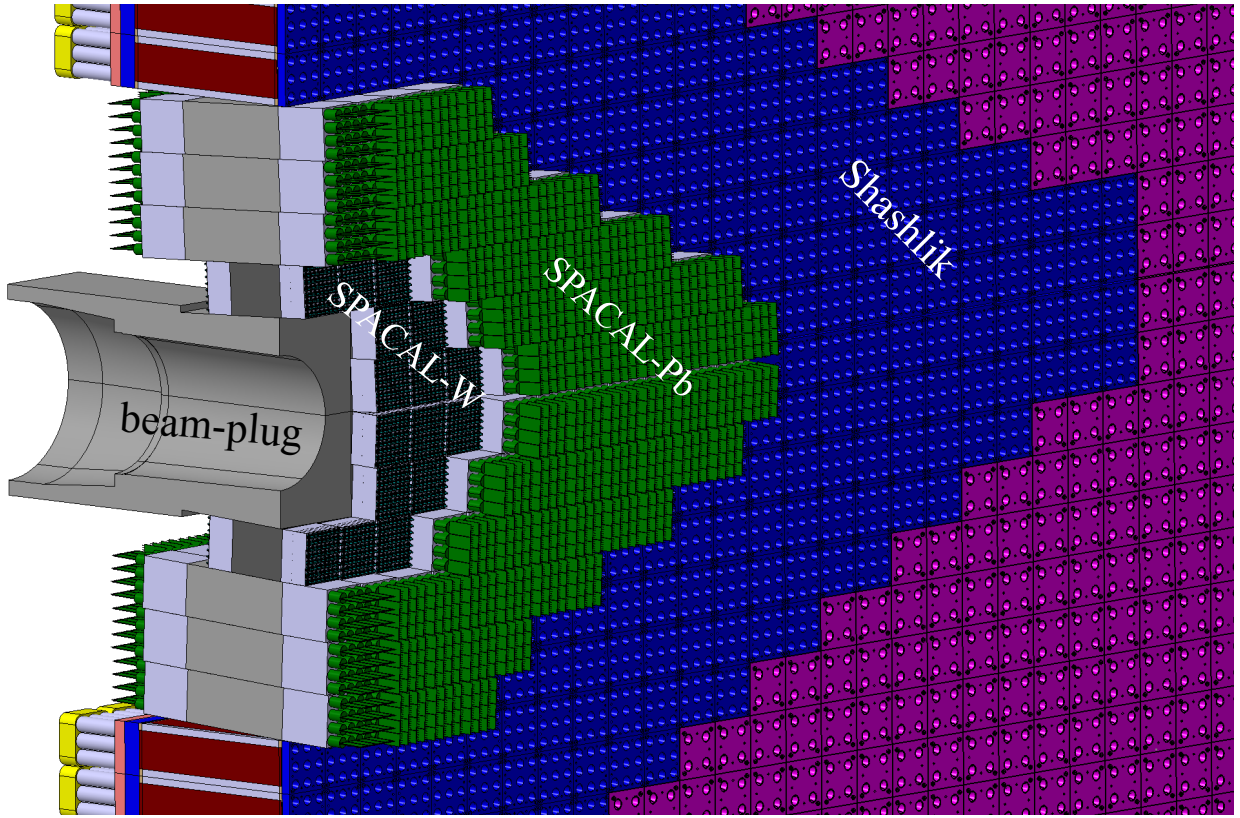
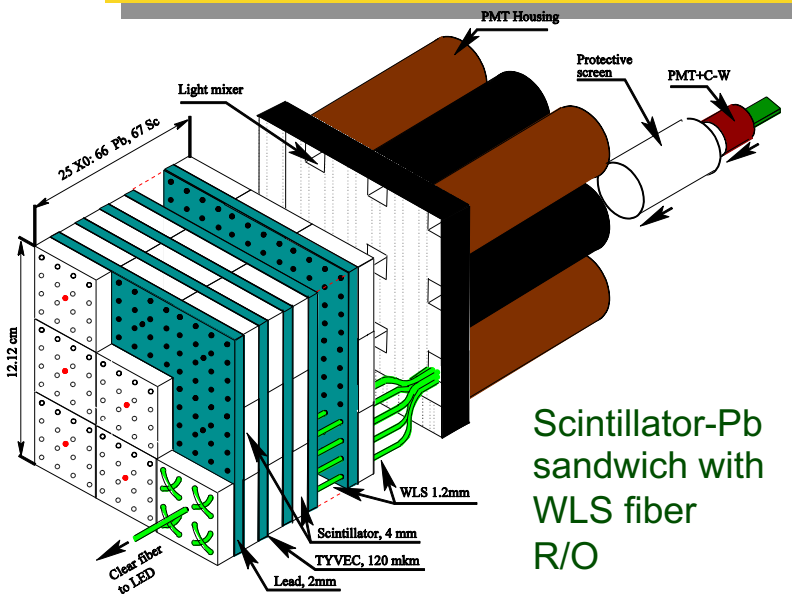
ECAL consolidation and upgrade plans

ECAL Upgrade II workshop, Orsay, 12-14 Dec 2022



Andreas Schopper

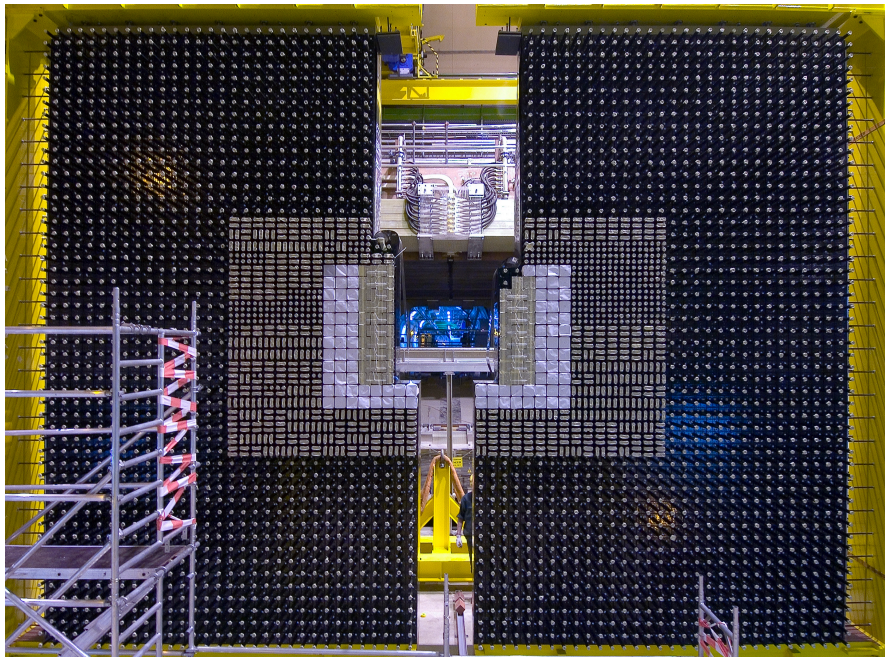
Performance of current ECAL



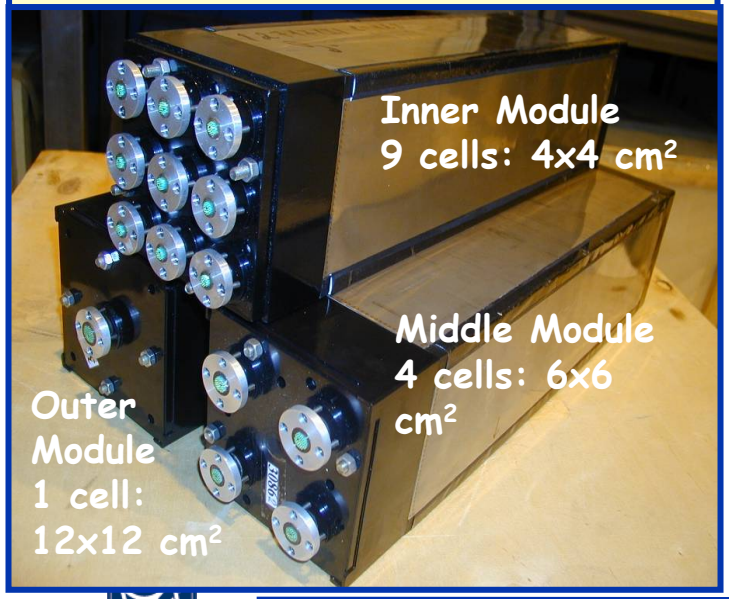
Scintillator-Pb sandwich with WLS fiber R/O

Current ECAL optimized for π^0 and γ reconstruction in the few to 100 GeV energy range at $\mathbf{L = 2 \times 10^{32}\ cm^{-2}s^{-1}}$

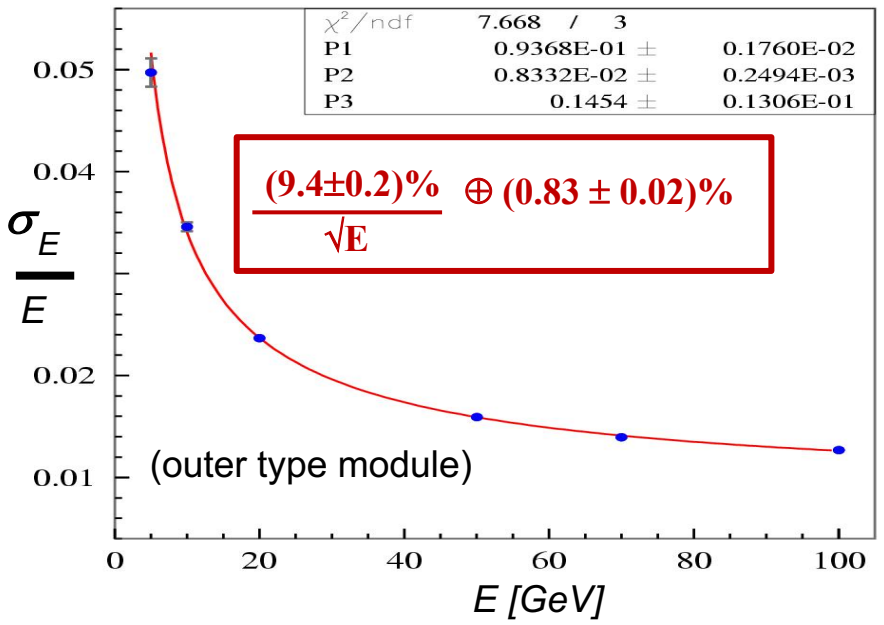
- 3312 modules and **6016 channels**
- radiation resistant **up to 40 kGy**
- three sections (Inner, Middle, Outer) of **cell size 4x4, 6x6, 12x12 cm²**
- **$\sigma(E)/E \sim 10\%/\sqrt{E} \oplus 1\%$**

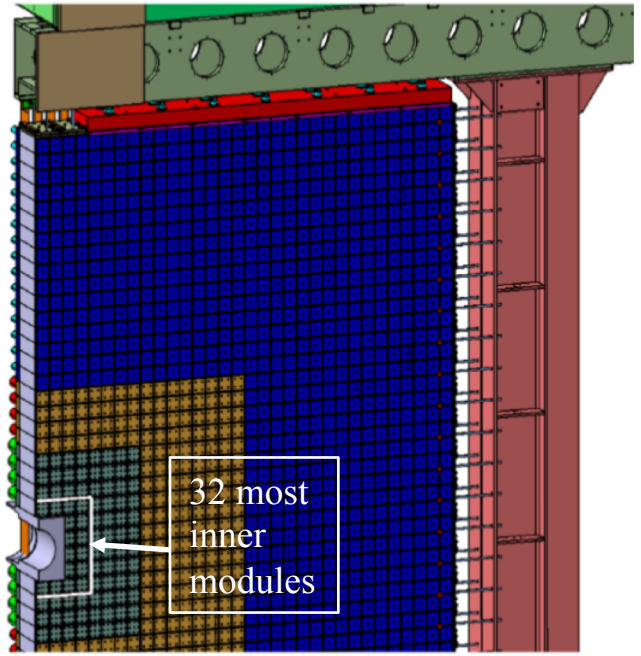


3312 shashlik modules with 25 X0



Energy resolution with electrons



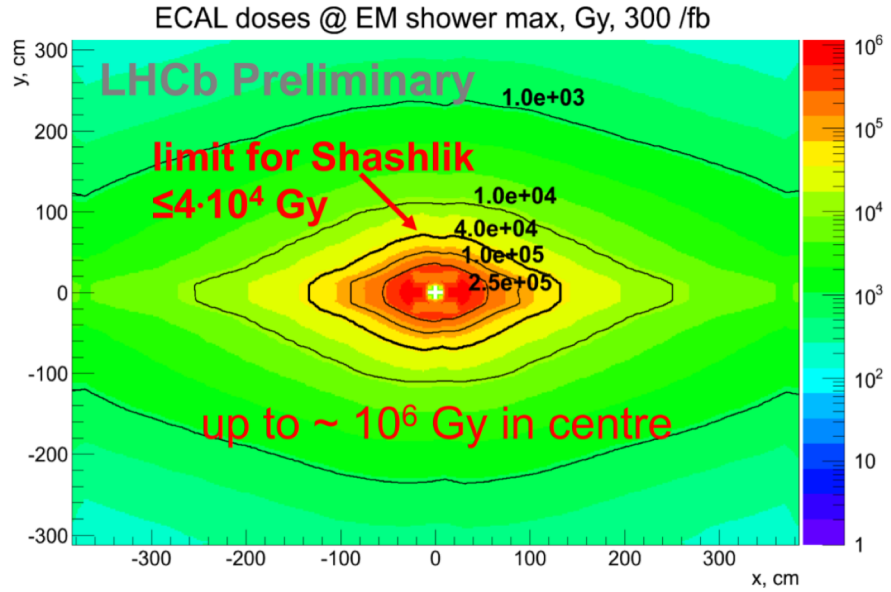


Requirements for ECAL under upgrade II conditions

Requirements for the Upgrade II:

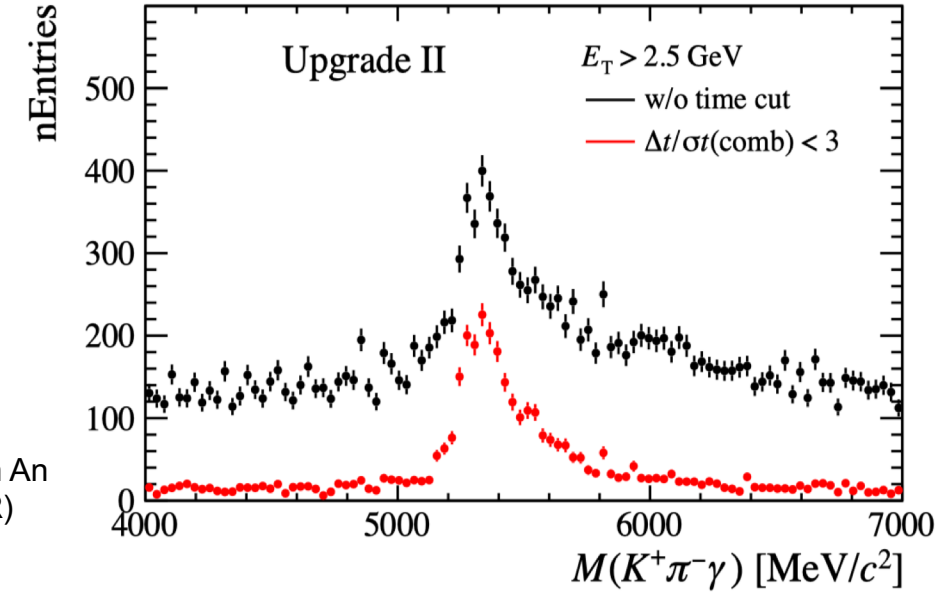
→ operation up to L = 1.5 x 10^{34} $cm^{-2}s^{-1}$ with Run 1&2 detector performance (assumption in physics TDR)

- Keep current energy resolution
- Sustain radiation doses up to 1 MGy and $\leq 6 \cdot 10^{15} cm^{-2}$ for 1MeV neq/cm^2 at 300 fb^{-1}
- Mitigate high occupancies and pile-up
  - ✓ Reduce occupancy by increasing granularity (down to 1.5x1.5 cm^2) and by following rhombic radiation map
  - ✓ Mitigate pile-up by introducing timing capabilities with O(10) ps precision
  - ✓ Improve reconstruction & PID by introducing Z-segmentation (double-sided R/O)
- Respect outer dimensions of the current modules: 12 x12 cm^2



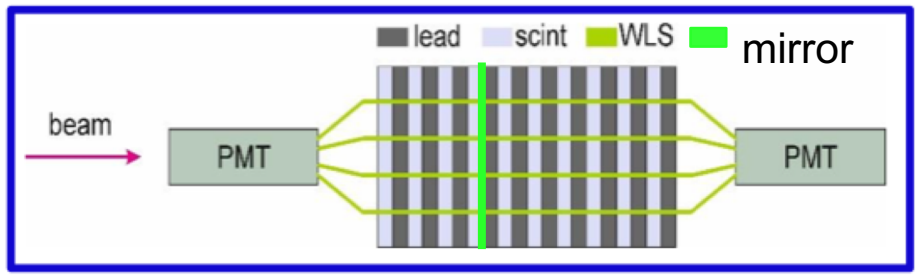
Matthias Karacson & Yuri Guz

Effect of timing cut on invariant mass for B→ K*γ



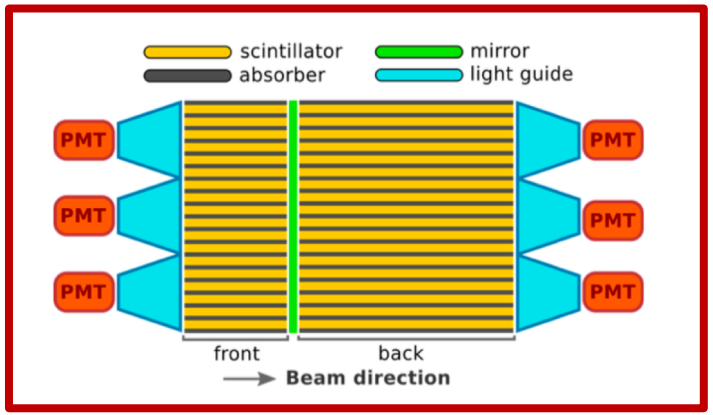
Liupan An (FTDR)

Shashlik



Baseline technologies for ECAL Upgrade II

SPACAL



➢ see Philipp's talk (next)

Upgraded Shashlik technology for outer region:

➢ Timing with new WLS fibres & long. segmentation
- ✓ Cost optimisation by refurbishing ≈2000 existing modules for improved timing
- ✓ Adapt to the required cell sizes by adding ≈1300 new modules
- ✓ 4x4, 6x6,12x12 cm^2 cell sizes (segmentation & double side readout)

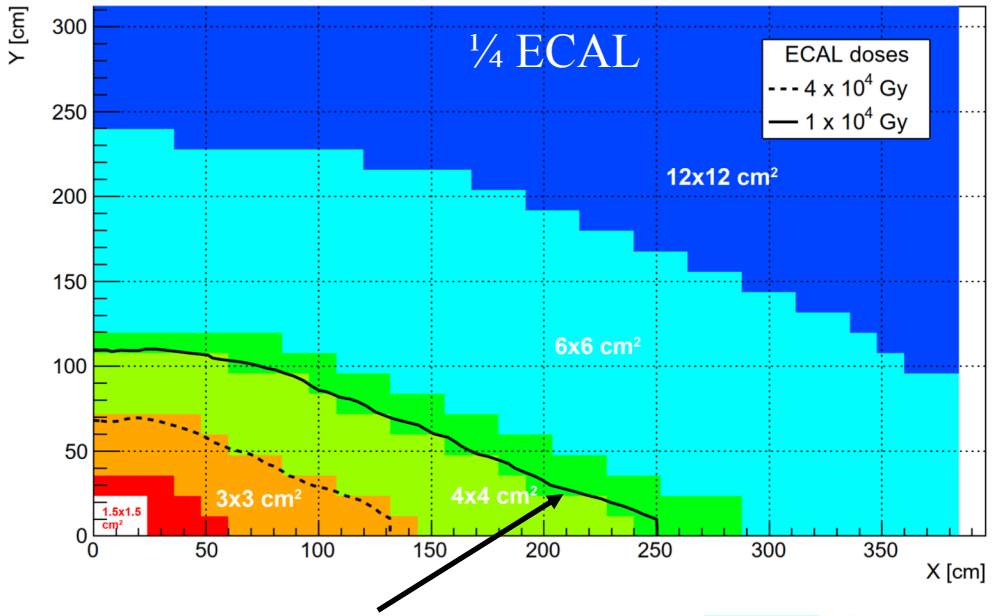
➢ All module sizes: 12 x12 cm^2

New SpaCal technology for inner region:

➢ 1 MGy → 200 kGy region with scintillating crystal fibres and W-absorber
- ✓ Development of radiation-hard scintillating crystals
- ✓ 1.5x1.5 cm^2 cell size with Z-segmentation & double-side readout

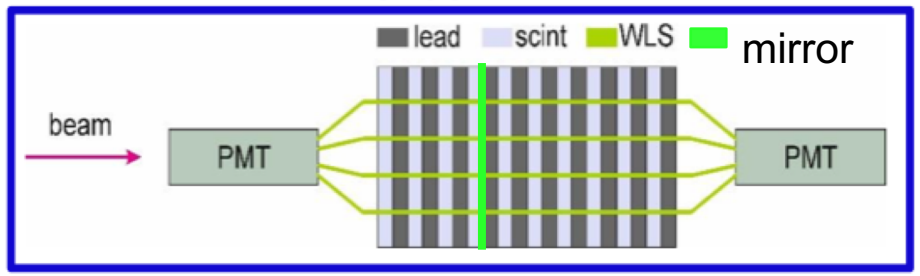
➢ 200 kGy → 40 kGy region with scintillating plastic fibres and Pb-absorber
- ✓ Need for radiation-tolerant organic scintillators
- ✓ 3x3 cm^2 cell size with Z-segmentation & double-side readout

LS3 consolidation: W absorber for innermost modules equipped with scintillating plastic fibres for 2x2 cm^2 cell size and single-side R/O



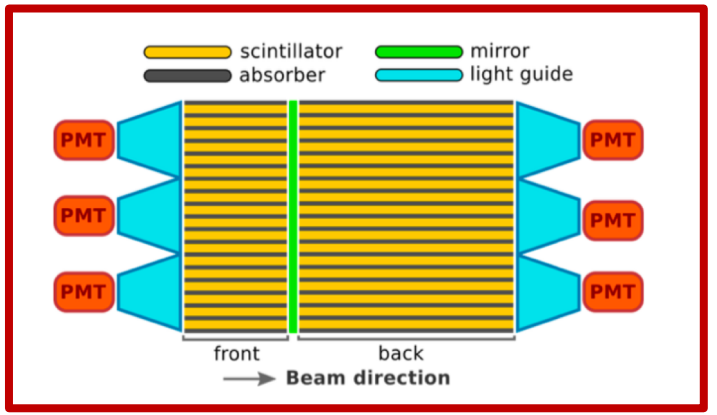
Radiation limit of current Shashlik technology

Shashlik



Baseline configuration for ECAL Upgrade II

SPACAL

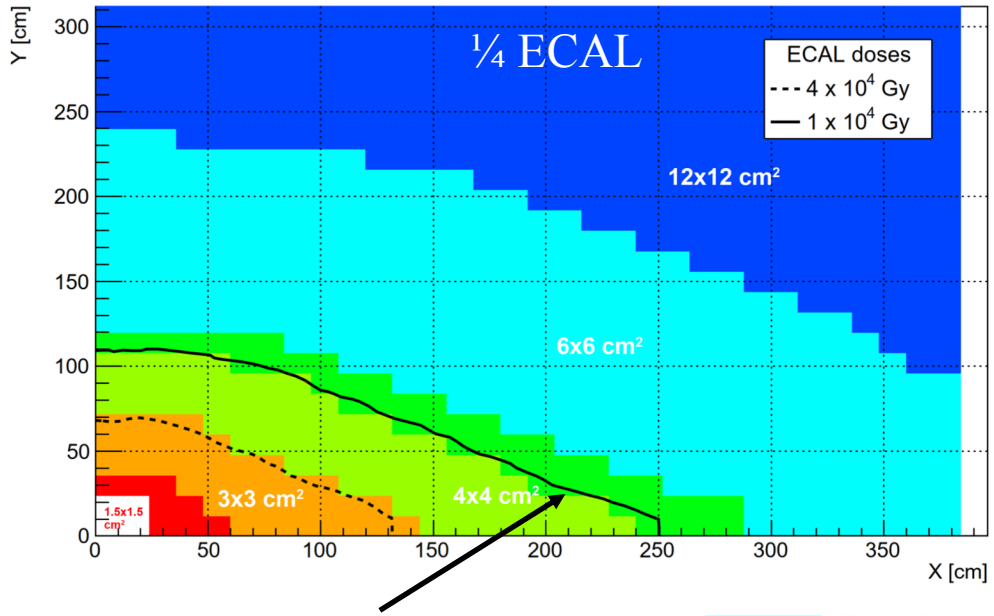


Cell size:	Modules:	
1.5 x 1.5 cm^2	32	*new* W-SPACAL for extreme conditions of up to 1 MGy
3 x 3 cm^2	144	*new* Pb-SPACAL with "moderate" radiation requirements of up to ≈ 200 kGy
4 x 4 cm^2	272	*new* Shashlik + 176 *refurbished* existing Shashlik with long. segmentation
6 x 6 cm^2	896	*new* Shashlik + 448 *refurbished* existing Shashlik with long. segmentation
12 x 12 cm^2	1344	*refurbished* Shashlik modules with long. segmentation

➢ a total of 15'104 cells

Number of channels:

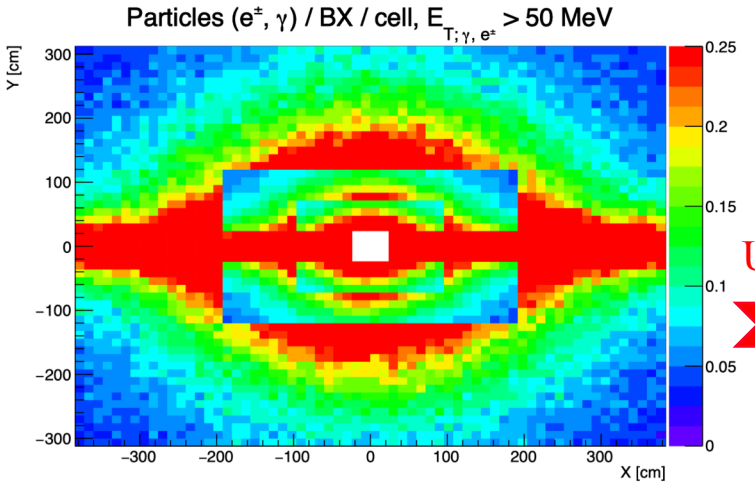
- ✓ Baseline: SPCAL & Shashlik **double**-sided R/O
  - ➢ 30'208 channels
- ✓ Downscope: SPCAL **double**-sided R/O , Shashlik **single**-sided R/O
  - ➢ 19'456 channels
- ❖ Current ECAL: 6064 cells with 6016 channels readout



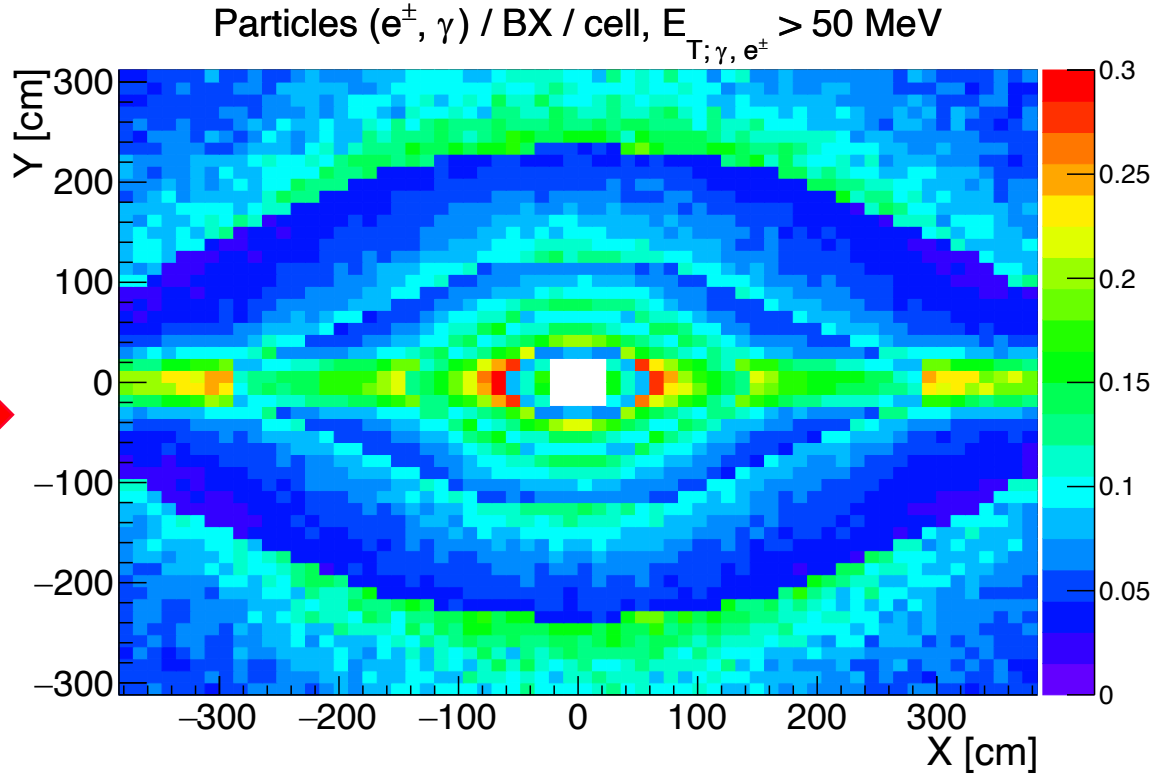
Radiation limit of current Shashlik technology

Particle flux in Upgrade II conditions

From current to UII:



UII



Mitigate high occupancies by:

- ✓ small cell size
- ✓ order 20 ps timing resolution
- ✓ optimized reconstruction algorithm
- ✓ longitudinal segmentation (dual R/O)

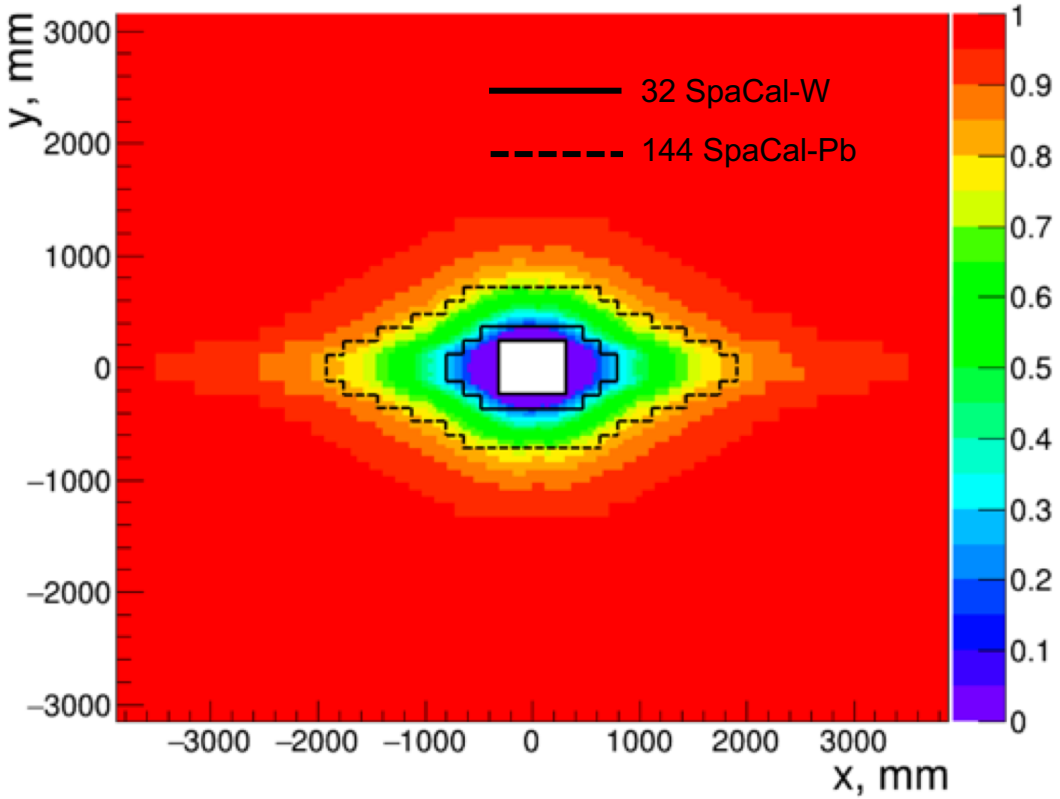
- ➢ baseline in current simulation
- ➢ still some room for optimization of most inner region

Philipp Roloff

- ➢ longitudinal segmentation can improve timing as well as shower separation

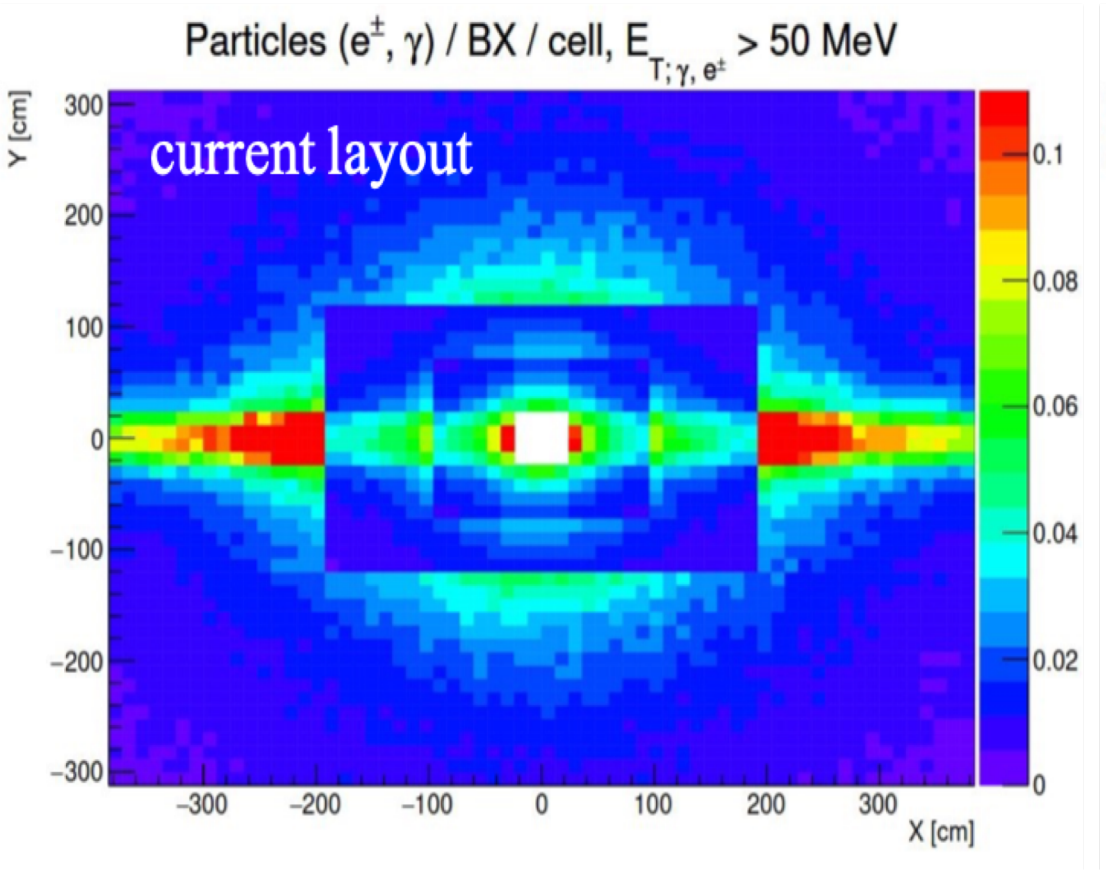
ECAL consolidation during LS3

ECAL cell efficiency after 2025 (48 fb−1)



Yuri Guz

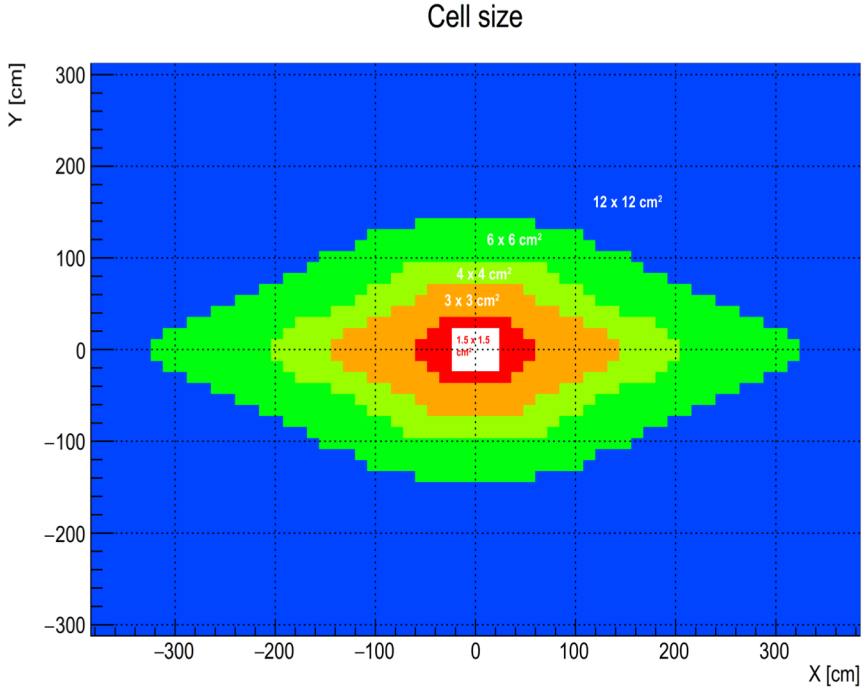
Particle flux at L = 2 x 10^{33} $cm^{-2}s^{-1}$



Philipp Roloff

- replace 176 modules in inner region
- introduce rhombic shape
- increase granularity (2x2cm^2 and 3x3cm^2 cell sizes)
- profit from new technologies for UII with timing capability

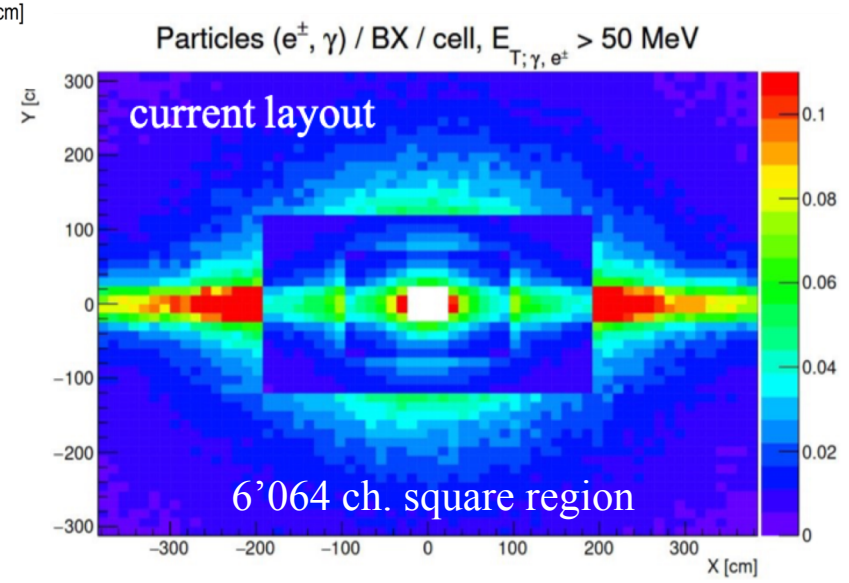
Baseline LS3 configuration

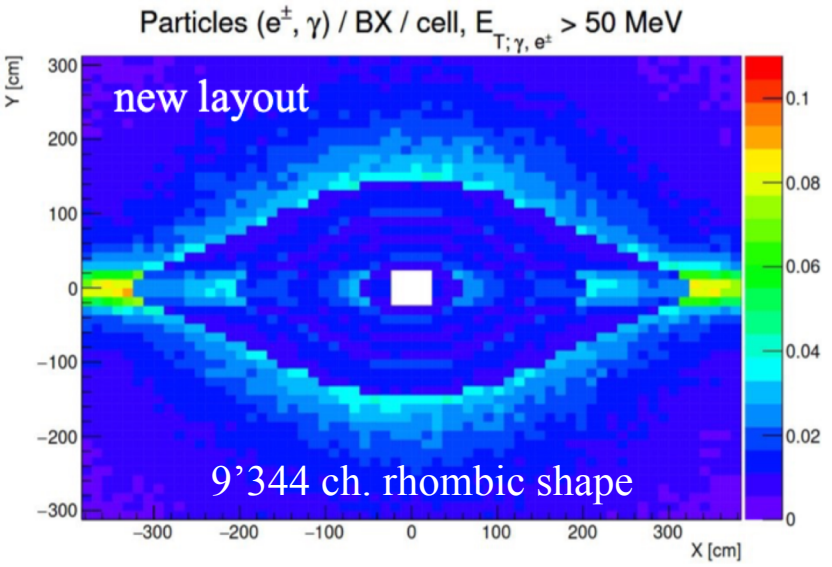


Cell size:	Modules:
2 x 2 cm²	32 *new* SpaCal-W modules with polystyrene fibers
3 x 3 cm²	144 *new* SpaCal-Pb modules (identical to UII)
4 x 4 cm²	176 existing Shashlik modules
6 x 6 cm²	448 existing Shashlik modules
12 x 12 cm²	2512 existing Shashlik modules

➢ everything in single sided R/O (no longitudinal segmentation)

Particle flux at L = 2 x 10^{33} $cm^{-2}s^{-1}$

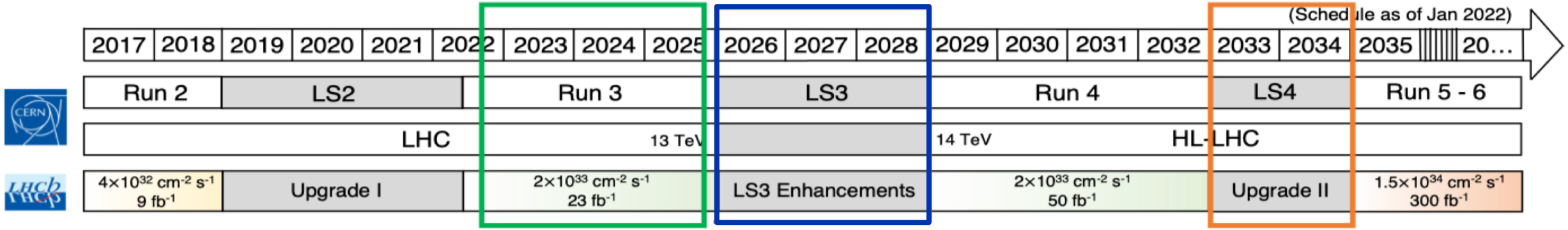




LS3 configuration:

- ✓ 9'344 cells/channels single sided R/O
- ✓ rhombic shape
- ✓ tilted SPCAL (3°+3°)
- ✓ ps-timing for new SPACAL modules
  → 3'456 new electronic channels

Baseline ECAL upgrade strategy (as agreed in FTDR)



After LS2 in 2022-2025:

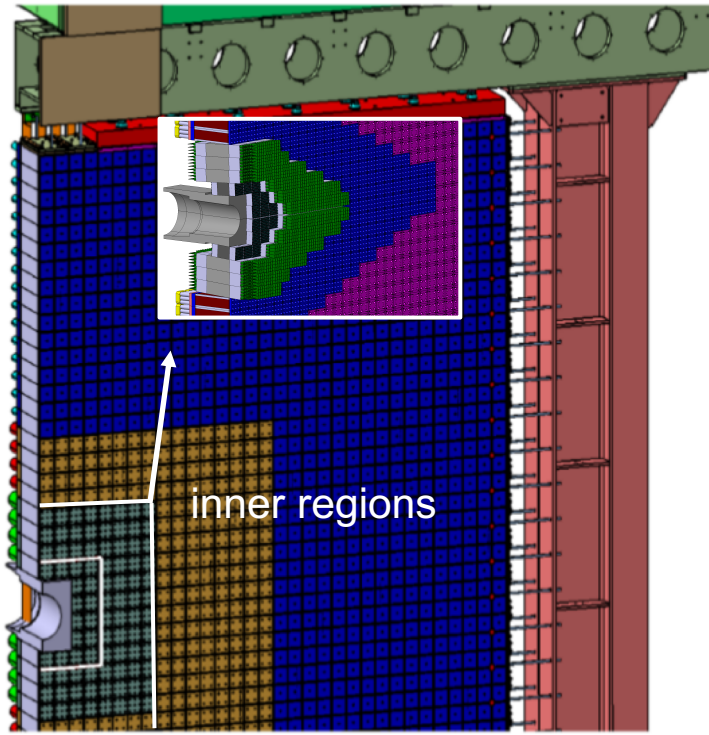
- ✓ Run with unmodified ECAL shashlik modules at L=2x10^{33} cm^{-2}s^{-1} (new 40 MHz R/O)

LS3 consolidation in 2026/28:

- ✓ Introduce **single section rad. tolerant** SPACAL (2x2 & 3x3 cm^2 cells) in **inner regions** and rebuilt ECAL in **rhombic shape** to improve performance at L=2(4)x10^{33} cm^{-2}s^{-1}
- ➢ **32** SPACAL-W & **144** SPACAL-Pb modules **compliant with Upgrade II** conditions
- ➢ Include **timing information with single sided R/O to inner regions**

LS4 Upgrade II in 2033/34:

- ✓ Introduce **double section rad. hard** SPACAL (1.5x1.5 & 3x3 cm^2 cells) and improve **timing of Shashlik modules** for a luminosity of up to L=15x10^{33} cm^{-2}s^{-1}
- ➢ Include **timing information with double sided R/O to full ECAL** to mitigate pile-up

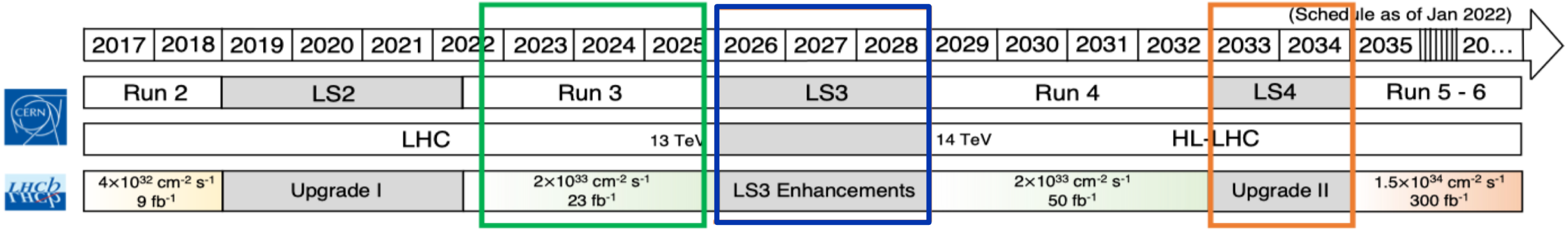


Planning towards ECAL consolidation in LS3 and upgrade II in LS4

Proposal of planning and scheduling:

- ✓ Light-weight **TDR for LS3 consolidation**:
  - ➢ Proposal: submit TDR to LHCC by September 2023 (combined PID TDR with RICH)
  - ➢ Physics performance improvement as compared to run 3 configuration
  - ➢ Demonstration of required technological performance (R&D and prototyping) for proposed consolidation
  - ➢ Infrastructure requirements for LS3 and LS4 (new platform)
  - ➢ Institute responsibilities
  - ➢ Planning, schedule (personnel loaded) and cost
- ✓ Light-weight **LHCb-internal review by U2PG** on LS3 consolidation :
  - ➢ Proposal: spring 2023 (followed by official agreement by Technical Board for proceeding with TDR)
  - ➢ Main reviewers: Hassan Jawahery, Guy Wilkinson (+ ad-hoc experts)
  - ➢ Should include: physics opportunities, technology readiness, schedule, availability of person-power and resources
- ✓ **Scoping Document:**
  - ➢ Sometime in 2024 (exact date to be decided by the collaboration, see talk by Matteo P.)
  - ➢ Comparison of physics performance for key channels between baseline and descoped option
  - ➢ Realistic estimate of cost for baseline option and descoped option

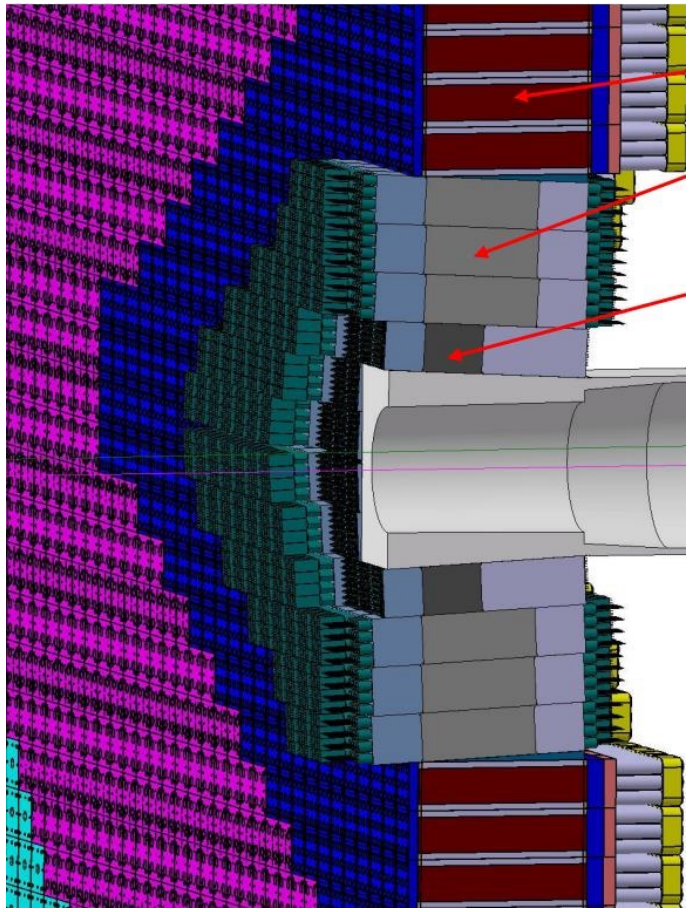
Scheduling of ECAL consolidation in LS3 and upgrade II in LS4



Summary of proposed schedule:

- ✓ April/May 2023: Light-weight internal U2PG review to approve ECAL LS3 consolidation (internal to LHCb Collaboration)
- ✓ September 2023: Light-weight PID TDR to LHCC for LS3 consolidation (ECAL & RICH)
- ✓ 2024: Scoping Document for LHCb Upgrade phase IIb (including ECAL)
- ✓ 2025-2027: production of 176 SPACAL modules, 3'500 new electronics channels and PCIe400
- ✓ 2026-2028: infrastructure modification (platform) and ECAL re-built (new modules, rhombic shape)
- ✓ 2026: TDR for ECAL Upgrade phase IIb in LS4
- ✓ 2028-2032: production/refurbishing shashlik modules, production of GAGG-SPACAL, introducing double sided R/O
- ✓ 2033-2034: ECAL re-built by adding new modules during LS4

Summary & Conclusion



- Aim to reach Run 1&2 performance with rad. hard technologies, increased granularity, long. segmentation and ps-timing performance
- Baseline technologies and configurations for LS3 and LS4 defined in FTDR
- LS3 baseline with additional 3500 channels to current ECAL and rhombic shape
- LS4 baseline with 30k R/O channels, descoped version with 20k R/O channels
- Light-weight U2PG Review and TDR for LS3 consolidation in Q1&Q3 2023
- Descoping document in 2024 and start of production for LS3 in 2025
- Tight schedule for LS3 infrastructure consolidation and ECAL re-built during LS3
- ECAL Upgrade II TDR in 2026, followed by serial production

- Optimize detailed layout → complete physics studies with different configurations
- Progress in determining final technologies → continue R&D in all areas (detector, electronics, R/O, …)
- Start realistic planning → define institutes responsibilities, schedule, cost, financial and personnel resources

→ New groups joining LS3 consolidation and LS4 upgrade II activities are most welcome (needed)!