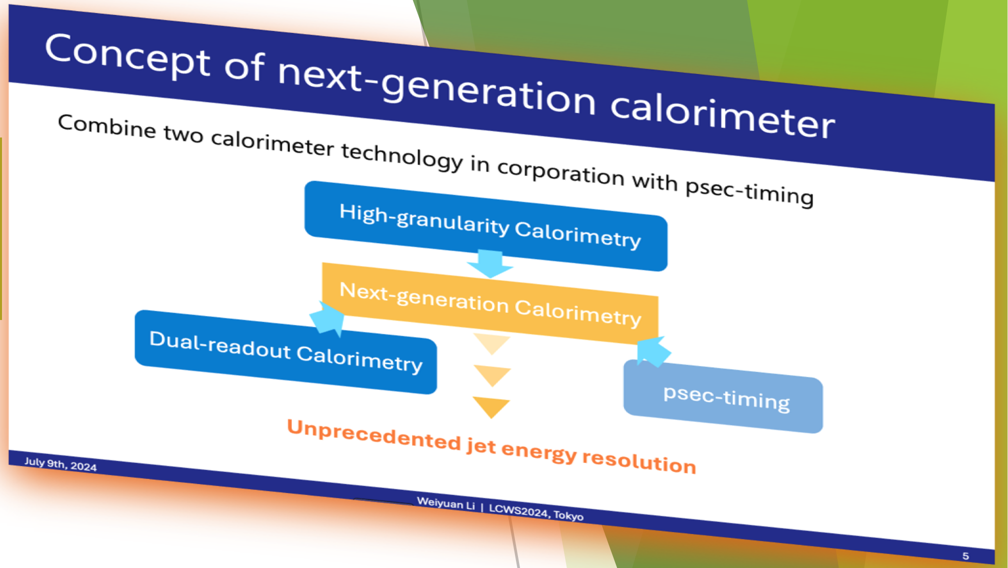

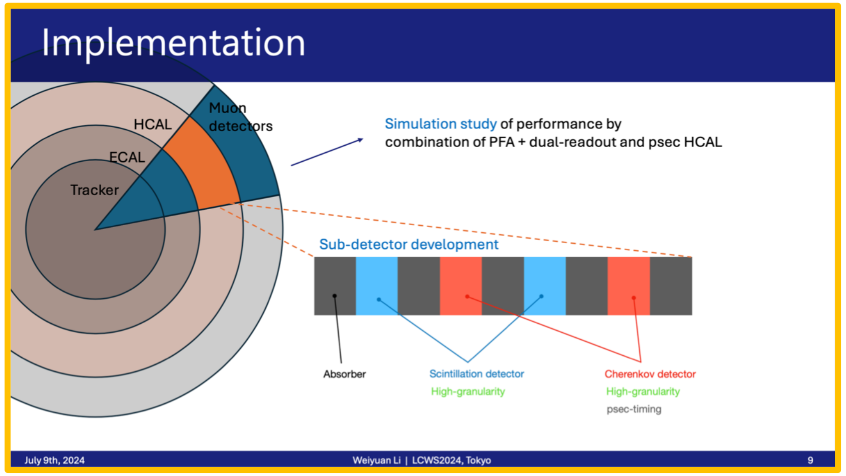

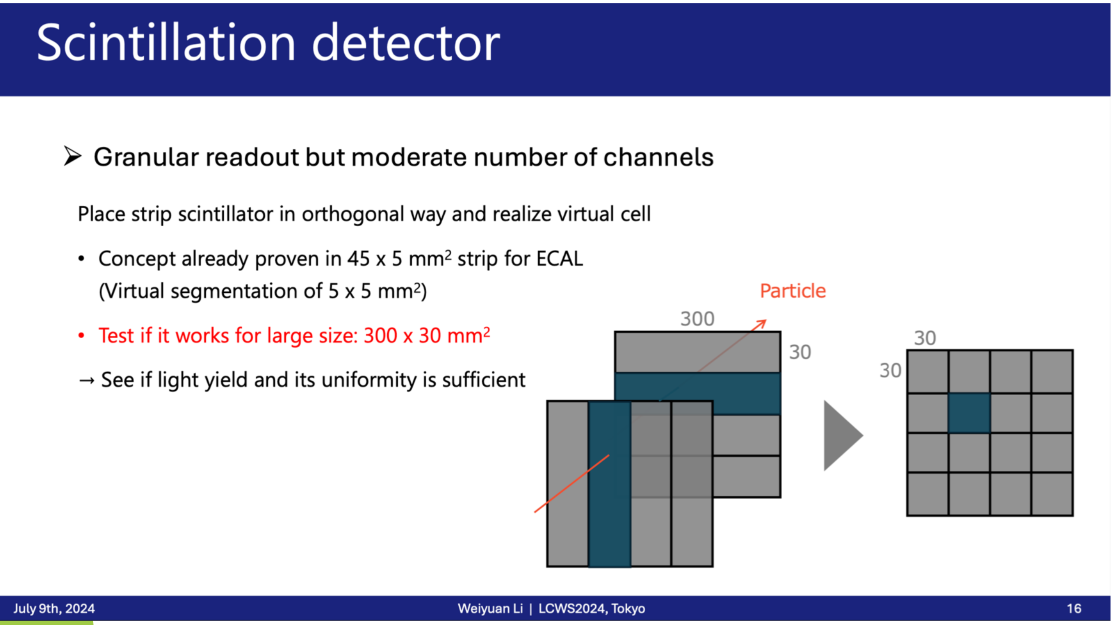

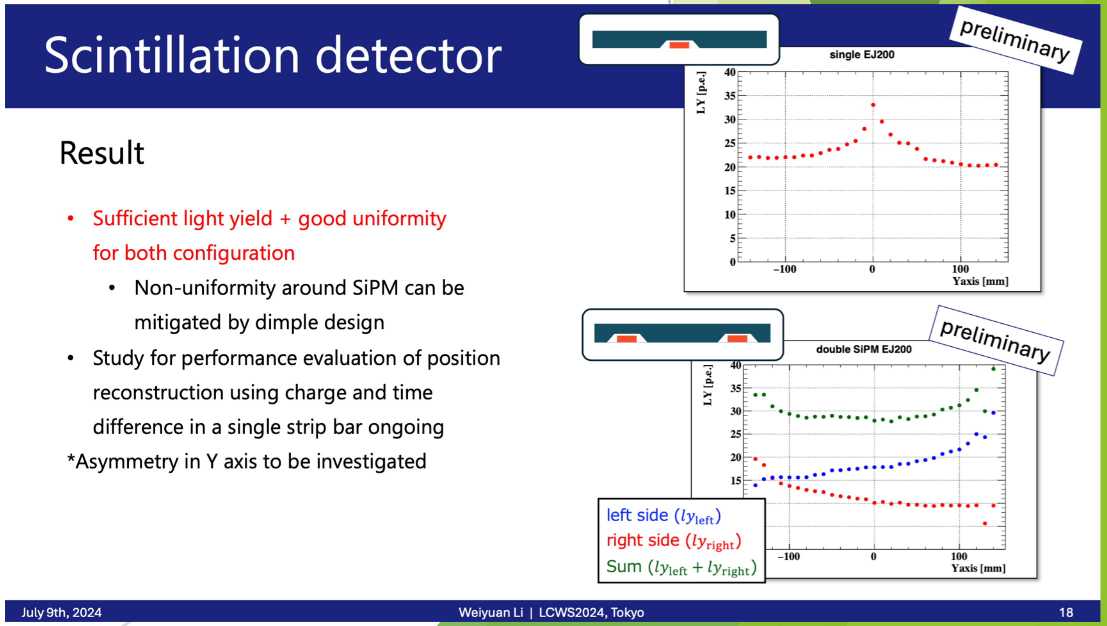

News ideas/future (09/07 morning)

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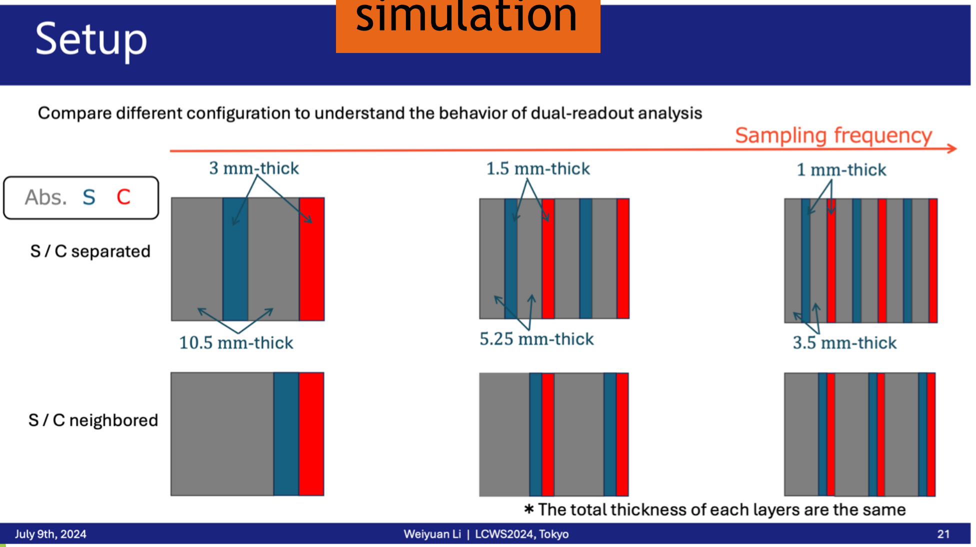
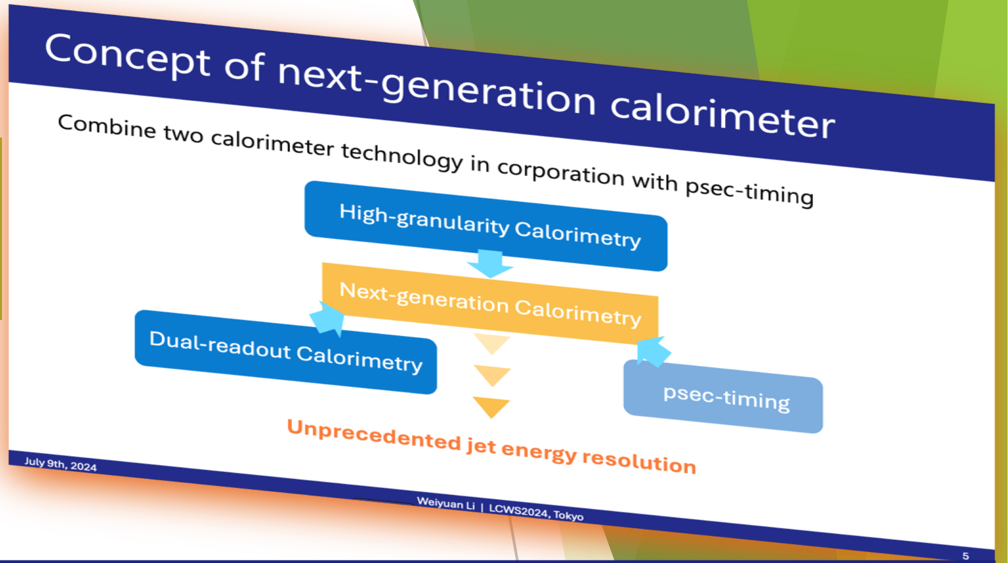
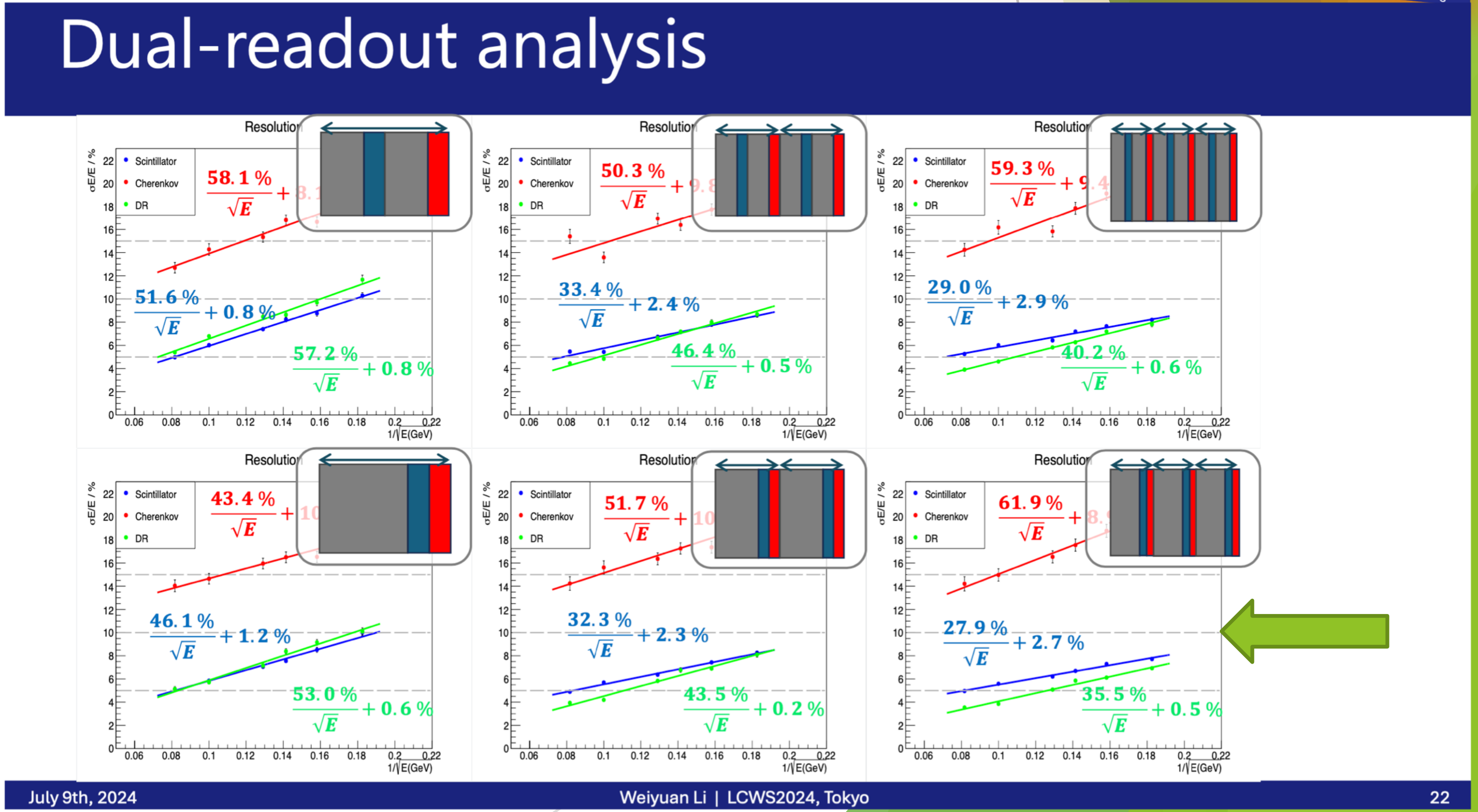
simulation



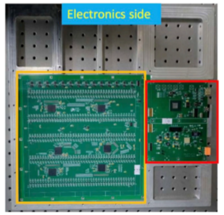




Test beam results (10/07 morning)

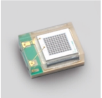
Status of high granular scintillator calorimeter for future electron positron colliders, Tatsuki Murata

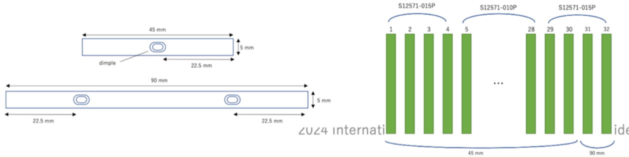
Sc-ECAL large technological prototype

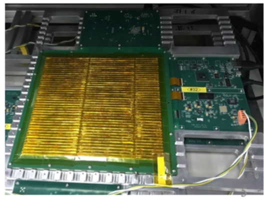


- All channels on each EBU can be individually readout by 6 SPIROC2E chips developed by OMEGA lab and CALICE collab.
  - High and low gain mode for wide dynamic range
  - 16 temperature sensors are implemented
- Two types of MPPC are used for SiPM on detection layer (manufactured by Hamamatsu K. K.)
  - S12571-010P, & -015P
- Last 2 layers have double SiPM readout part
  - Using 90 mm length strip instead of standard 45 mm strip

	Pixel size	# of pixel	gain
S12571-010P	10 um	10,000	1.35×10^5
S12571-015P	15 um	4,489	2.3×10^5



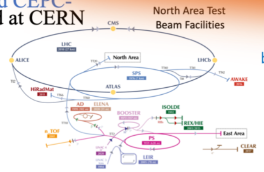


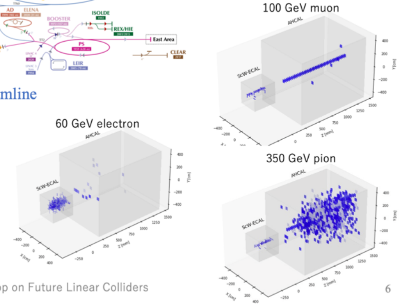


Test beam experiment

- Test beam experiment for Sc-ECAL and CEPC-AHCAL combined system is conducted at CERN SPS&PS
  - SPS : site 887, H8 beamline
    - October 19th to November 2nd, 2022
    - High energy beam (10-160 GeV)
    - μ^+, π^+, e^+
  - SPS : Site 887, H2 beamline
    - April 26th to May 10th, 2023
    - High energy beam (10-350 GeV)
    - Higher energy and purity beam than 2022's H8 beamline
    - μ^-, π^-, e^-, p^-
  - PS : Site 157, T9 beamline
    - May 17th to 31st, 2023
    - Low energy beam (1-15 GeV)
    - μ^-, π^-, e^-
- Collaborators
  - UTokyo, Shinshu university, USTC, IHEP, SJTU

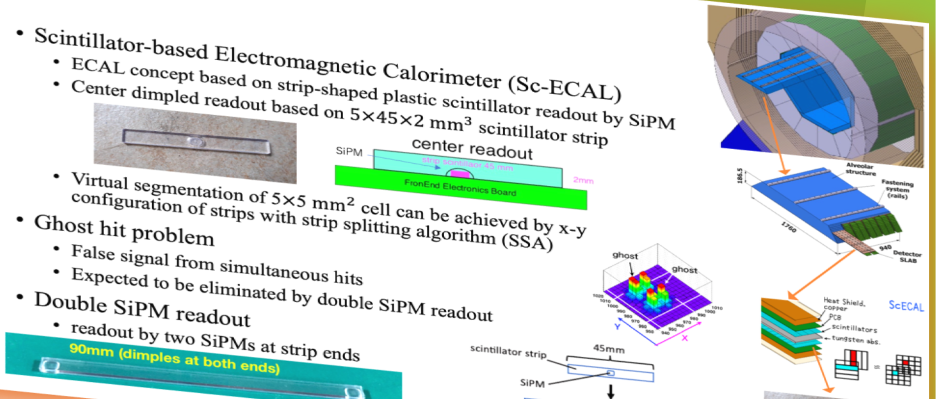
CEPC-AHC... progress is...





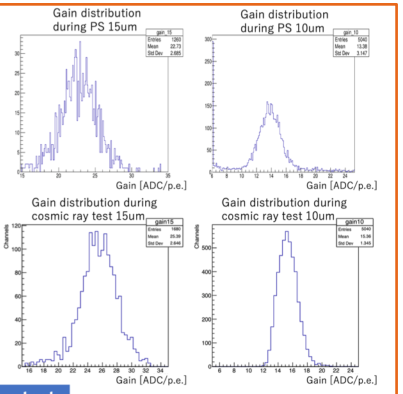
Sc-ECAL

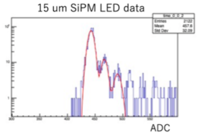
- Scintillator-based Electromagnetic Calorimeter (Sc-ECAL)
  - ECAL concept based on strip-shaped plastic scintillator readout by SiPM
  - Center dimpled readout based on 5×45×2 mm³ scintillator strip
  - Virtual segmentation of 5×5 mm² cell can be achieved by x-y configuration of strips with strip splitting algorithm (SSA)
- Ghost hit problem
  - False signal from simultaneous hits
  - Expected to be eliminated by double SiPM readout
- Double SiPM readout
  - readout by two SiPMs at strip ends



LED calibration

- LED data are taken during the 2023 beam test
  - SPS : 3 times (at the beginning and the middle of the beam test)
  - PS : every day
- LED data are fitted with multi-gaussians to calculate gain for each channel
- Increased the bias voltage of all channels at the beam test to compensate temperature difference from the CR test
  - The gains still decreased compared to the cosmic ray test

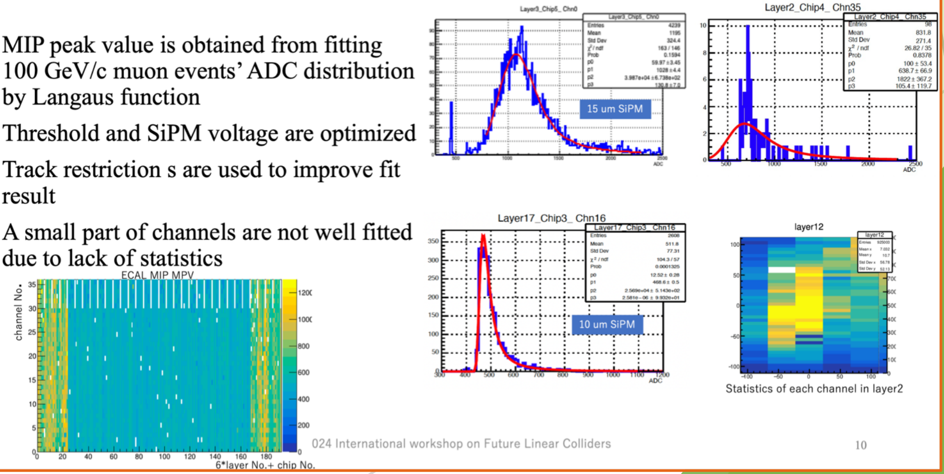




ECAL	Cosmic Ray test	Beam test
temperature	~20 C	25~29 C
Bias voltage	-	+0.5 V

MIP calibration

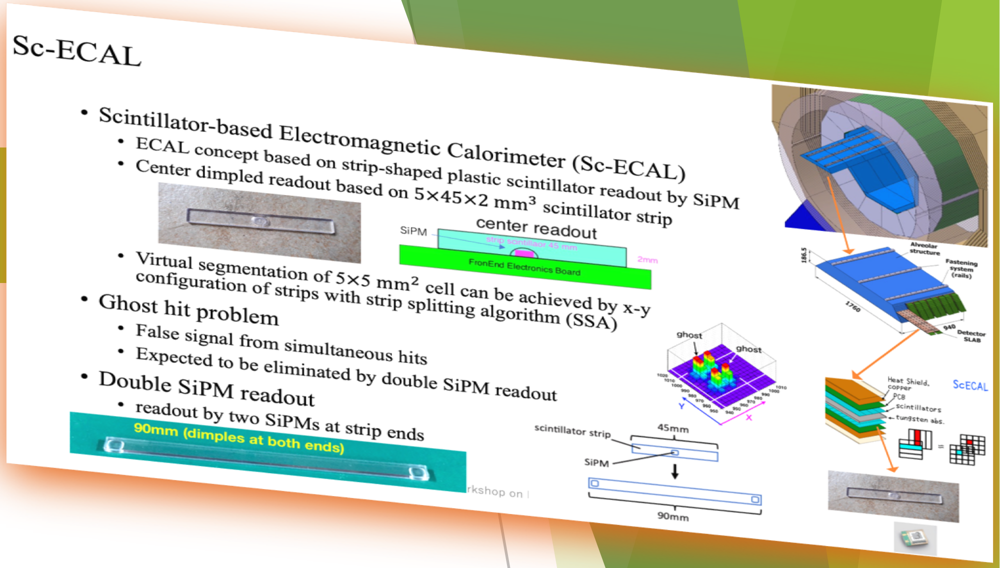
- MIP peak value is obtained from fitting 100 GeV/c muon events' ADC distribution by Langaus function
- Threshold and SiPM voltage are optimized
- Track restriction s are used to improve fit result
- A small part of channels are not well fitted due to lack of statistics



Statistics of each channel in layer2

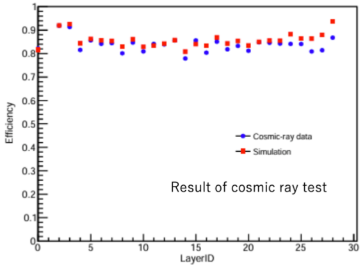
Test beam results (10/07 morning)

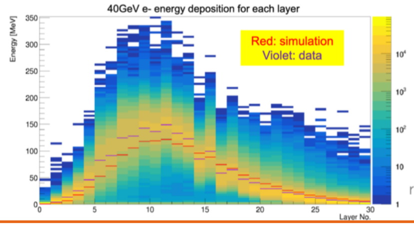
Status of high granular scintillator calorimeter for future electron positron colliders, Tatsuki Murata

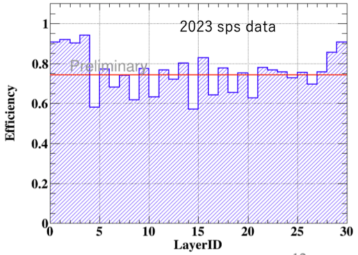


Detection efficiency of strips

- Definition of efficiency :
  - (# of hits which hit exist on the track fitting) / (estimated # of hit from track fitting)
- Detection efficiency of layers is calculated using track fit
  - A layer's hit strips are excluded from the track fitting
  - Efficiency of a layer is the ratio of events that have corresponding hits in the layer to all events
- Detection efficiency is fluctuating among layers
  - Same behavior with the energy distribution







r Colliders

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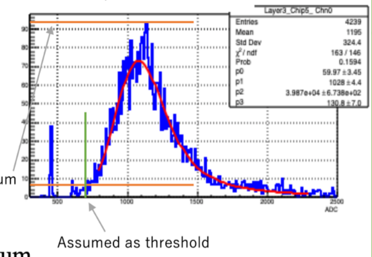
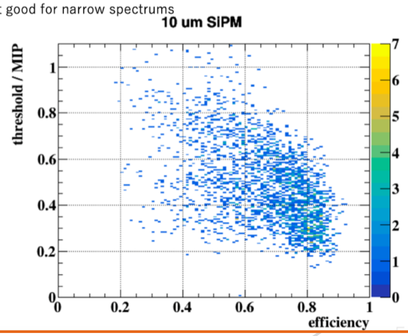
Correlation of threshold and detection efficiency

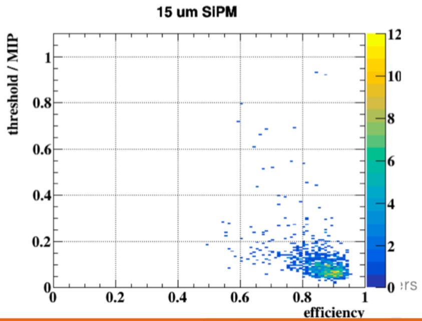
- Threshold are too high to cut lower edge of MIP spectrum
- Estimated threshold with constant fraction
  - ADC value with 1% of maximum height is assumed as threshold
    - This method might not be true for 15 um SiPMs
    - Might be a good indicator for 10 um SiPMs with rising edge in the spectum
- Lower threshold channels have higher efficiency

MIP spectrum of a channel (15 um)

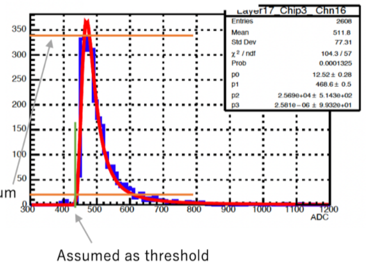


This MIP is from the fit
Not good for narrow spectrums





MIP spectrum of a channel (10 um)



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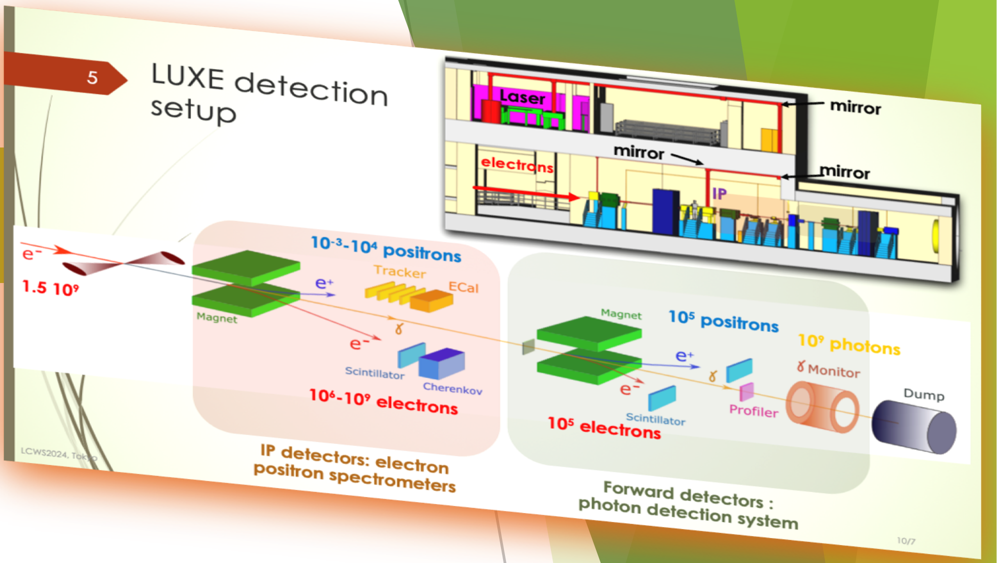
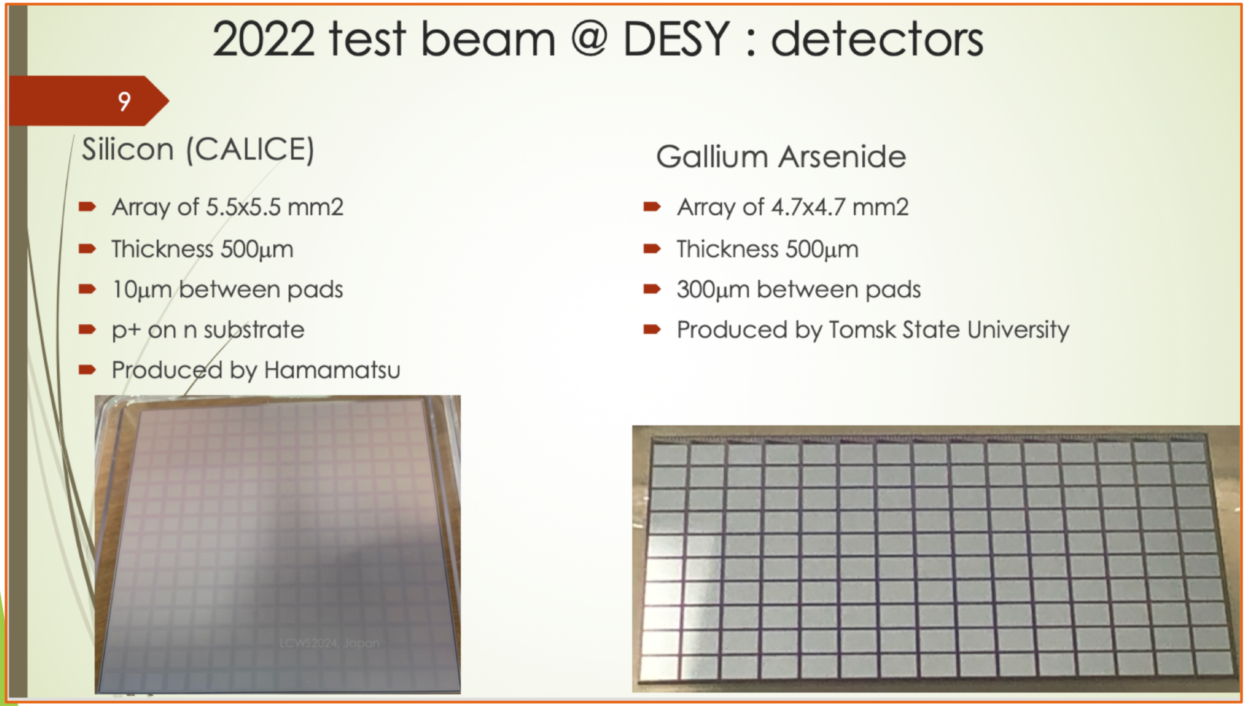
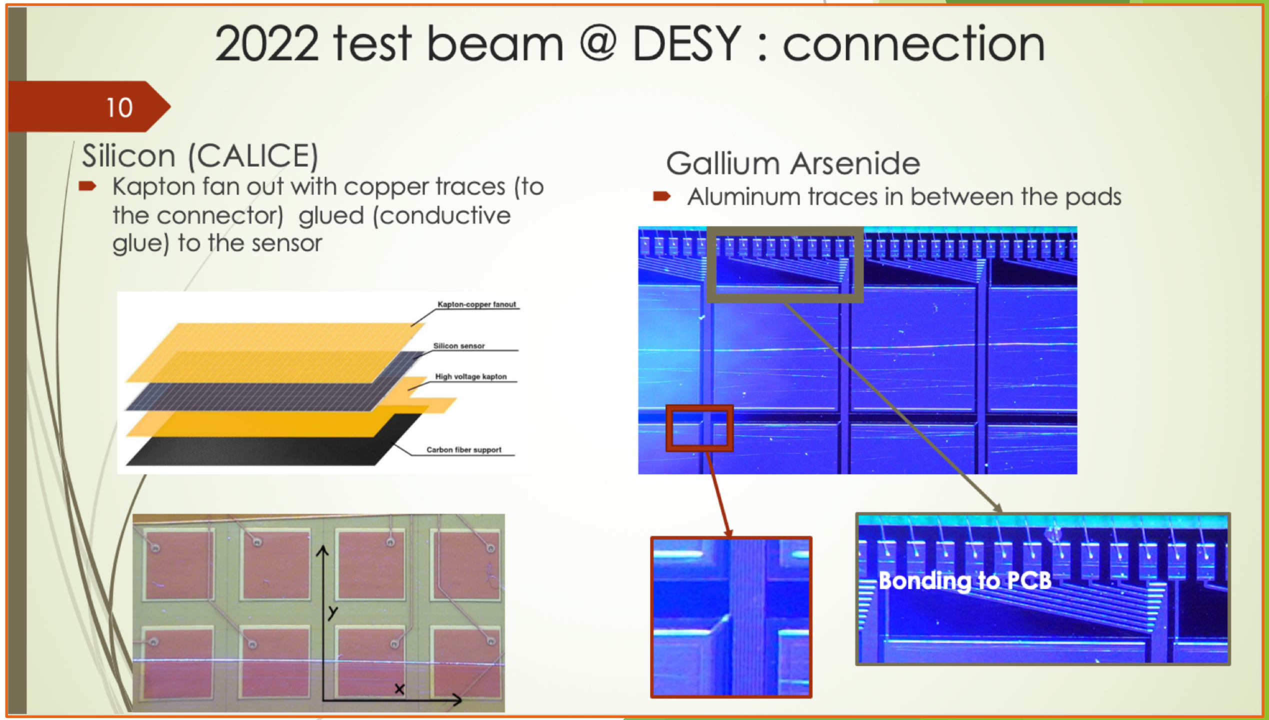
Test beam results (10/07 morning)

Test-beam measurements of instrumented sensor planes for a highly compact and granular electromagnetic calorimeter, YB







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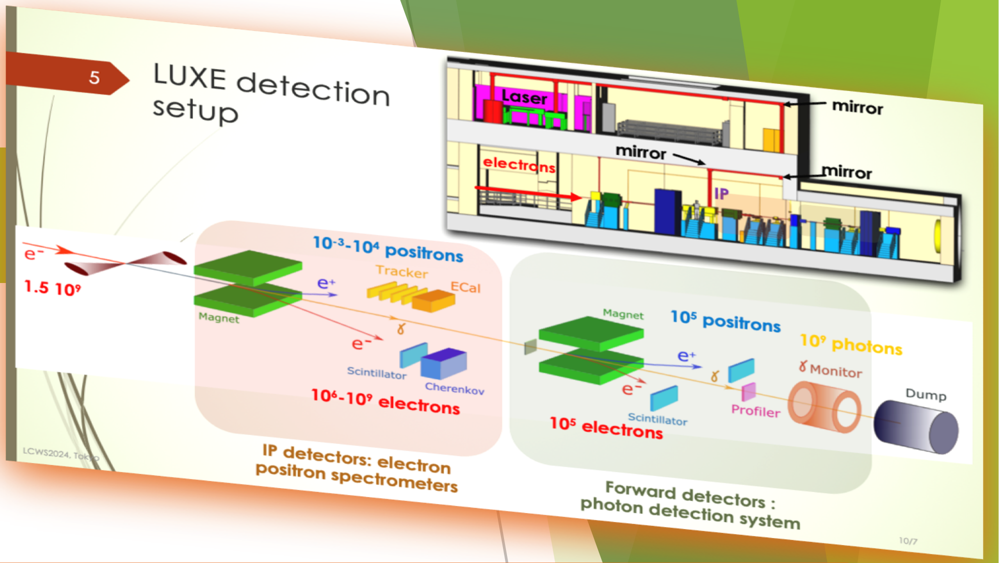
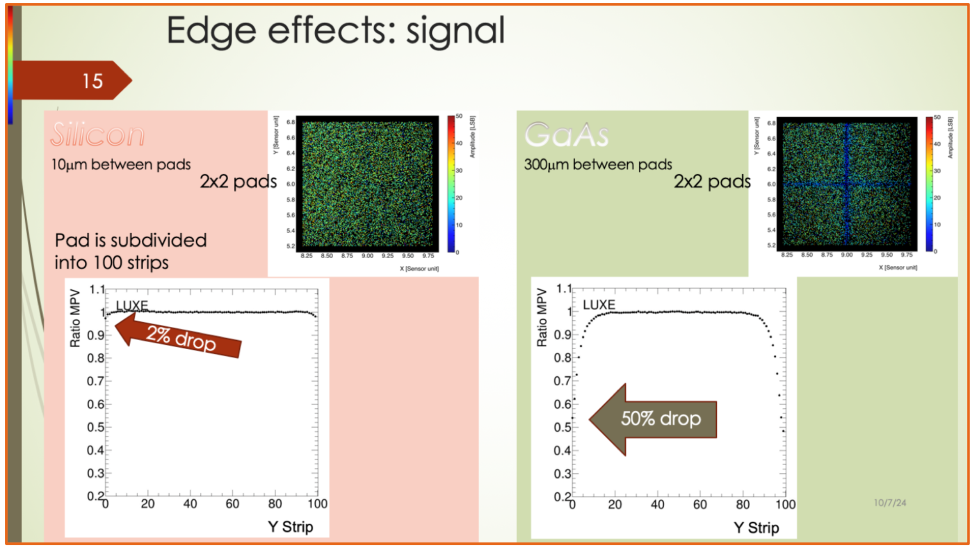
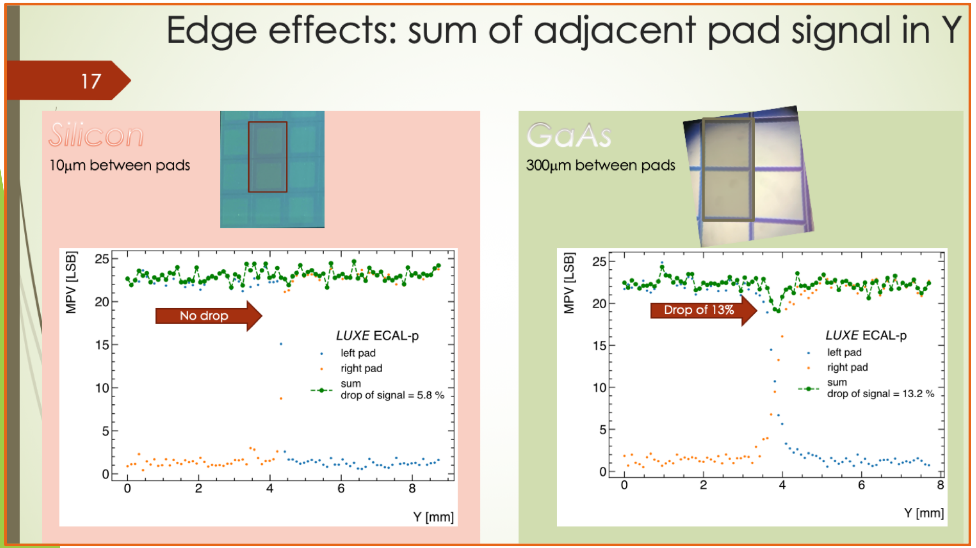
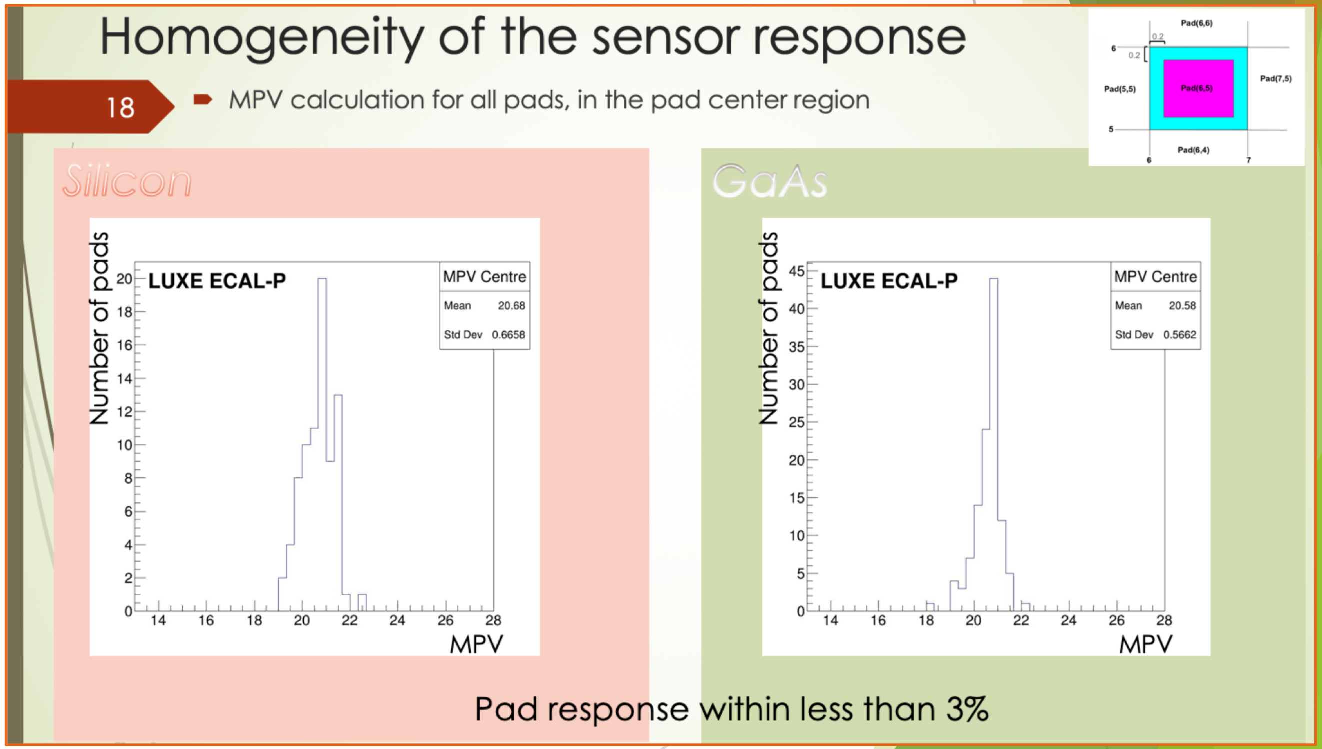






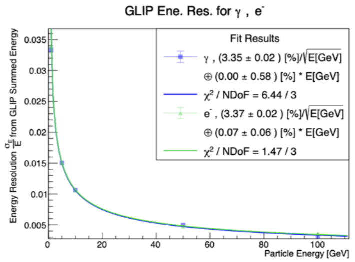


Test beam results (10/07 morning)

Photon and Electron Reconstruction in an Ultra-High Granularity Forward Calorimeter , Brendon Madison

High Granularity Proposal: GLIP

- Granular Long Instrument for Precision (GLIP)
- Multiple designs, original here
- 40 X_0 , 1/6 X_0 layers, 1mm Si, SiW sandwich in xy detector
- Reco. using various algorithms
- Ene. res. of $\approx \frac{3.36\%}{\sqrt{E}} + 0.02\%$
- θ resolution at least ≈ 0.2 mrad
- Moliere radius of 9.4 mm
- Length of 110 cm

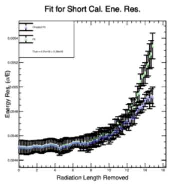


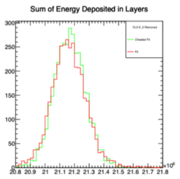
Broad Outline

- **What are we doing today?**
- Presenting work on precision forward calorimeter at e^+e^- Higgs Factories
- **Why?**
- Physics goals require precision on luminosity, want to measure DiGammas too
- **How?**
- Use new detector, GLIP, and some new methods

GRIP the Fit Results

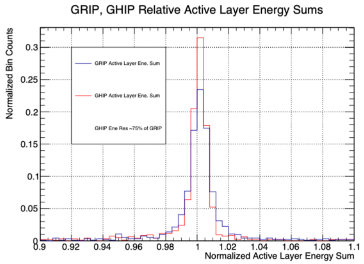
- Decrease in energy resolution but can truncate at least 15 X0 down to 25 X0
- Energy resolution worsened by 18%
- 0.45% to 0.53%
- Reduces GLIP length to 69 cm!
- So GRIP would be much shorter!
- "cheated" result indicates that the model can be much better too





GHIP , A heavier LumiCal

- Can reduce length by using more than $\frac{1}{6}X_0$ but will lose energy resolution
- Alternative – Use 1mm CdTe pads to supplement ene. res. of SiW
- Go to $\frac{1}{3}X_0$
- Si will still be small for space/angle res.
- Reduces GLIP length to 49 cm!
- Energy resolution improves , 75% of GRIP



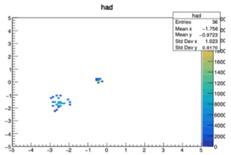
Test beam results (10/07 morning)

Photon and Electron Reconstruction in an Ultra-High Granularity Forward Calorimeter , Brendon Madison

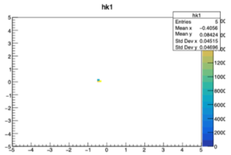
How to measure angles?

- ILD LumiCal uses layer clustering (here kMeans) and Log-Weighting (LW)
- This will be the “standard”
- Will also propose alternative – MSR
- Minimal Stochastic Reconstruction (MSR) uses local event variance to find least varying measurement

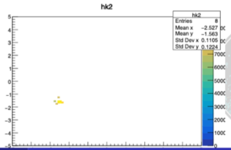
Toy MC of Hits



kMeans + LW Cluster 1



kMeans + LW Cluster 2



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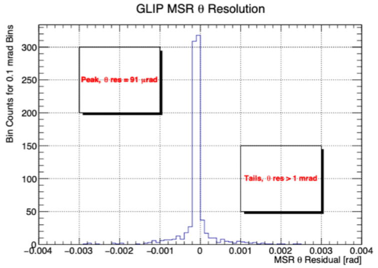
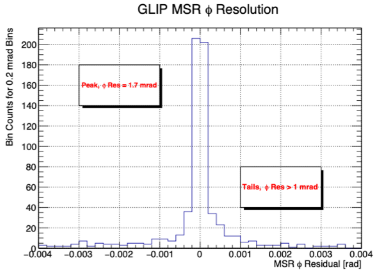
- Physics goals require precision on luminosity, want to measure DiGammas too
- **How?**
- Use new detector, GLIP, and some new methods

Result, Future of MSR Method

- MSR at least x2 better than clustered LW in θ resolution
- MSR at least 10x better in ϕ resolution
- Future: Check complimentarity to standard method , looks like some events MSR measures poorly
- If good, could use in boosted decision tree with standard to achieve greater resolution?



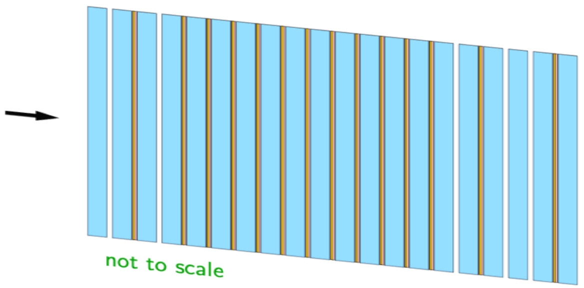


Simulation (10/07 afternoon)

Longitudinal structure optimization for the high density electromagnetic calorimeter, Aleksander Filip Zarnecki

Motivation

ECALp longitudinal structure optimization



Best solution is always to instrument all calorimeter gaps.

However, only 15 layers likely to be instrumented in LUXE phase I.

- how much will performance of the calorimeter be affected?
- how to choose empty layers to minimize the effect?

⇒ need for a dedicated study

Configuration scan

Approach

Analytical procedure has been developed, allowing for very fast calibration optimization and energy/position measurement precision estimate for arbitrary configuration of active layers.

Layers can be easily "deactivated" in MC by forcing their calibration factors to zero.

Analytical procedure can be easily repeated for multiple configurations...

With $N = 20$ gaps in ECALp, the total number of possible layer configurations is

$$N_{comb} = 2^{20} - 1 = 1'048'575$$

(1 to 20 layers instrumented) which can be checked in $\mathcal{O}(1h)$ (energy scan 2.5 – 15 GeV).

We can then look for the optimal configuration for given number of instrumented layers...

Energy or position resolution shown relative to that of fully instrumented calorimeter

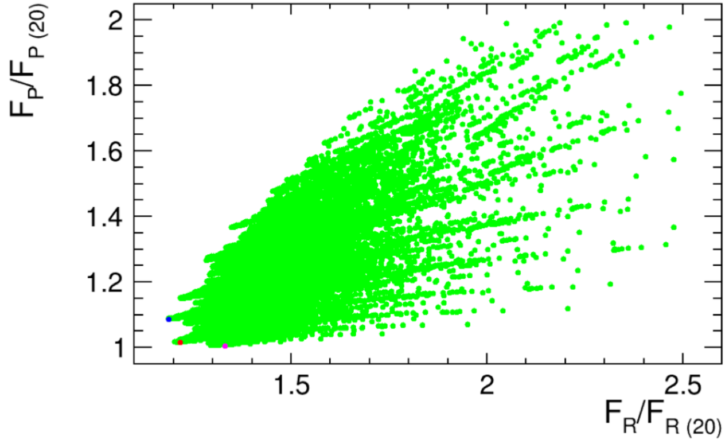
Configuration scan

Optimization

Position vs energy resolution optimization results for N=15 layer configurations 2.5–15 GeV

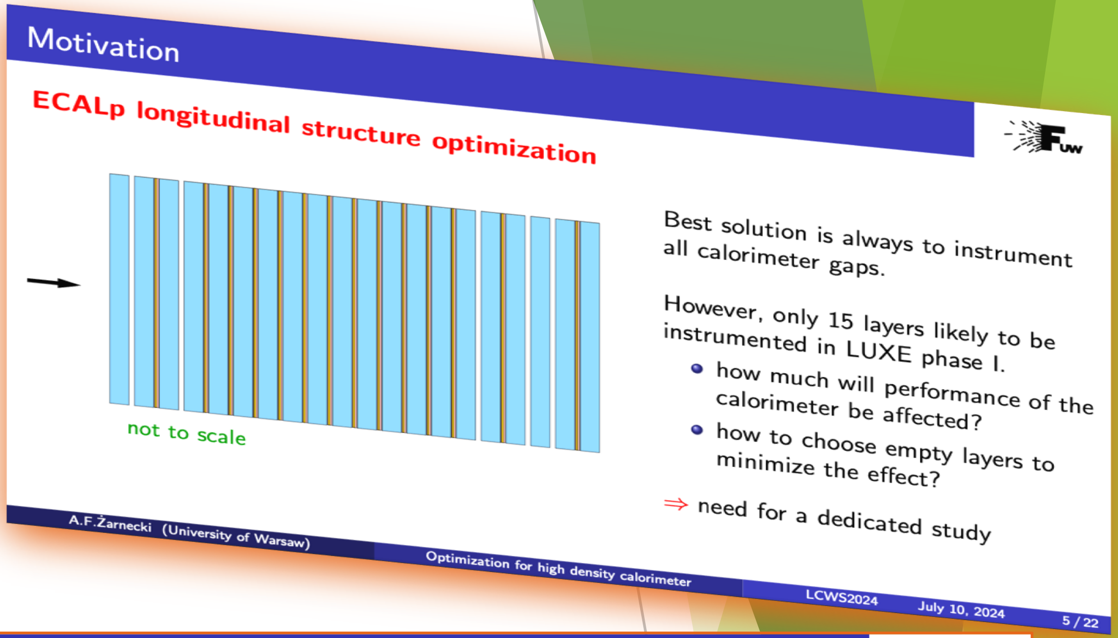
Indicated configurations:

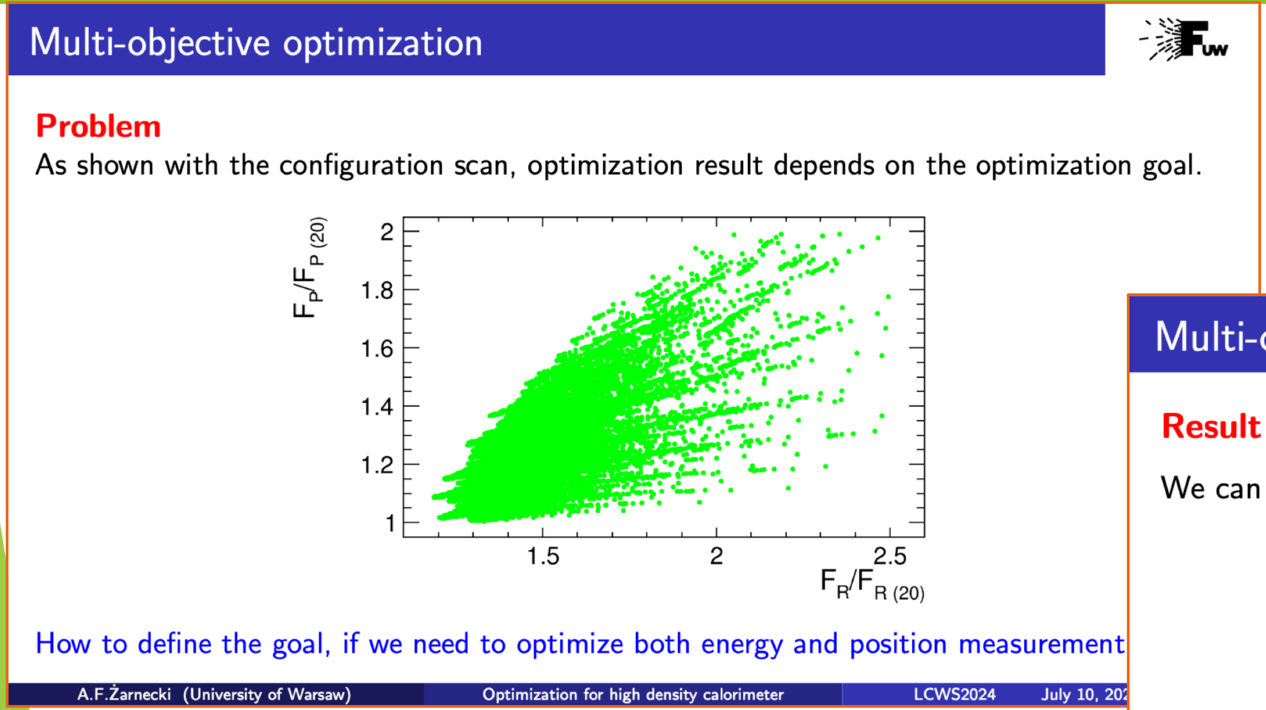
..|||||||||||||||...
.|||||||||||||||....
|||||||||||||||.....

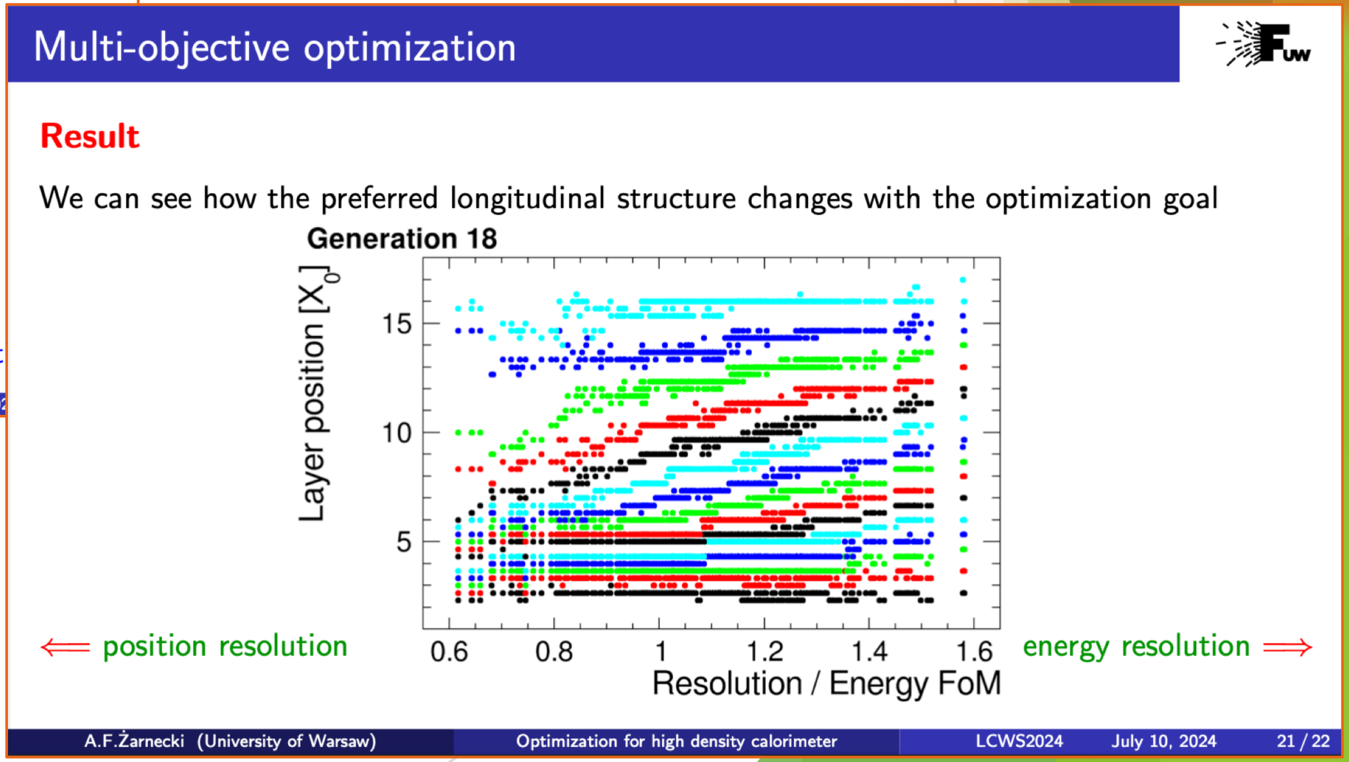


Simulation (10/07 afternoon)

Longitudinal structure optimization for the high density electromagnetic calorimeter, Aleksander Filip Zarnecki





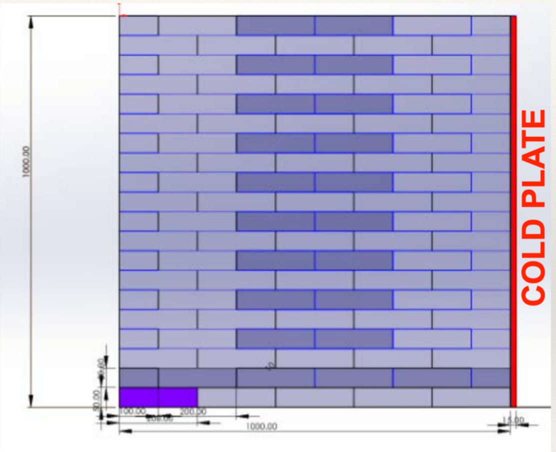


Pareto front

Simulation (10/07 afternoon)

The SiD Digital ECal Based on Monolithic Active Pixel Sensors, Jim Brau

Thermal Model for Heat Removal from SiD ECal



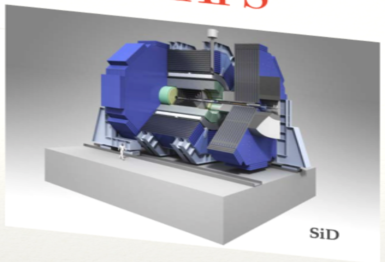
1 layer of 5 x 20 cm^2 MAPS sensors

- MAPS generates 1 μW/pixel CW.
  - ~kW/m^2 (each sensor is 100 cm^2)
- Power pulsing critical for heat management
  - ILC duty cycle ~0.5% (<10 W/m^2)
  - CLIC/C^3 <0.01% (<1 W/m^2)
- What is temperature rise (ΔT) on end opposite the cold plate?

SiD Digital ECal J. Brau - 10 July 2024 8

SiD Digital ECal Based on MAPS

- SiD upgrade now under development with 25 x 100 μm^2 (or 25 x 50/25 μm^2) digital pixels in electromagnetic calorimeter and tracker.
  - Replacing the ILC TDR ECal design using 13 mm^2 analog pixel sensors.
- Heat management is critical to success.
- How well can we measure energy and shower structure with this digital system:
  - Compared to SiD baseline with analog measurements?
  - Can the detailed structural measurements be used to improve measurement?
  - Would a neural net optimization offer an improvement?
- What are the limits of transverse separation and measurement?



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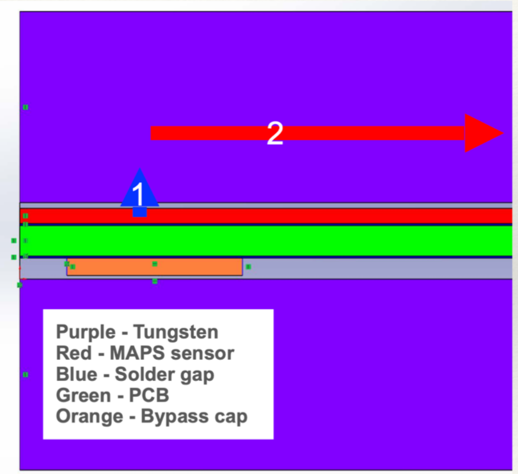
Heat conduction from ECal sensor to cold plate



- First heat flows through 300 μm N_2 to tungsten
  - ΔT << 1 K
- Then heat flows thru tungsten to cold plate
  - Tungsten absorber lengths 0.5-1.0 m
  - Temperature rise is length dependent
- Duty cycle - .0007% (C3/CLIC) - ΔT ~ 0.5 - 2 K
- Duty cycle - .005% (ILC) - ΔT ~ 4 - 16 K
  - Without power pulsing temperature blows up and needs active cooling

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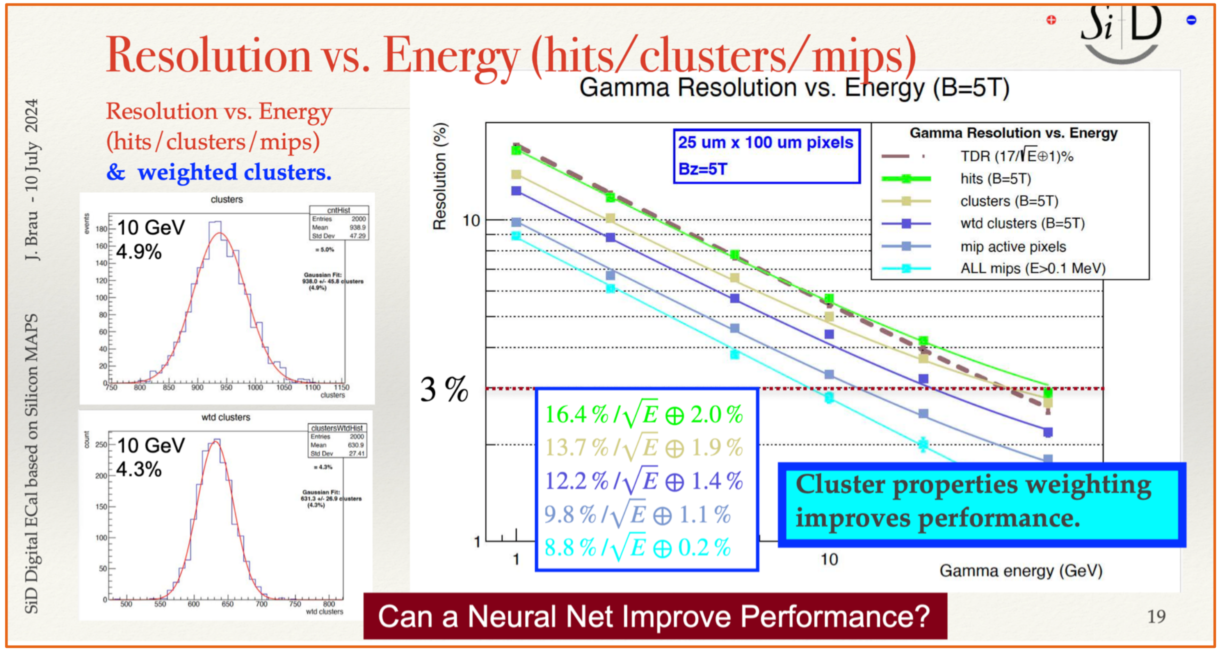
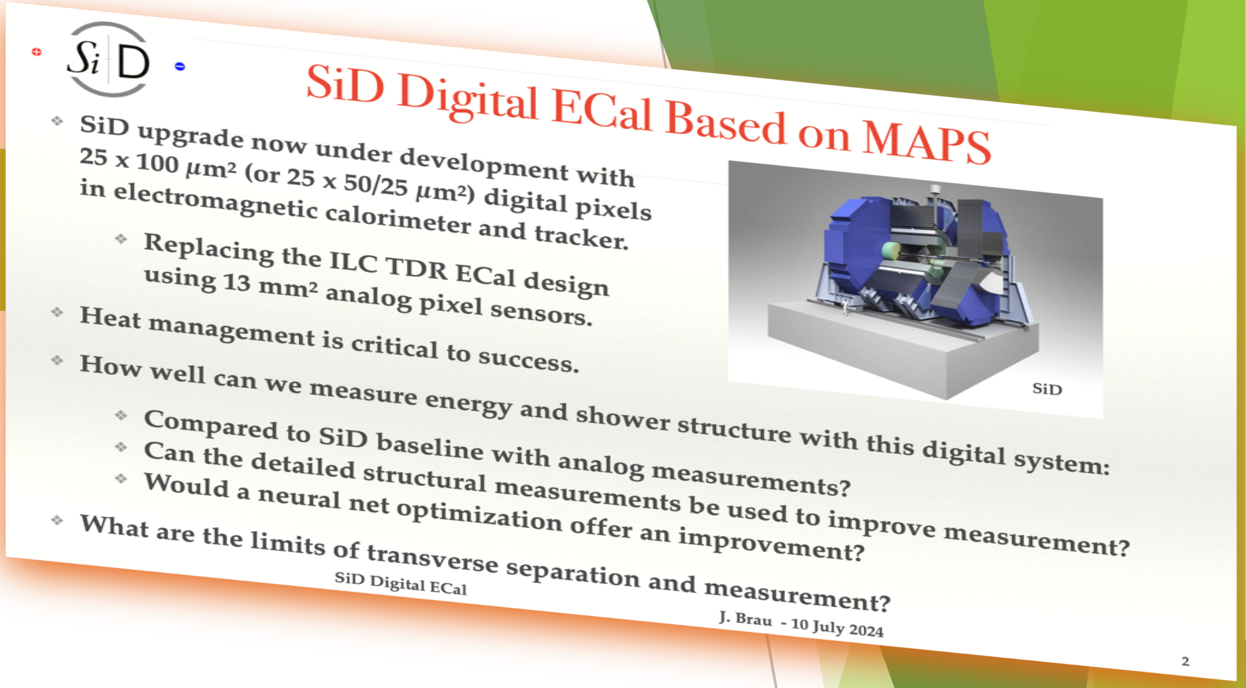
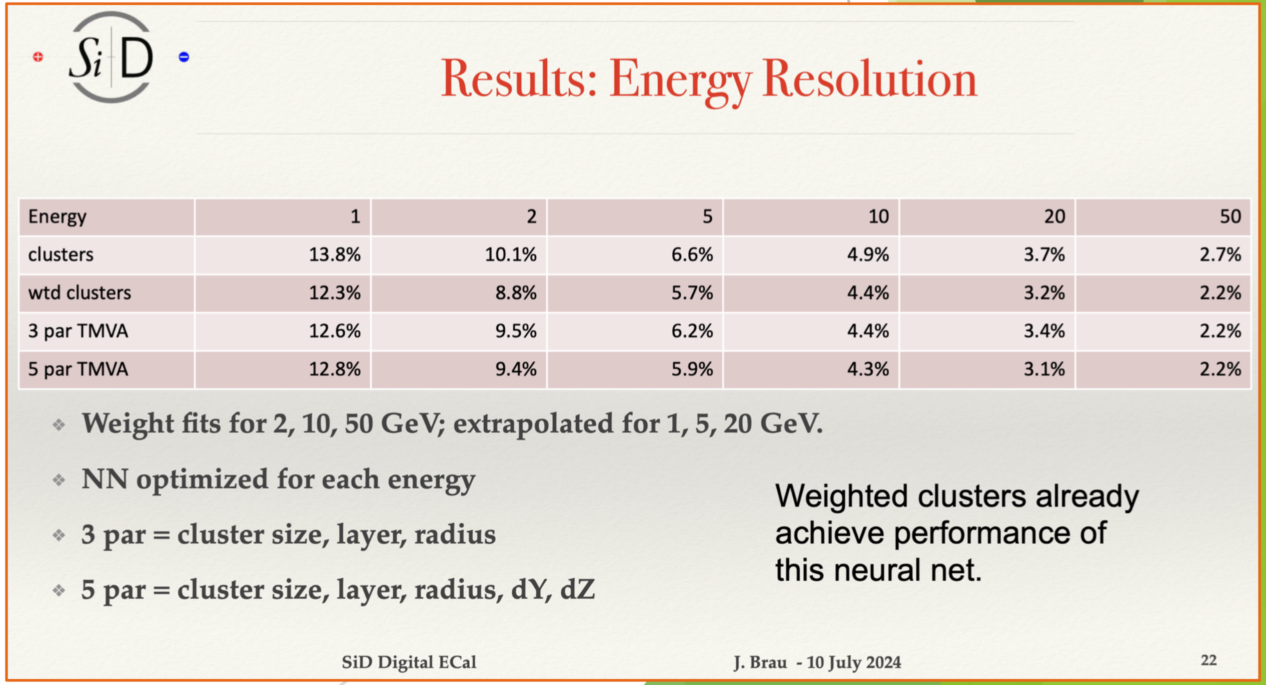
Simulation (10/07 afternoon)

The SiD Digital ECal Based on Monolithic Active Pixel Sensors, Jim Brau







Results: Energy Resolution

Energy	1	2	5	10	20	50
clusters	13.8%	10.1%	6.6%	4.9%	3.7%	2.7%
wtd clusters	12.3%	8.8%	5.7%	4.4%	3.2%	2.2%
3 par TMVA	12.6%	9.5%	6.2%	4.4%	3.4%	2.2%
5 par TMVA	12.8%	9.4%	5.9%	4.3%	3.1%	2.2%

- Weight fits for 2, 10, 50 GeV; extrapolated for 1, 5, 20 GeV.
- NN optimized for each energy
- 3 par = cluster size, layer, radius
- 5 par = cluster size, layer, radius, dY, dZ

Weighted clusters already achieve performance of this neural net.

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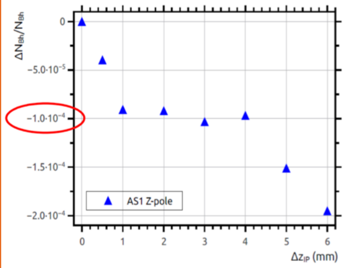
Simulation (10/07 afternoon)

Metrology requirements for the integrated luminosity measurement at ILC , Ivan Smiljanić

Metrology — Beam properties

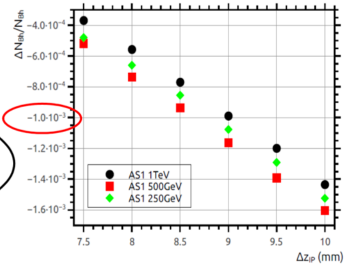
Further on beams: axial displacement of the IP (Δz_{IP})

⇒ beam synchronization



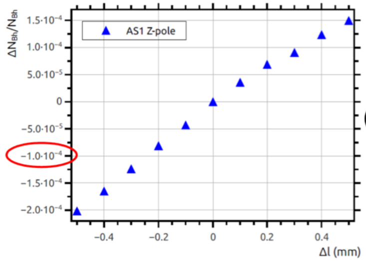
~ 9 mm (30 ps) at higher energies

~ 4 mm (13 ps) needed at the Z-pole



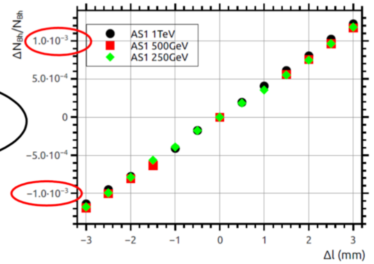
Metrology — Detector mechanics and positioning

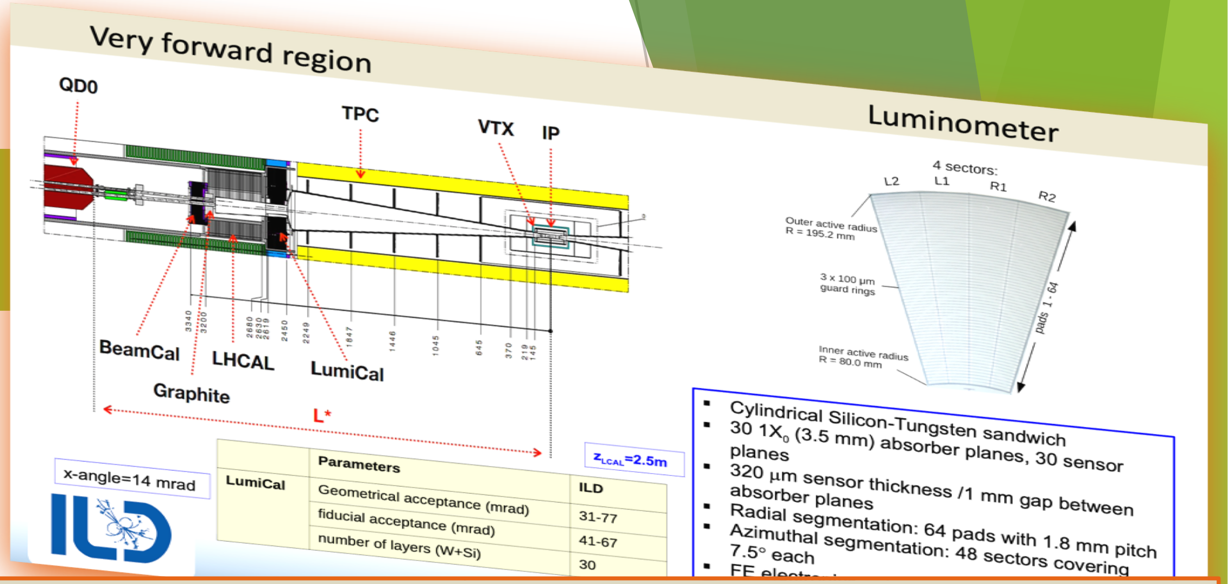
Distance between luminometer halves (symmetric) (**Δl**)



< 3 mm at higher energies

~ 200 μm at the Z-pole (feasible with FSI)





Conclusion on metrology

parameter	Z-pole	250 GeV	500 GeV	1 TeV
Δr_{in} (μm)	20	200	200	200
Δr_{out} (μm)	60	600	600	550
σ_r (mm)	0.3	0.5	0.5	0.5
Δl (mm)	0.2	2.5	2.5	2.5
σ_{xIP} (mm)	0.35	0.65	0.65	0.65
σ_{zIP} (mm)	5	10	10	10.5
tilt (mrad)	14	35	35	35
Δx_{IP} (mm)	0.3	0.6	0.55	0.6
Δz_{IP} (mm)	4	8.5	8.5	9
$\Delta\tau$ (ps)	13	27	27	30
$\sigma_{E_{BS}}$ (MeV)	114	500	1000	2000
ΔE (MeV)	4.5	125	250	500
$\Delta\mathcal{L}/\mathcal{L}$	$3.3\cdot10^{-4}$	$3.3\cdot10^{-3}$		

- The major challenges only at the Z-pole
- Inner aperture of the luminometer relaxed with the asymmetric counting
- Position reconstruction in the first plane (300 μm) slightly below prototyped performance (440 μm); Can be resolved with a tracker plane in front of the luminometer
- Asymmetric bias in beam energies (~ 5 MeV)
- Δ(√s) for the cross-section calculation (~ 5 MeV, all energies)