



1st FCC-ee luminometer workshop

<https://indico.cern.ch/event/1690381>

< Mon 27/07 Tue 28/07 All days >

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Session legend

Experience with compact SiW calorimetry from the FCAL Collaboration (and DRRCalo WG1)

Monday morning session

09:00	Welcome and introduction to workshop 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Mogens Dam 09:00 - 09:10
	The need for high precision luminosity measurement at FCC-ee 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Jan Eysermans 09:10 - 09:30
	MC Generator BHLUMI for luminometry at FCC-ee 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Wiesiek Placzek 09:35 - 10:00
10:00	Radiative corrections and new physics in luminosity predictions 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Francesco Pio Ucci 10:05 - 10:30
	Coffee 10:35 - 11:00
11:00	The LEP legacy - From a reading of the OPAL paper 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Mogens Dam 11:00 - 11:25
	Interplay between MDI and Lumical designs 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Fabrizio Palla 11:30 - 12:05
12:00	Beam-beam effects on small angle Bhabha luminosity measurement 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Emmanuel Francois Perez 12:10 - 12:30

13:00	Lunch 12:35 - 13:45
14:00	FCAL General Introduction 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Wolfgang Lohmann 13:45 - 14:05
	Test beam 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Adrian Irles 14:10 - 14:30
	Mechanics 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Grzegorz Grzelak 14:35 - 14:45
15:00	Electronics 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Marek Idzik et al. 14:50 - 15:10
	Simulation 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Mihai Potlog 15:15 - 15:25
	Alignment 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Barek Brudnowski 15:30 - 15:45
16:00	Noise/Calibration and MC comparison 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Melissa Almanza Soto 15:50 - 16:05
	Moliere radius, gap effect, etc 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Nofar Kleinman 16:10 - 16:25
	Coffee 16:30 - 16:50
17:00	FCC-ee CDR LumiCal design 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Mogens Dam 16:50 - 17:10
	MAPS based LumiCal 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Duccio Abbaneo 17:15 - 17:35
18:00	Quantum sensor based Luminometer 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Ben Kilminster 17:40 - 18:00

< Mon 27/07 Tue 28/07 All days >

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Session legend

Discussions and presentation of plans of the various involved groups

Tuesday morning session

09:00	CEPC LumiCal design 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Suen Hou 09:00 - 09:20
	Background simulations 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Yan Benhammou 09:25 - 09:40
	LumiCal simulation studies 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Mogens Dam 09:45 - 10:00
10:00	FCC-ee Beam Instrumentation for luminosity monitoring 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Dr Robert Kieffer 10:05 - 10:25
	Coffee 10:30 - 11:00
11:00	Luminosity measurement via di-photon final state 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN Alain Blondel 11:00 - 11:25
	Considerations on luminosity measurement processes: Bhabhas, diphotons, radiative Bhabhas, ee_to_dimuons Graham Wilson

12:00	Lunch 12:00 - 13:30
13:00	Discussions and presentation of plans of the various involved groups: Discussions and presentation of plans of the various involved groups 40/S2-C01 - Salle Marie Skłodowska-Curie, CERN
14:00	
15:00	
16:00	



The need for high precision luminosity measurement at FCC-ee

Jan Eysermans
1st FCC-ee Luminometry Workshop
July 27 2026

Toy lineshape fit: impact of systematic uncertainties



Fit configuration	Z mass (keV)	Z width (keV)	$\sigma_{0, \text{hadr}}$
Statistical only	3	2	4×10^{-7}
Center-of-mass: absolute 100 keV	100	2	4×10^{-7}
Center-of-mass: absolute 100 keV + point-to-point 40 keV	104	22	4×10^{-7}
Beam-energy spread: absolute 50 keV	3	11	5×10^{-6}
Luminosity: absolute 1×10^{-4}	3	2	1×10^{-4}
Luminosity: absolute 1×10^{-4} + point-to-point 1×10^{-5}	13	10	1×10^{-4}
Combined uncertainties	105	27	1×10^{-4}

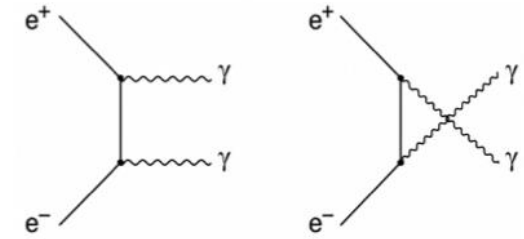
- **Z mass:** dominated by the absolute center-of-mass energy calibration, giving an uncertainty of 100 keV
 - Minor impact on point-to-point luminosity (8×10^{-5} point-to-point results in an 100 keV impact on the Z mass)
- **Z width:** sensitive to point-to-point center-of-mass, luminosity and beam-energy-spread uncertainties
 - Point-to-point luminosity comparable impact than beam-energy spread
 - A point-to-point luminosity uncertainty of approximately 1×10^{-5} gives an impact comparable to a 40 keV point-to-point energy uncertainty
- **Peak cross-section $\sigma_{0, \text{hadr}}$:** dominated by the absolute luminosity uncertainty
 - Beam-energy spread gives a smaller but non-negligible contribution
 - Absolute luminosity uncertainty remains ~2 orders above the beam-energy-spread contribution and ~3 orders above statistics-only, so improvements at every level are therefore useful

Wide-angle di-photon: $e^+e^- \rightarrow \gamma\gamma$



Experimental features

- Measured primarily in the central ECAL, with possible extension toward the lumical region
- Event rate $O(10-100)$ below small-angle Bhabha scattering, depending on angular acceptance
- Expected to be less sensitive than small-angle Bhabha scattering to beam-induced effects

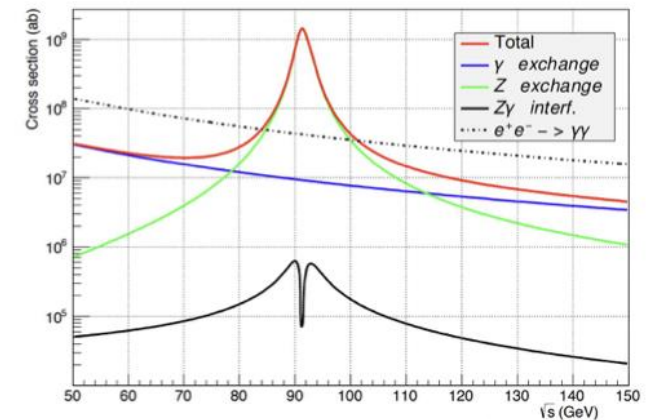


Theoretical considerations

- Pure QED at Born level, with no Z dependence,
- Dependence on $\alpha_{\text{QED}}(0)$ only at LO (strongly reduced $\Delta\alpha_{\text{had}}$ contribution)
- Reduced interference between initial-state radiation and the hard-scattering diagrams

Theory status and targets

- Existing predictions currently provide approximately 10^{-3} level precision
- A path toward NNLO and 10^{-4} level precision appears realistic
- Reaching 10^{-5} requires dedicated theory work



$$\sigma(e^+e^- \rightarrow \gamma\gamma) = \frac{2\pi\alpha^2}{s} \left\{ \ln \frac{1 + \cos \theta_{\min}}{1 - \cos \theta_{\min}} - \cos \theta_{\min} \right\}$$

https://doi.org/10.1142/9789814503273_0005
<https://doi.org/10.1016/j.physletb.2019.134976>

Detector requirements for luminosity measurements



Lumical requirements for small-angle Bhabha

- Precise control of acceptance, radial alignment, and angular scale
- Asymmetric acceptance method reduces sensitivity to radial misalignment
- Electron-photon separation: requires tracking in front of lumical?
- Dealing with abundant beam backgrounds (SR, IPC) in the MDI/forward region
- Observation: can lumical acceptance be relaxed if statistical precision remains far below theory/systematics?



ECAL requirements for wide-angle di-photon

- Excellent angular resolution over entire ECAL acceptance
- Electron/photon separation crucial to suppress fakes from $Z \rightarrow e\bar{e}$ or Bhabha
- Alignment of the ECAL and other sub detectors up to the desired precision (10^{-5}) (see next slide)

Common detector/systematic strategy

- Each channel is also a background to the other $\rightarrow$ strong need for electron/photon separation
- Treat Bhabha and di-photon channels in a combined fit
- Correlate common systematics: acceptance, alignment, material, reconstruction
- Synergy with the on-peak $\alpha_{\text{QED}}(m_Z)$ measurement

Readout / trigger

- BX spacing ≈ 25 ns
- Luminosity events must be collected unbiased
- If a trigger is used, trigger efficiency and prescales must be controlled at the target precision



Work ahead (in the EW group)



A (long) list of tasks in the EW group

- Implement Z lineshape scan and study in more detail the correlations with other experimental uncertainties
 - Deconvolution full lineshape to Born level
- Setup analyses for the luminosity measurements – to start with FastSim (Delphes)
 - Bhabha and di-photon
 - Combination of measurements under various systematic/detector assumptions (e.g. resolutions, misalignment, ...)
 - Study and exploit absolute vs. point-to-point uncertainties
- Towards full simulation: verify these assumptions
 - Optimize electron reconstruction
 - Electron-photon disambiguation important to suppress radiative bhabha
 - Impact of beam-beam effects and beam backgrounds on the measurement
- Setup workflow for alignment and in-situ calibration
 - Work out combined measurement: couple alignment tracking with calorimeter
- Study detector designs and choices
 - Lumical: single proposal so far?
 - ECAL/tracker: DR/crystal/preshower – Si/Gas/STRAW

**Needs on luminosity measurements also
means needs of person power!**

Reach out to us if you are interested
in contributing to one of these items!

Subscribe to e-group

fcc-ped-physicsgroup-ewprecision@cern.ch

**EW Experimental contacts: Matteo Defranchis,
Josh Bendavid, Jan Eysermans**

fcc-ped-physicsgroup-ewprecision-admin@cern.ch

MC Generator BHLUMI for luminometry at FCC-ee

Wiesław Płaczek

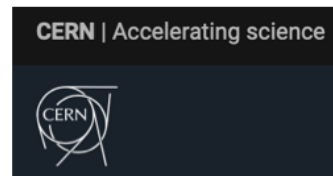


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NATIONAL SCIENCE CENTRE
POLAND

Grant no. 2023/50/A/ST2/00224



1st FCC-ee Luminometry Workshop, CERN, 27-28 July 2026

Conclusions and outlook

❖ **BHLUMI 4.04** - MC event generator for SABS process including YFS $\mathcal{O}(\alpha^2)_{\text{prag}}^{\text{exp}}$ QED corrections

- **state-of-the art** at **LEP** for **luminosity** measurement
 - ✓ precision of **0.038%** at **Z-peak**
- **starting point** for **luminometry** at **FCC-ee**,
 - ✓ at **Z-peak**, precision of **0.01%** or **better** can be achieved
 - ✓ at **higher** energies **sub-permille** precision possible

➡ **Needed:**

- **upgrade** to (CEEX) YFS $\mathcal{O}(\alpha^3)_{\text{prag}}^{\text{exp}}$ **photonic** corrections
- inclusion of **Z and s-channel** γ contributions with all interferences (possibly with NLO EW correction)
- perhaps **light-fermion pairs**
- appropriate **upgrade** of **testing** toolbox (OLDBIS $\oplus$ LUMLOG, etc.)

✓ **Components available**



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DI PAVIA



Radiative corrections and new physics in luminosity predictions

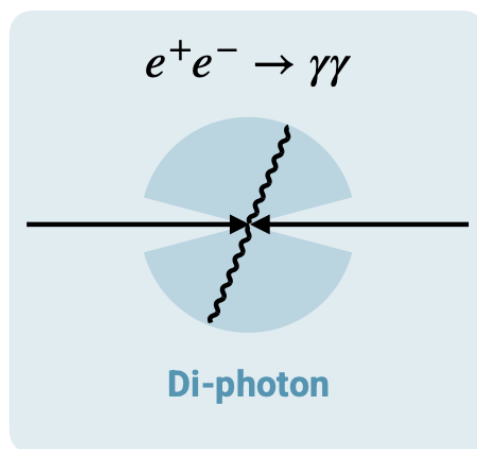
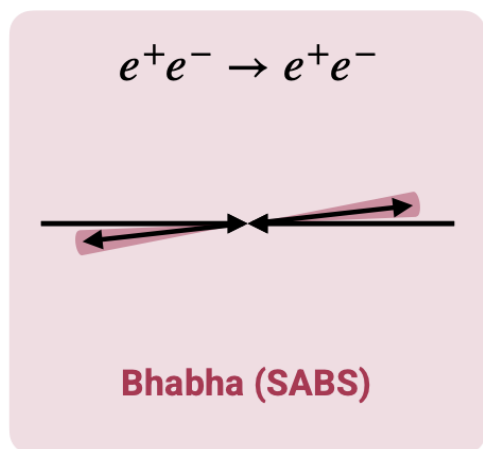
Francesco Pio Ucci

1st FCC-ee Luminometry Workshop
CERN, Jul 27–29, 2026

Luminosity measurements

At lepton colliders, the Luminosity is measured through a **benchmark process**

$$L = \int \mathcal{L} dt = \frac{1}{\epsilon} \frac{N_0}{\sigma_0^{\text{th}}}$$



$\simeq 10^{-4}$

Current knowledge

BabaYaga

$\simeq 10^{-5}$

Precision target

Error

$$\frac{\delta L}{L}$$

$\parallel$

$$\frac{\delta \epsilon_{\text{exp}}}{\epsilon_{\text{exp}}}$$

$\oplus$

$$\frac{\delta N_0}{N_0}$$

$\oplus$

$$\frac{\delta \sigma_0^{\text{th}}}{\sigma_0^{\text{th}}}$$

Requests

Low background,
clear exp. signature

$\sigma \simeq \mathcal{O}(10^2 - 10^3 \text{ nb})$
Large cross section

$\sigma^{(n)} = \left(\frac{\alpha}{\pi}\right)^n \log^n \frac{Q^2}{m_e^2}$
Calculable at high precision

FCC-ee

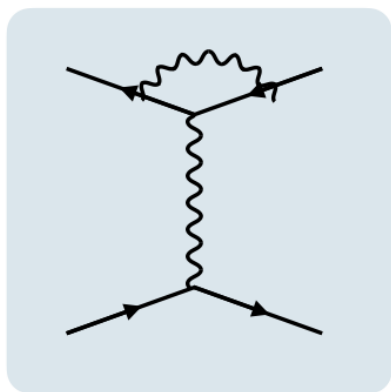
$< 10^{-4} \div 10^{-5}$

$\simeq 10^{-5}$

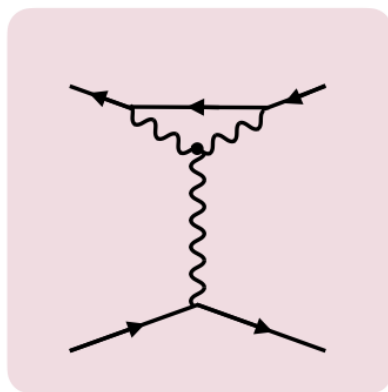
$< 10^{-6}$

$< 10^{-4} \div 10^{-5}$

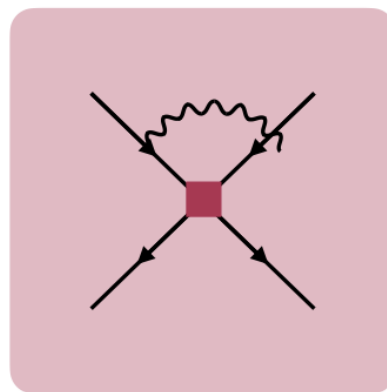
Status and future prospects



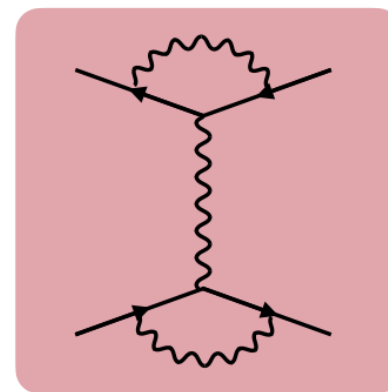
NLOPS QED



NLO EW



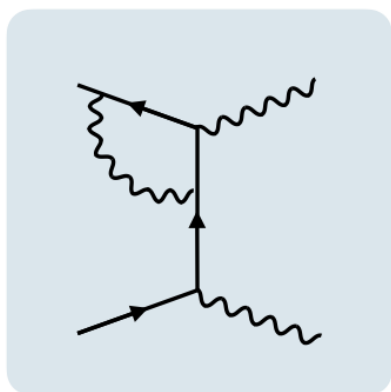
NLO SMEFT



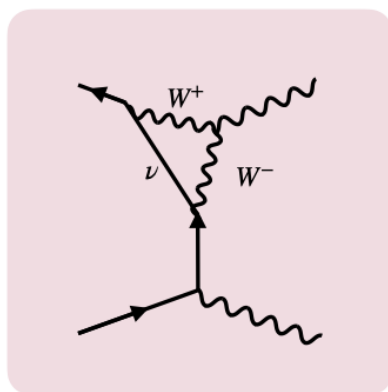
NNLO matching

Precision

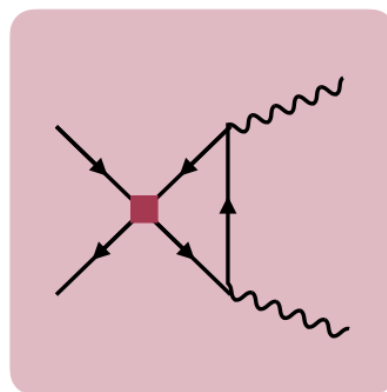
10^{-5}



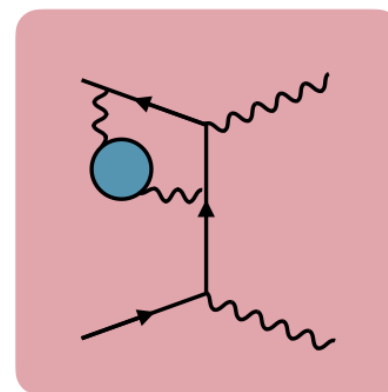
NLOPS QED



NLO EW

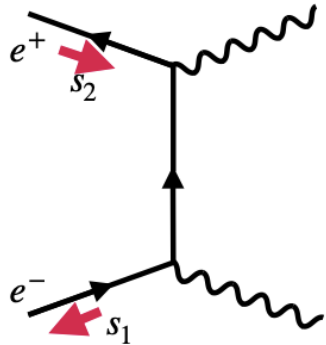


NLO SMEFT



NNLO fermionic/bosonic

$e^+e^- \rightarrow \gamma\gamma$: Polarised calculation



Development of BabaYaga@NLO with longitudinal polarisations

$$(\not{p}_1 - m) \rightarrow (\not{p}_1 - m) \frac{1}{2} (1 + \gamma_5 \not{s}_1)$$

$$s_1 = \lambda_- \frac{\sqrt{s}}{2} (\beta, 0, 0, 1)$$

$$\sigma(P_{e^-}, P_{e^+}) = \frac{1}{4} \sum_{\lambda_{\pm} = \pm 1} (1 + \lambda_- P_{e^-}) (1 + \lambda_+ P_{e^+}) \sigma_{\lambda_-, \lambda_+}$$

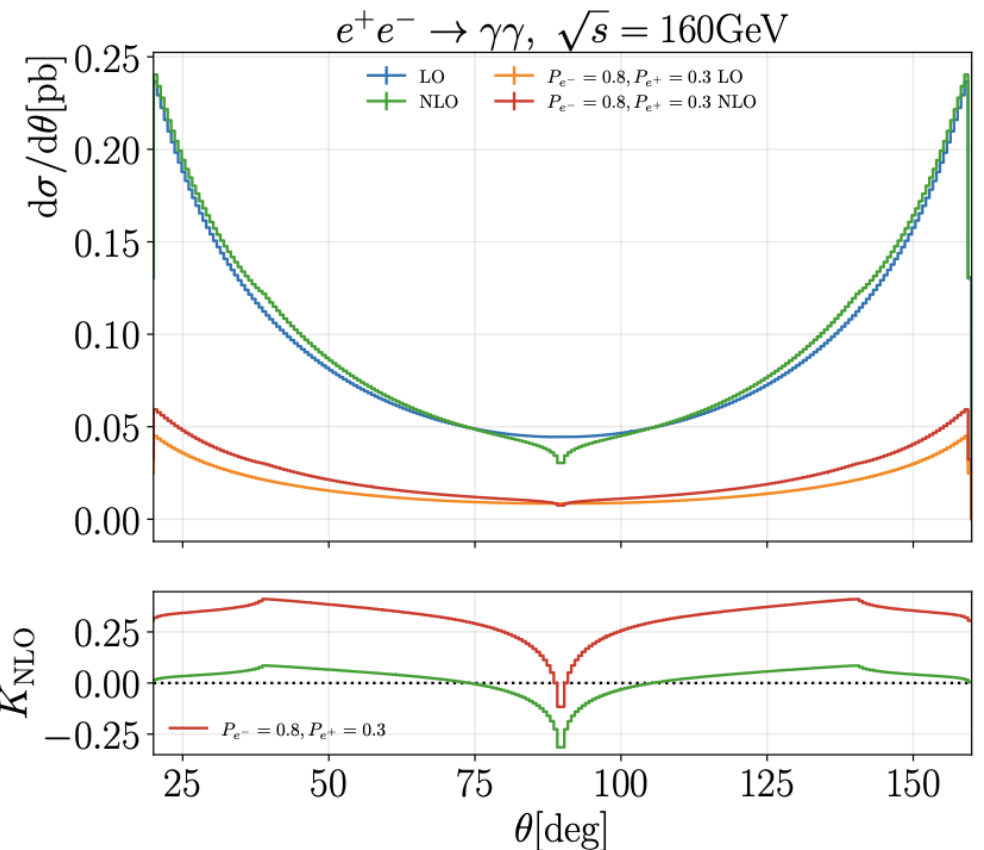
Next step: matching with Parton Shower

$$P(z) = \frac{1+z^2}{1-z} \quad \text{The soft limit is unchanged}$$

$$g_{i,+}^{(\text{out})}(p_i, k) = \frac{1}{p_i k} \left[P_{ff}(z_i) - \frac{m_i^2}{p_i k} \right] - g_{i,-}^{(\text{out})}(p_i, k)$$

$$g_{i,-}^{(\text{out})}(p_i, k) = \frac{m_i^2}{2(p_i k)^2} \frac{(1-z_i)^2}{z_i},$$

The collinear limit has to take into account the polarisation of electrons



Status of BabaYaga

Process	Order	Accuracy
$e^+e^- \rightarrow e^+e^-$	NLOPS QED LO EW LO SMEFT	$\mathcal{O}(0.1\%)$
$e^+e^- \rightarrow \mu^+\mu^-$	NLOPS QED LO EW	$\mathcal{O}(0.1\%)$
$e^+e^- \rightarrow \gamma\gamma$	NLOPS QED NLO EW NLO SMEFT	$\mathcal{O}(0.1\%)$
$e^+e^- \rightarrow \pi^+\pi^-$	NLOPS QED FF (FxsQED, GVMD, FSQED)	$\mathcal{O}(0.1\%) \oplus \delta F_\pi$
$e^+e^- \rightarrow e^+e^-\gamma$	NLOPS QED	
$e^+e^- \rightarrow \mu^+\mu^-\gamma$	NLOPS QED	
$e^+e^- \rightarrow \pi^+\pi^-\gamma$	NLOPS QED FF (FxsQED)	

Luminosity

● $e^+e^- \rightarrow \gamma\gamma$ NNLO pair corrections

In progress:

- Compute exact NNLO QED virtual and real pair corrections via dispersive methods

- For now, at low energies

- Calculate NLO SMEFT corrections for FCC-ee luminometry

Next-future:

- Include Z exchange for pair corrections

● $e^+e^- \rightarrow X$

Future plans:

- NNLO matching with ISR/ NLL resumption

The LEP Legacy

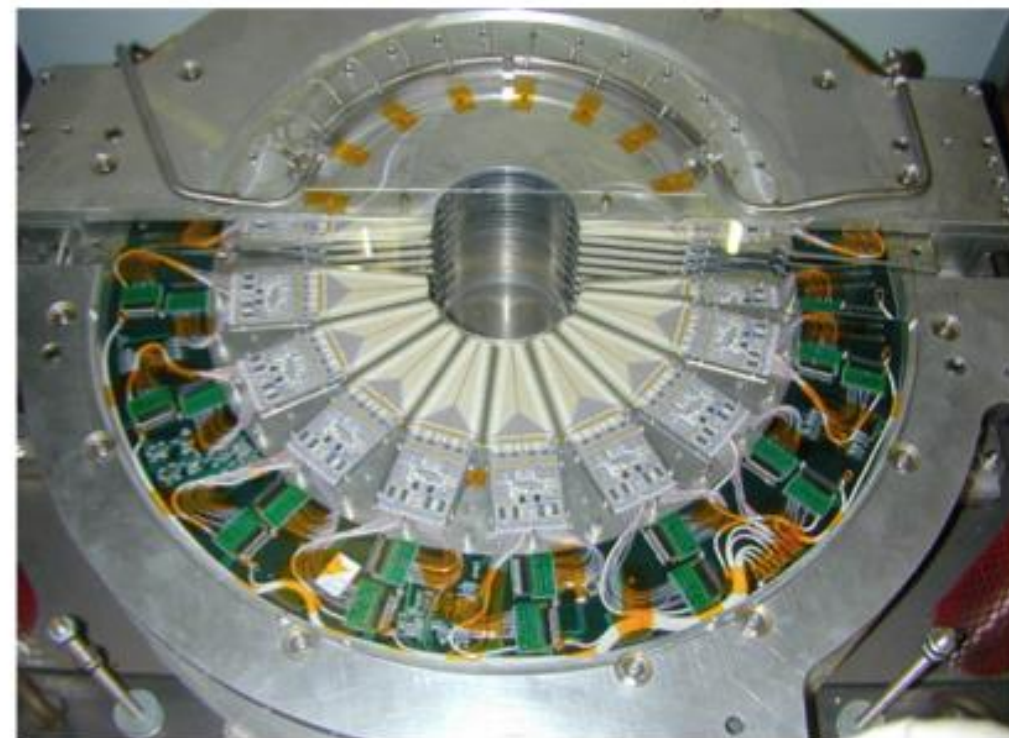
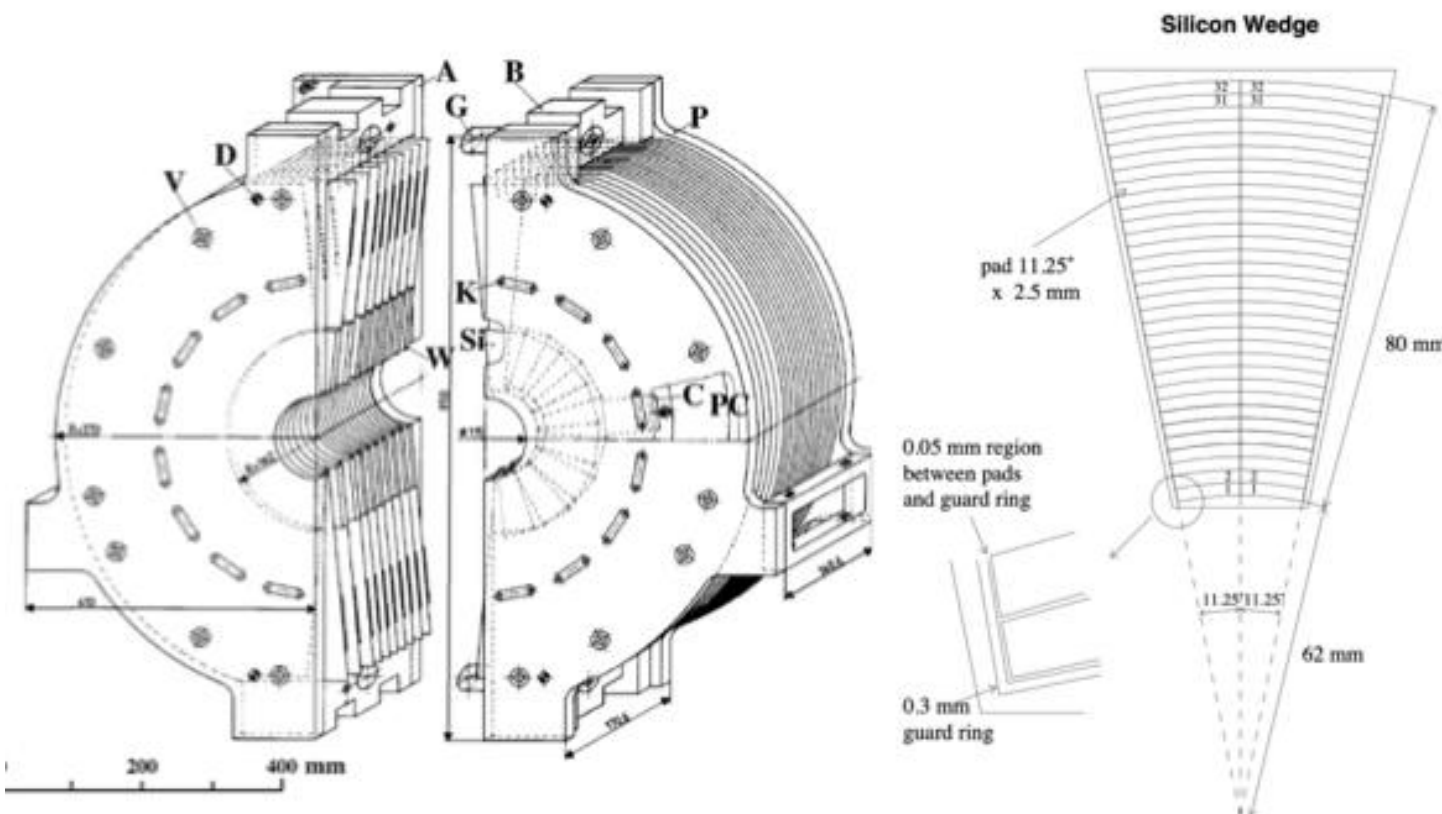
From a reading of the OPAL Luminosity paper

1st FCC-ee Luminometer Workshop
CERN, 27-28 July, 2026

Mogens Dam
Niels Bohr Institute

SiW Calorimeter

- Set of two calorimeters encircling the beam pipe at $z \simeq \pm 2.5$ m
- 19 layers of Si sensors, 18 layers of W absorber:
 $14 \times 1X_0 + 4 \times 2X_0 = 22X_0$ in total
- Si sensor radial coverage: 62 – 142 mm
 32 strips of 2.5 mm each



Conclusions

- ◆ OPAL measured luminosity via small angle Bhabha scattering to an experimental precision of 3.4×10^{-4}
- ◆ Use was made of a compact SiW sandwich calorimeter constructed to be as symmetrical and homogeneous as possible
- ◆ Every step of the detector construction and the analysis is beautifully documented in their comprehensive paper
- ◆ There is a lot to learn from a (enjoyable) careful read

INTERPLAY BETWEEN MDI AND LUMICAL DESIGNS

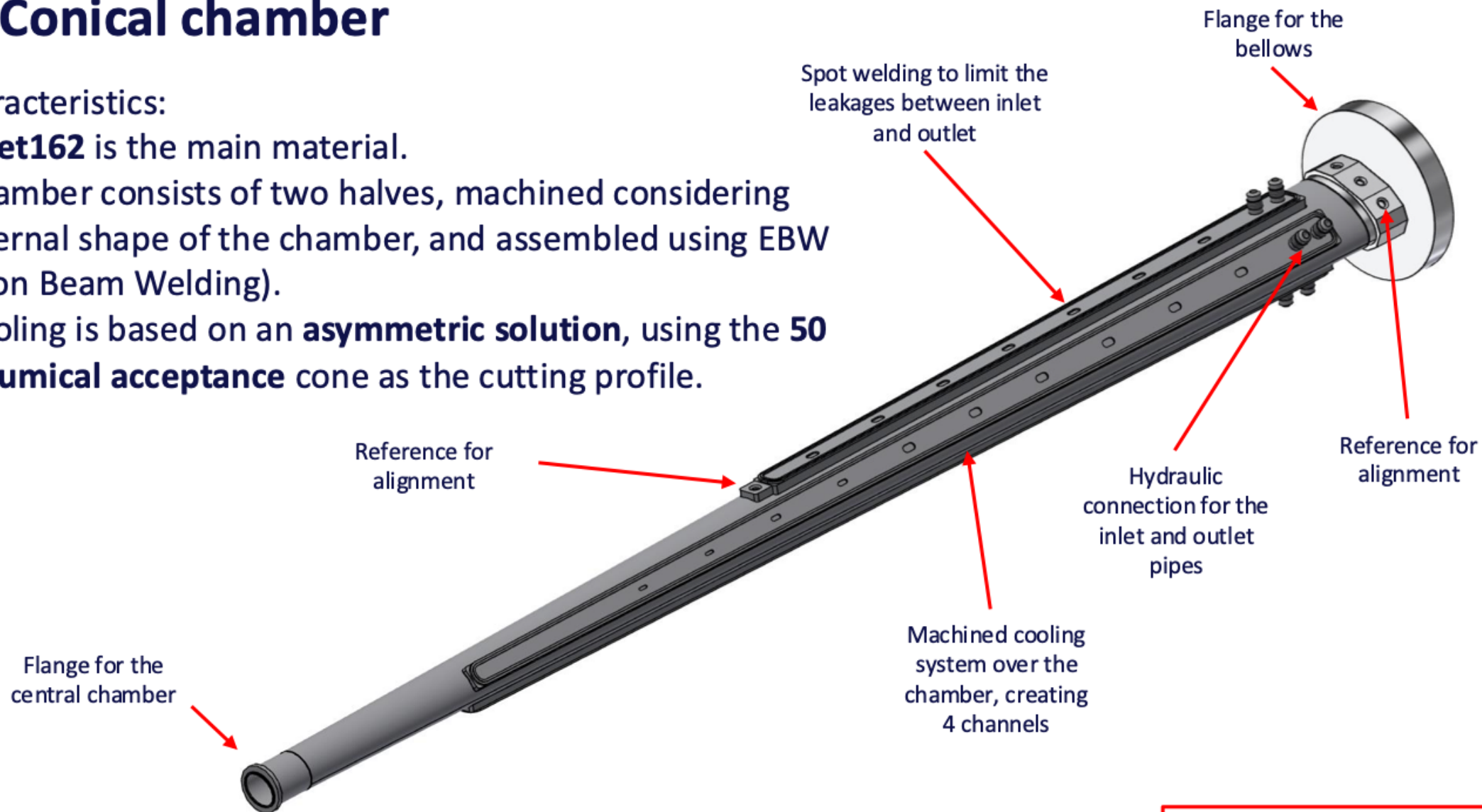
Fabrizio Palla
INFN Pisa

1st FCC-ee Luminometry Workshop
CERN
27 July 2026

Ellipto-Conical chamber

Main characteristics:

- **AlBeMet162** is the main material.
- The chamber consists of two halves, machined considering the internal shape of the chamber, and assembled using EBW (Electron Beam Welding).
- The cooling is based on an **asymmetric solution**, using the **50 mrad Lumical acceptance** cone as the cutting profile.



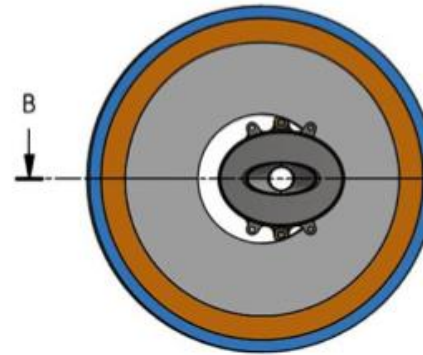
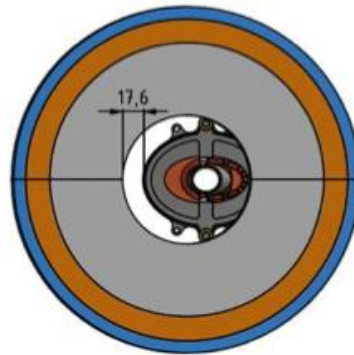
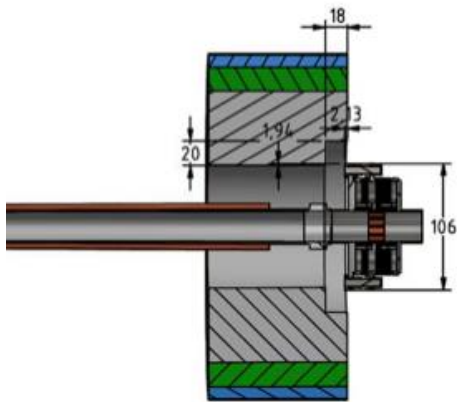
Courtesy F. Franesini

Bellows designed to allow LumiCal to be mounted as a single piece:

- Minimise the constant term in energy resolution
- Allows to use single 12" wafers for silicon sensors



Needs special mechanical tools to insert it and then center around outgoing beampipe



Courtesy S. Lauciani



Centered position for pipe insertion



Final position centered outgoing beam

Techn Instrum **10**, 16 (2023). <https://doi.org/10.1140/epjti/s40485-023-00103-7>

Endcap design

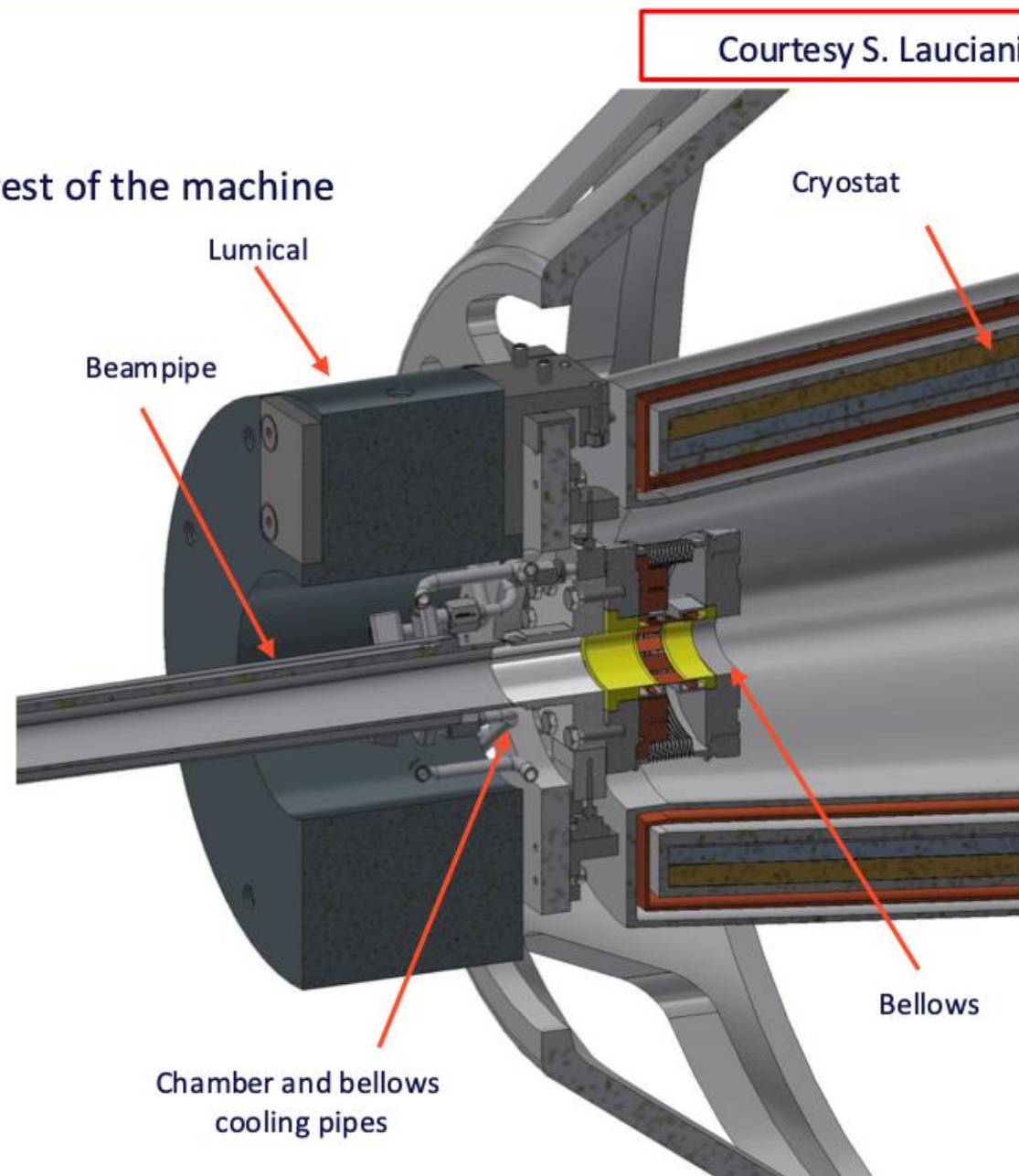
Endcap is the **interface** between the IR beam pipe and the rest of the machine

The area around endcap is highly overcrowded:

- Endcap provides:
 - Structural stiffness for support tube
 - Lumical support
 - Beampipe support and alignment
- It must allow space for:
 - Chamber and bellows cooling pipes
 - Lumical services
 - Likely integration of BPMs
 - first-stage vacuum pumping

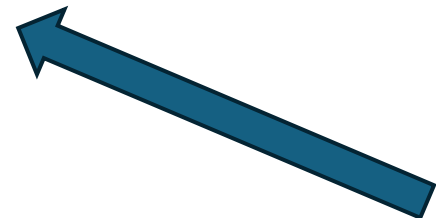
However, many elements are still undefined

- Lumical defined at envelope level only
- Final cryostat design
- BPM and first-stage pumping system



Conclusions and prospects

- The design of the LumiCal must comply with the tight requirements of the MDI, to guaranteeing the highest and more stable luminosity of FCC-ee
 - In particular, to respect the choice of unique IR for all IP's and energies.
- The design of the MDI must minimise the impact on the LumiCal
 - Very congested region, with extremely demanding integration issues
 - Beam pipes material and geometry
 - Fringing magnetic field
 - Mechanical integration, in particular the services
- **Need to study and integrate all LumiCal variants and optimise their performance**
 - Currently only one LumiCal has been considered, some mechanical integration studies, still lacking important integration details (cables, fibres, cooling)
- **Join and work together with the MDI team**



Beam-beam effects on small angle Bhabha luminosity measurement

E. Perez (CERN)

FCC-ee Luminometry workshop
July 27, 2026

For details, see :

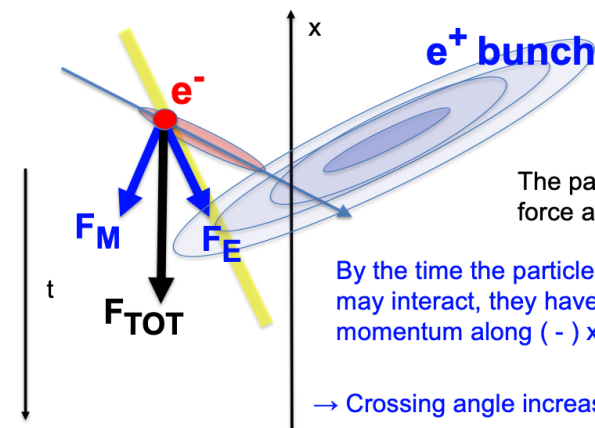
“Beam-beam effects on the luminosity measurement at FCC-ee”,
G. Voutsinas, E. Perez, M. Dam, P. Janot, [JHEP 10 \(2019\) 225](#)

26.07.27

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E.Perez

Beam-beam effects



Before it reaches the IP :
The Lorentz force felt by the electron is along the x axis, pointing downwards.

The particle is accelerated by this force along -x, and it gains energy.

By the time the particles reach the IP and may interact, they have acquired a net momentum along (-) x.

≡ the “px-kick”
(~ 3.5 MeV)

→ Crossing angle increases: $\Delta(\alpha/2) = \text{Kick} / E_e$

$\Delta\alpha = 0.17 \text{ mrad}$, i.e. $\Delta\alpha / \alpha \sim 0.5\%$

Equivalent to a transverse boost, it applies to all events :

- a smearing of the θ distribution of the outgoing e[±], with no net bias.
- negligible effect on the LumiCal acceptance of the Bhabha's

26.07.27

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E.Perez

Conclusions

It is possible to control the luminosity bias due to the EM focusing of the Bhabha electrons. Two methods can be exploited :

- the measurement of the px-kick using dimuon events in the central detector
- in-situ determination using an acollinearity variable measured in the Lumical :
 - mis-alignment effects can be disentangled from beam-beam effects even under conservative assumptions for the mis-alignment

They both exploit the fact that the beams do not collide head-on.

Each ensures a residual uncertainty on the absolute luminosity $< 10^{-4}$. Both should be used, providing nice consistency cross-checks between several observables that are related to beam-induced effects.



FUTURE
CIRCULAR
COLLIDER

NIELS BOHR INSTITUTE
UNIVERSITY OF
COPENHAGEN



FCC-ee CDR LumiCal

1st FCC-ee Luminometer Workshop
CERN, 27-28 July, 2026

Mogens Dam
Niels Bohr Institute

CDR LumiCal Design

Design considerations:

- ◆ Need to control geometry to precision of $\mathcal{O}(1\ \mu\text{m})$

- Keep geometry as simple as possible

Multilayer barrel with all layers having identical circular geometry

- ◆ 25 layer SiW sandwich

- 3.5 mm W ($1\ X_0$) + 1.0 mm gap for Si sensors

- ◆ Physical dimensions

- Sensitive region: $r = 55\text{-}115\ \text{mm}$

- Region for "services": $115\text{-}145\ \text{mm}$

- Calorimeter front face at $z = 1074\ \text{mm}$

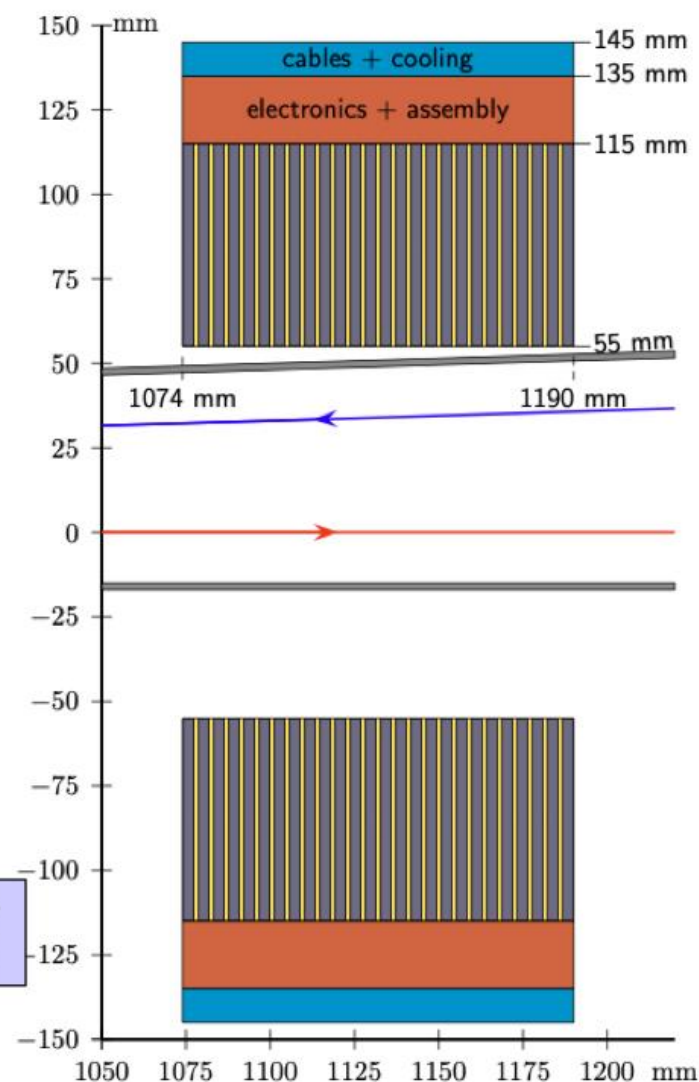
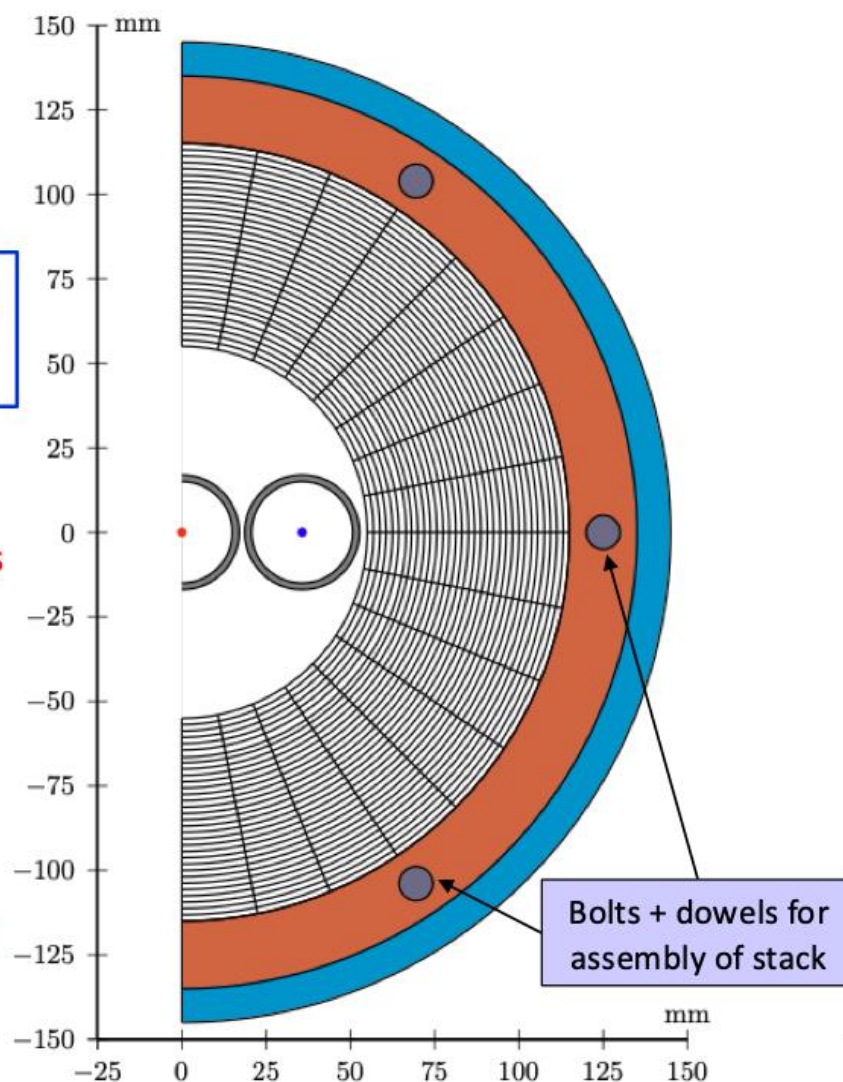
- ◆ Proposed segmentation

- 32x32 pads/layer ($1.875 \times 10^{-22}\ \text{mm}^2$ pads)

- 25,600 channels per LumiCal

- ◆ Weight

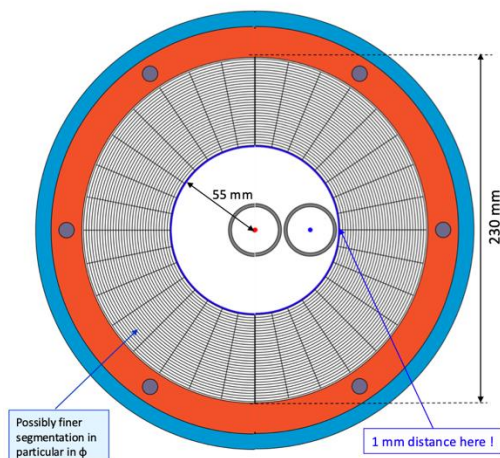
- About 65 kg per LumiCal



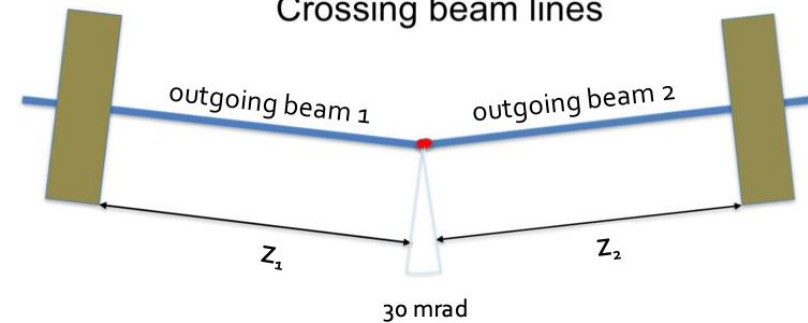
Considerations for improved geometrical precision

- ◆ Suggest to construct LumiCals as full barrels and not (as at LEP) as two clam-shelled half barrels
 - Avoid systematic from half-barrel separation
 - Beam-pipe flange has been already designed to allow LumiCal with $\varnothing$ 110 mm hole to slide over
- ◆ Fabricate each Si layer from a single 300-mm Si wafer?
 - Uncertainty on acceptance boundaries would essentially be controlled by Si sensor lithography
 - Can such Si sensors be produced?
 - And what about thermal stability: cracking?

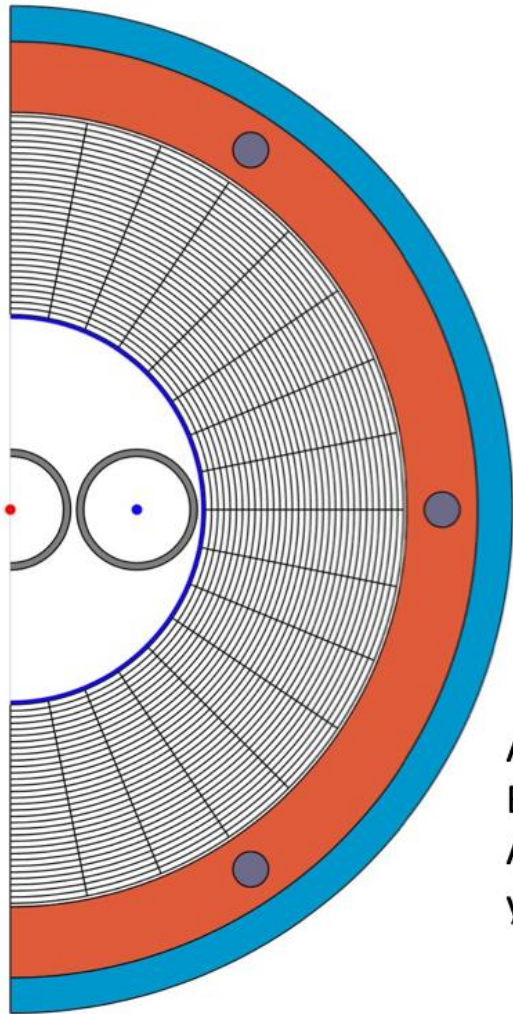
How to construct/stack such a device?



Crossing beam lines



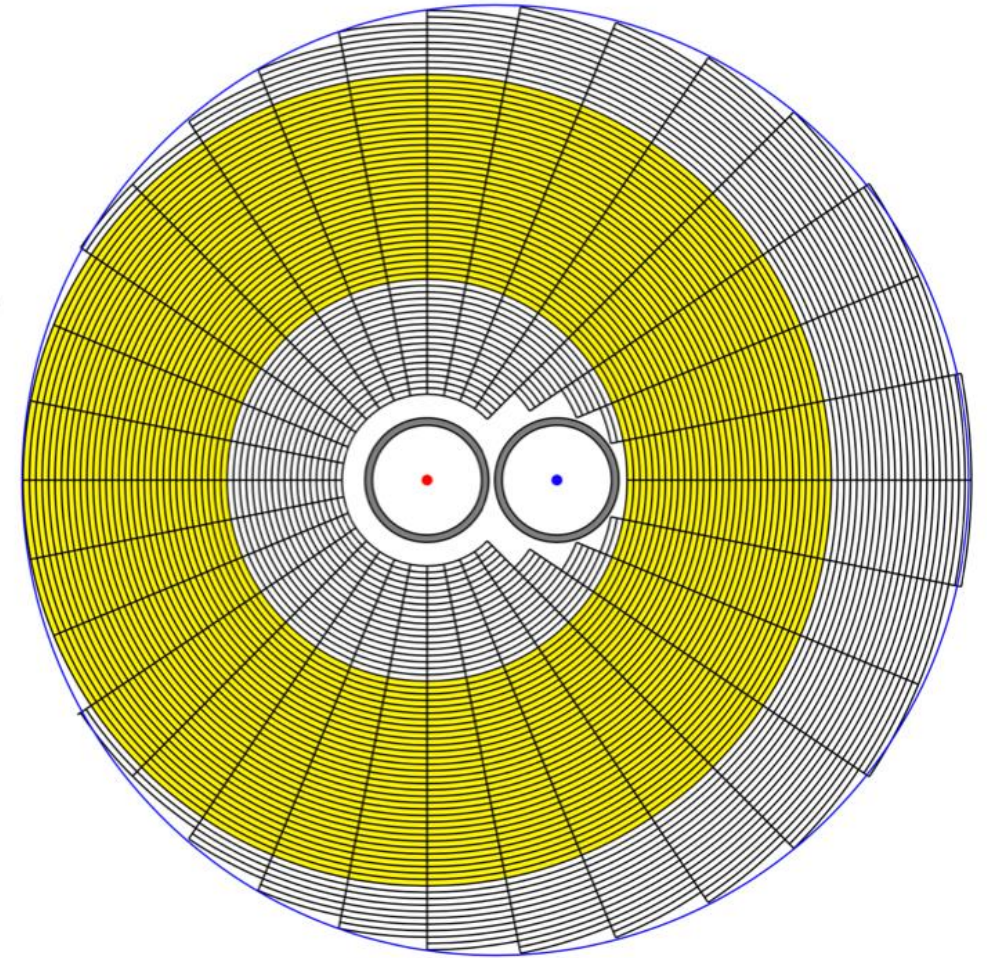
Centered on outgoing beam but still "symmetric" in global system



Pads shown in yellow at the right are identical between two drawings



Anything can be drawn...
But can it be built?
And how to control geometry of
yellow region to $\mathcal{O}(1\ \mu\text{m})$



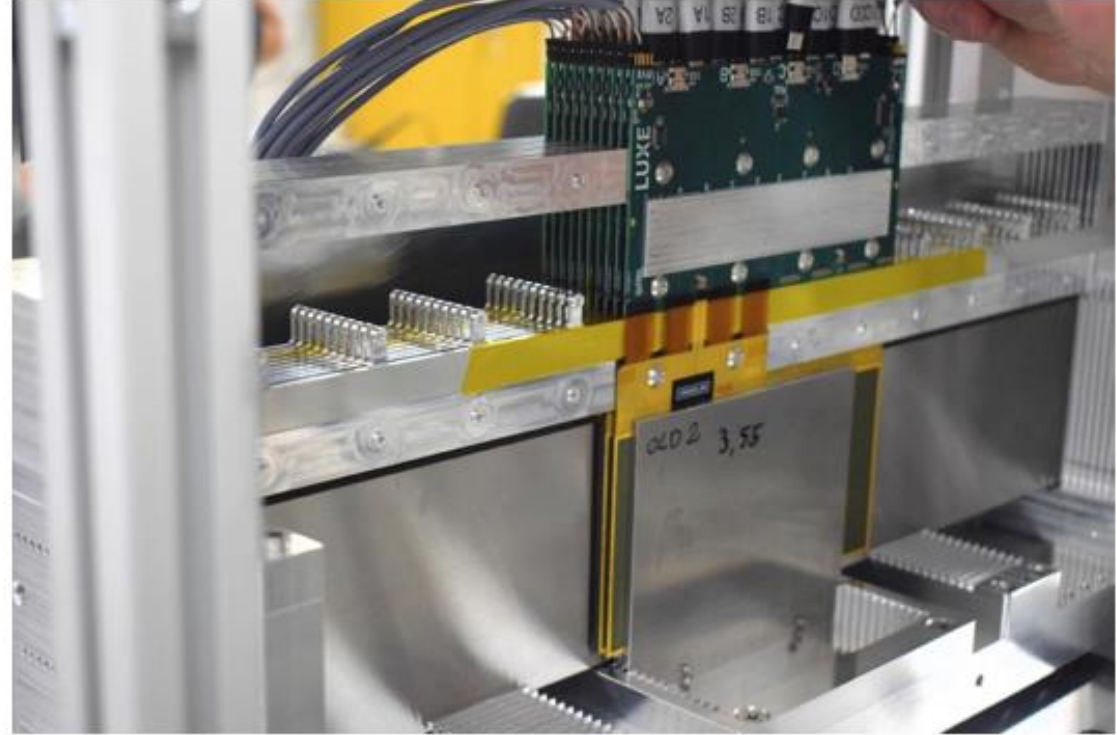
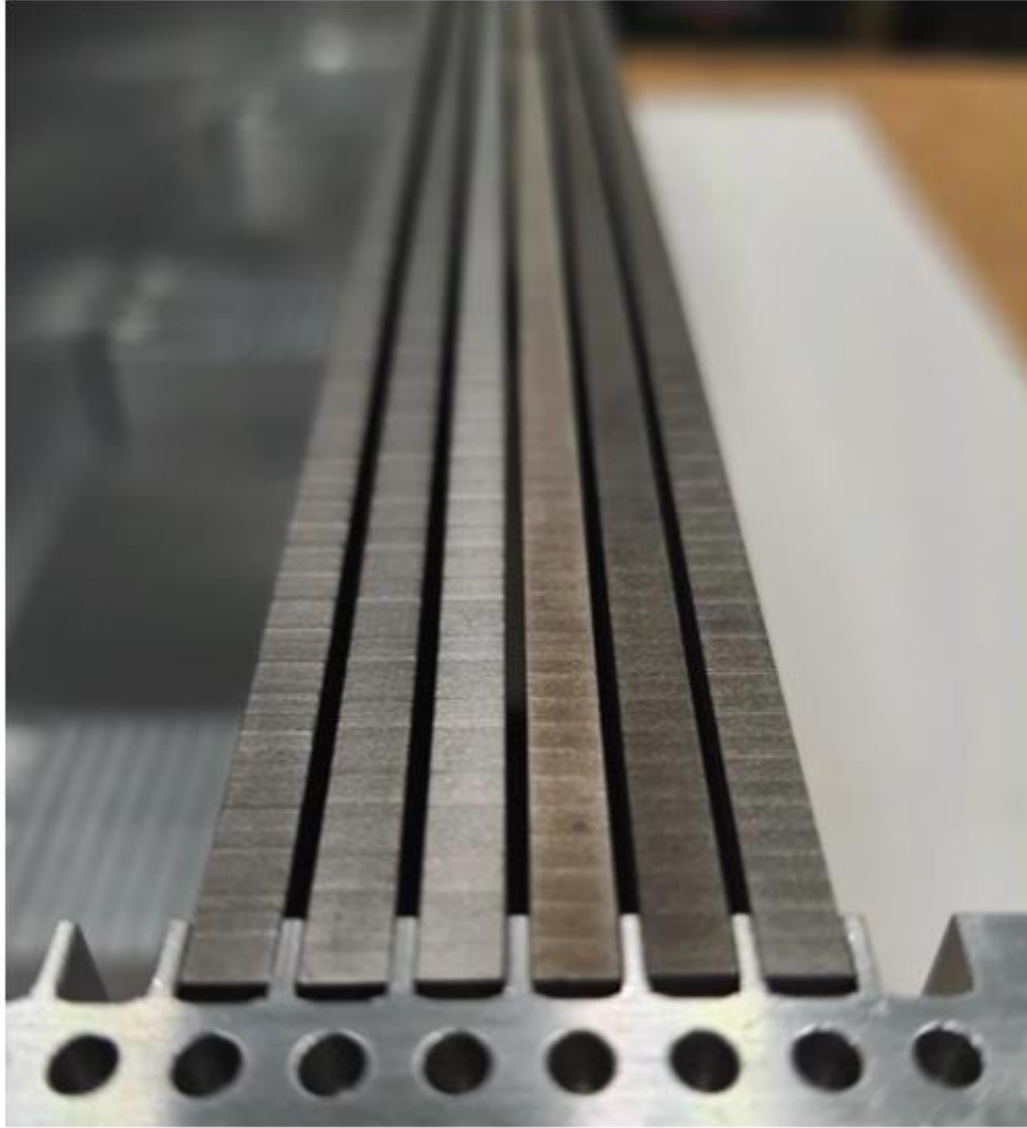
Coverage from global $\theta = \sim 35$ to $110\ \text{mrad}$ for all ϕ

ECALp – LUXE: Testbeam ventures, sensors and connectivity

A. Irles on behalf FCAL Collab.



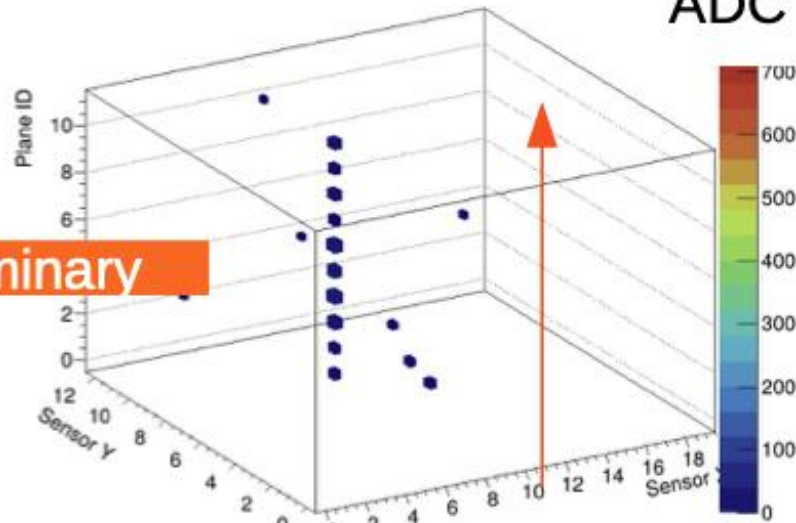
Compact calo



ZS online data

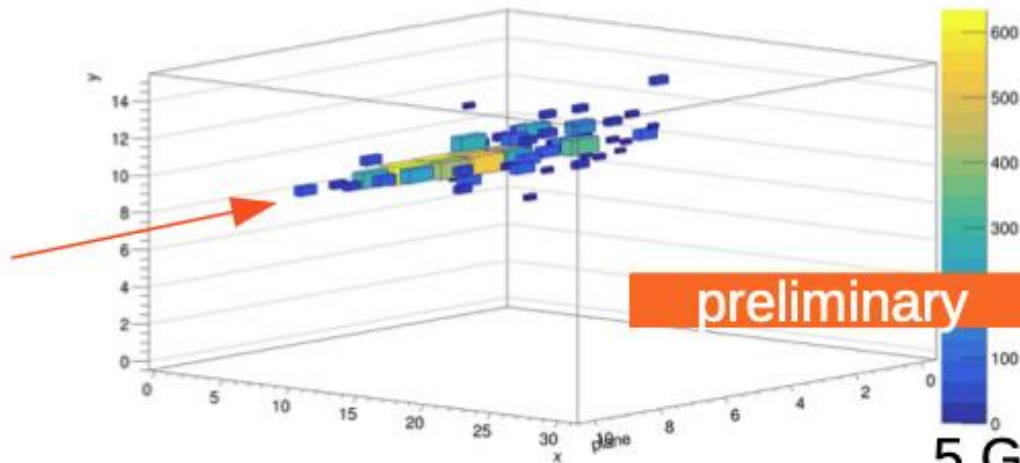
Event Display - TLU: 657

ADC



preliminary

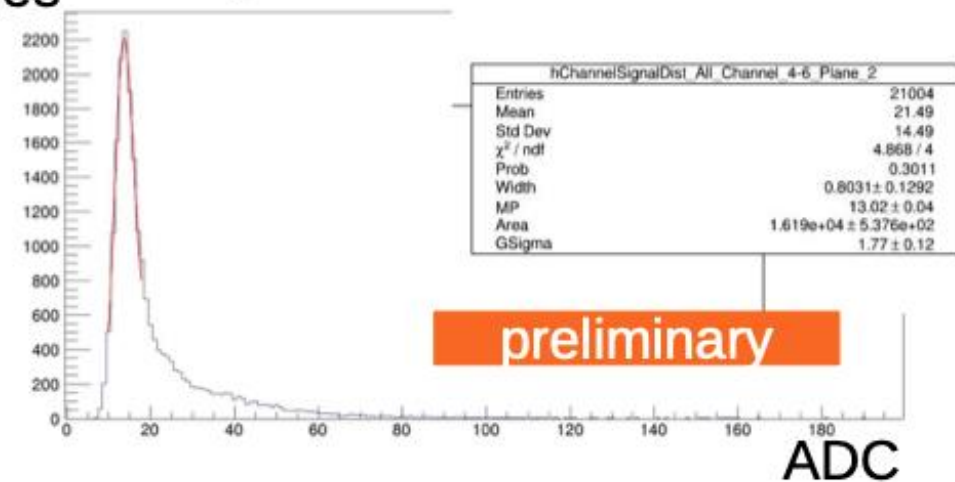
Event 190000 run 1340



preliminary

entries

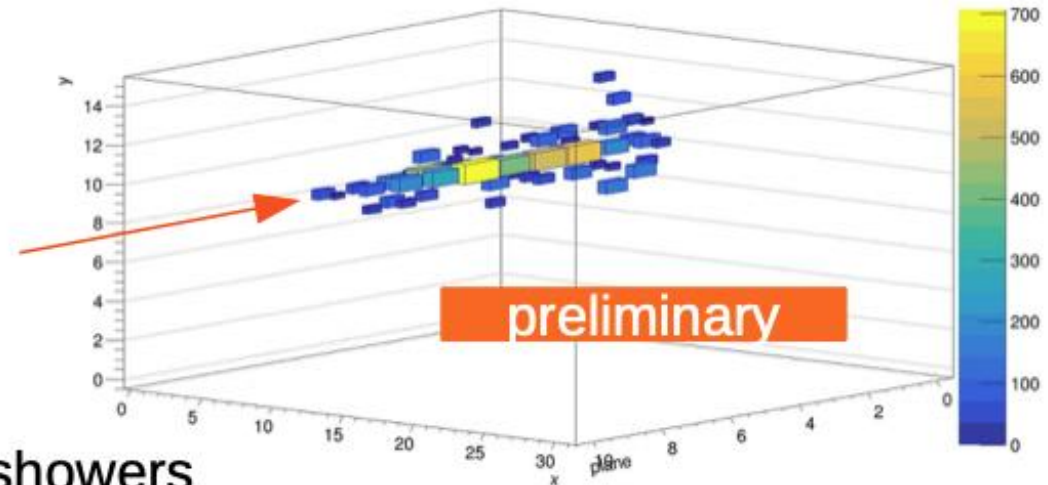
Signal distribution in channel (4,6) Plane 2 run 1491



preliminary

ADC

Event 260000 run 1340



preliminary

5 GeV showers

Quasi-online data reconstruction for monitoring.



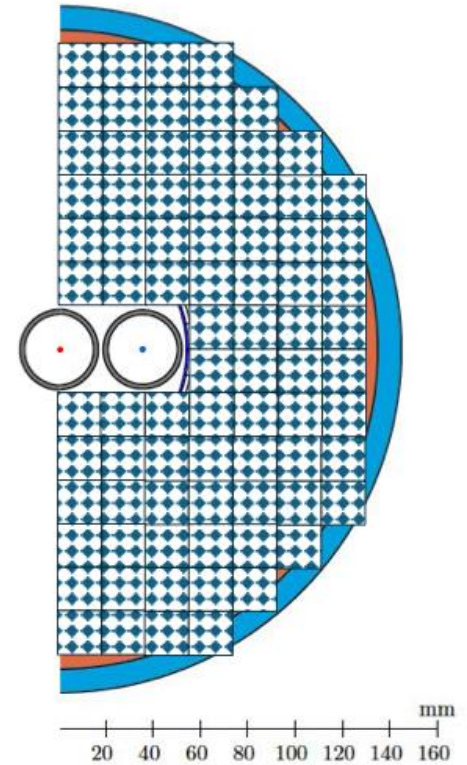
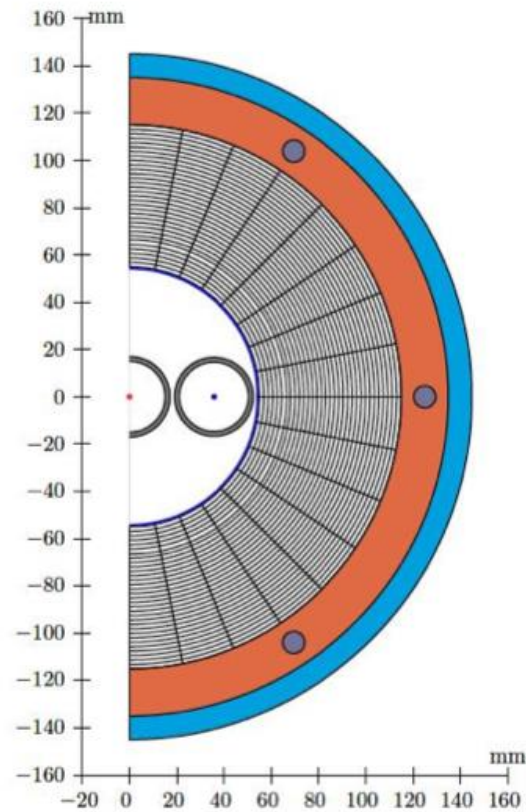
A MAPS-based LumiCal

Initial considerations

Monolithic Active Pixel Sensor

Basic idea:

- Replace Si strips with MAPS positioned as close as possible around the beam pipe(s)



MAPS option – in conclusion

- A LumiCal based on stitched MAPS offers several potentially attractive features
- The feasibility of stitching with the required geometry remains to be demonstrated
- The requirement for fast timing could introduce an additional significant (prohibitive?) challenge
- The MAPS option is worth pursuing, but it cannot be taken for granted or adopted as the baseline
- At this stage, engaging with the foundry would be premature
- We can develop a credible detector concept and, once the project has reached a more concrete stage, initiate discussions with the foundry
- In the meantime, the timing requirements will hopefully also have been clarified

Luminometer concept using SNSPDs

Superconducting Nanowire Single Particle Detectors (SNSPDs) for tracking and calorimetry

Ben Kilminster
University of Zurich (UZH)
July 27th, 2026



July 27, 2026

On behalf of the UZH Team:
Dr. Vagelis Gkougkousis
Dr. Anna Macchiolo
Alexandre Hennessy (PhD, joint w/ CERN)
Yang Xin (Masters → PhD in fall)
Cédric Renda (Bachelors)

B.Kilminster, SNSPDs for HEP

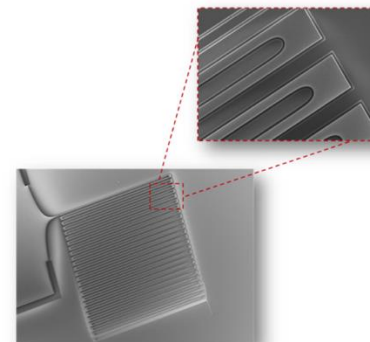


DRD5



CMi

1



July 24, 2026

B.Kilminster, SNSPDs for HEP

Meandering wire of superconducting material:

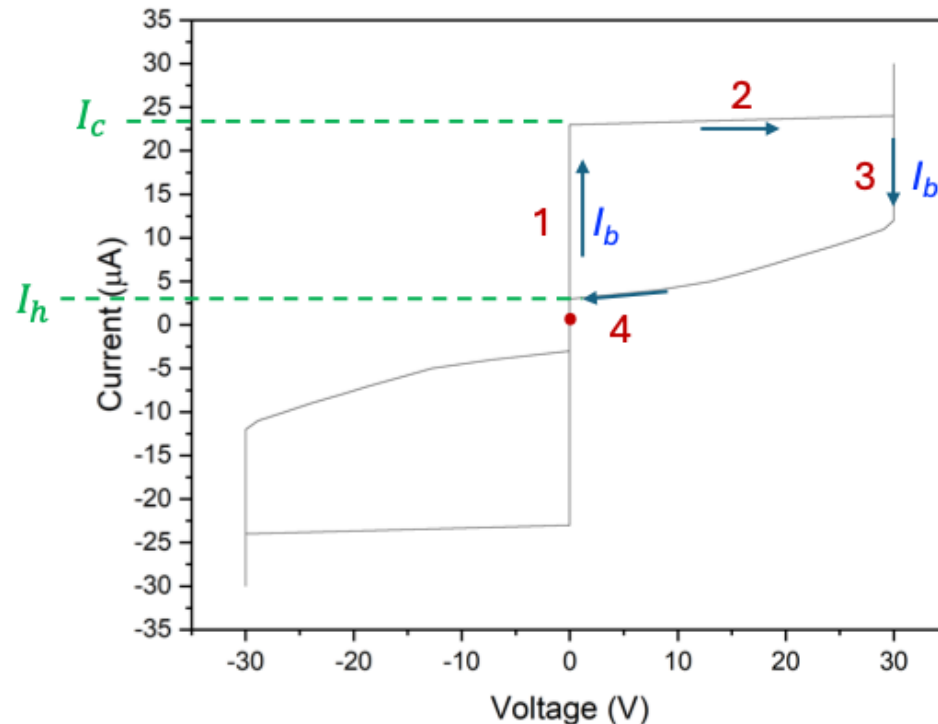
- Wire : ~100 nm width, ~10 nm height
- Substrate: Si, SiN, SiC, sapphire, diamond
- Operating temperature below superconducting critical temperature T_C

Here "Quantum sensor": Measures change in state from superconducting to conducting

2

Characteristics of SNSPD

Example of an IV measurement: hysteresis curve



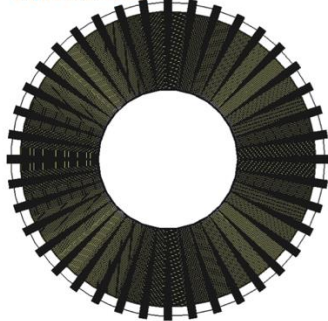
- (0,0): Wire is superconducting below its T_C (no resistance).
- 1: Apply increasing bias current I_b produces no voltage.
- 2: When $I_b = \text{critical current } (I_c)$, a resistive region nucleates. Significant part of wire becomes normal (resistance R_{nw}).
$$V = I_b R_{nw}$$
- 3: Lowering I_b , resistive state persists due to Joule self-heating.
- 4: When $I_b \leq \text{hysteresis current } (I_h)$, superconductivity recovers.

To operate as a particle sensor: Apply a bias current just below the critical current I_c
→ **Small energy deposit creates transient resistive region (2)**

SNSPD Lumical detector concept

We consider same geometric volume as Si/W LumiCal
Each detector layer fabricated on a **single 12-inch** (30.48cm) silicon wafer cut to d=23cm
Sensor wires arranged in Tracks and sectors

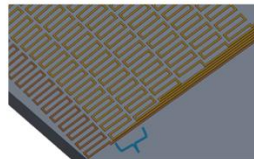
40 phi sectors of 9°



July 24, 2026

B.Kilminster, SNSPDs for HEP

- 20 X 12" single wafers, 1 wafer per layer
- 200nm-wide wires arranged per sector as 60 X 1mm wide tracks at a given radius from 54 mm to 114 mm
- Radial readout corridors between sectors, 1mm wide
- Readout region active as superconductive pattern on ring
 - Sensor geometry: 50 % Fill Factor
- One alignment track at the outer edge, R = 115 mm



1-mm track at given radius

- Each wire extends from perimeter to a given radius, meanders across 9° sector, then returns to perimeter
- 1mm track from 54-115mm
- **Wire readout on 2 sides at outer radius for position resolution**

11

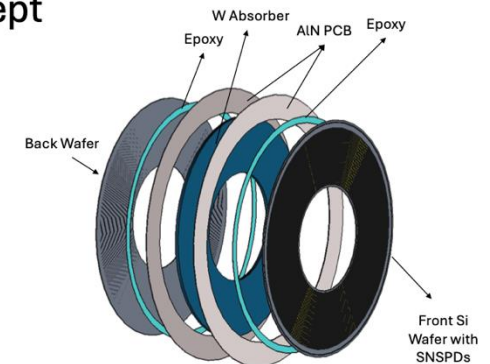
SNSPD Lumical concept



SNSPD wires are fabricated on 12-inch silicon wafers

July 24, 2026

B.Kilminster, SNSPDs for HEP



Cooling accomplished by looping liquid helium tubes along AIN PCB in contact with silicon wafer

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Conclusions & Outlook

- SNSPDs provide interesting possibility for LumiCal
 - Excellent timing, position resolution
 - Small feature sizes allow precise determination of fiducial acceptance
 - Low-energy photon response may improve shower sampling δE
- Progress
 - Basic detector concept developed
 - Instrumenting 300 cm² of SNSPD wires on wafer seems possible
 - Learning to do fabrication: goal is to optimize designs
 - Lab tests, beam tests encouraging
- Ongoing
 - Developing full simulation for understanding/optimizing detector response
 - Optimizing wire geometries for higher tracking efficiency at 45 GeV
 - Optimizing amplifier designs, readout concepts
- Future
 - Plan to target higher T_c / lower L_K materials (MgB₂) for better performance & easier implementation
- No showstoppers, but many challenges ahead !

FCC-EE BEAM INSTRUMENTATION FOR LUMINOSITY MONITORING AND IP TUNING

Robert Kieffer, and Pablo Mooney of the CERN BI group.

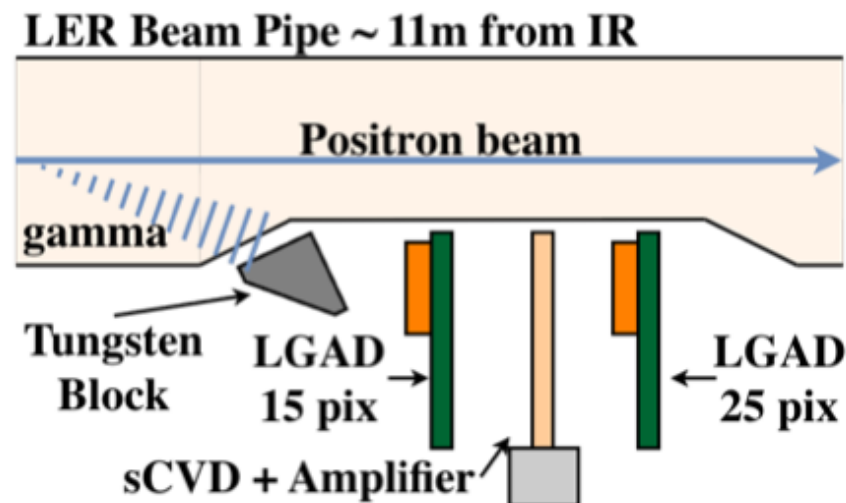
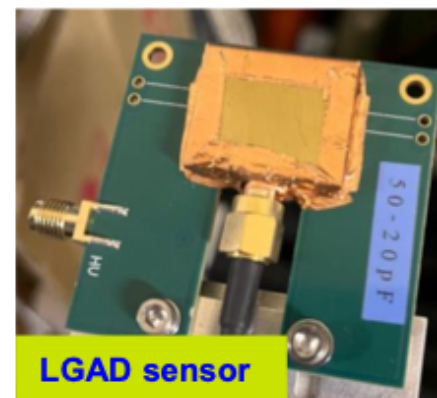
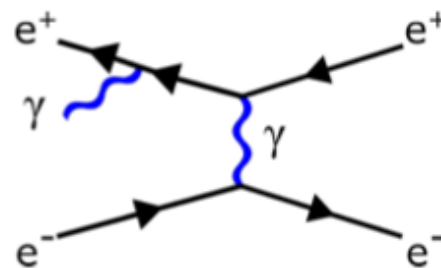
Radiative Bhabha relative luminosity monitoring

We recently joined the Lumibelle2 collaboration within SuperKEKB dedicated to radiative Bhabha relative luminosity monitoring.

The instrument uses CVD diamond sensors and Low Gain Avalanche Diodes (LGAD) to provide online bunch by bunch and train integrated luminosity monitoring signals to the operators.

The system as also been designed to drive a locking amplifier feeding specific dithering magnets to control the horizontal beam position at IP (currently not in use).

Ref: Fast luminosity monitoring for the SuperKEKB collider
doi:10.18429/JACoW-IBIC2018-MOPA13



BS Exit window monitoring

In case the screen option is not feasible:

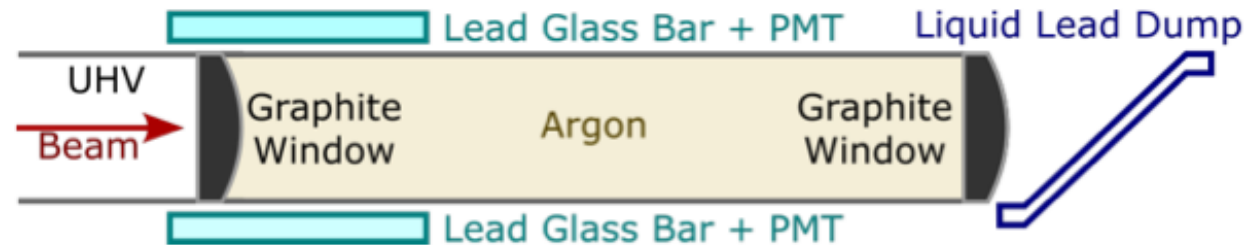
- too much thermal power in the screens.
- too much radiation background generated.

We could monitor the radiation generated on the graphite windows just before the liquid lead dump.

This system could provide the profile position as for the screen, studies undergoing to see which spatial resolution can be obtained.

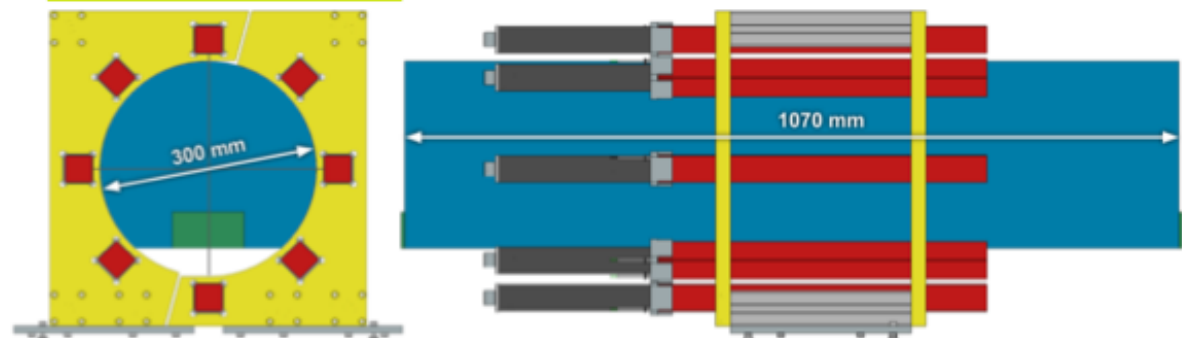
It could also serve as a useful BS dump protection system.

FCC BS dump design



Ultra high vacuum region and liquid lead dump area with lead glass scintillator bar placement

Reference design



Dump leakage calorimeter design at FLASHForward at DESY
<https://arxiv.org/html/2508.17991v2>

Conclusion

- A precision of 10^{-4} – 10^{-5} seems achievable using particle generators.
- The $\gamma\gamma$ channel should be further investigated in collaboration with ECAL experts.
- Detector backgrounds in the luminosity detector started. Work ongoing.
- The **compact silicon–tungsten calorimeter** concept has been successfully demonstrated, and results are now available for a different geometry developed for **LUXE**. Several new ideas are currently under study.
- Other promising approaches based on **MAPS** are also being investigated. A new concept using **superconducting nanowires** is under development.
- The **integration of the luminometer** will be challenging. A dedicated technical meeting will be organized soon, bringing together MDI and luminometer experts to discuss the different options, constraints, and technical challenges.