Commissioning of ILC-inspired CMOS pixel detectors (PLUME) with e+e- collisions from SuperKEKB

A joint-venture of

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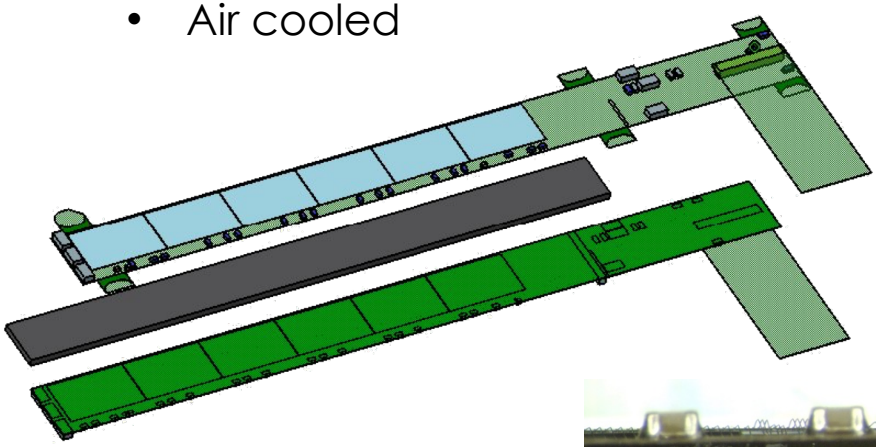
- PLUME recap'
- SuperKEKB - Belle II commissioning
- PLUME install & switch on
- First data

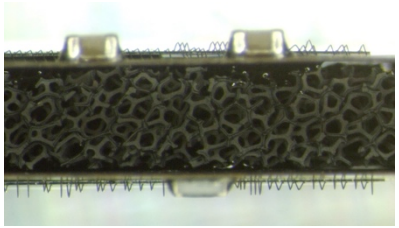
PLUME recap'

- Motivations: explore ILD-VXD double-sided 1st layers
  - Spatial resolution 3 µm
  - Material budget 2x 0.15% X_0
  - Length 125 mm, thickness ~2 mm
  - Air cooled



- Consortium
  - With initial contribution from Oxford

- Two generations
  - Based on same sensor: MIMOSA-26
  - PLUME-1 targeted functionality
    - reached 0.6 % X_0
  - PLUME-2
    - Cu-flex: 0.42 %X_0
    - (Al-flex: 0.35 % X_0 connector issues)

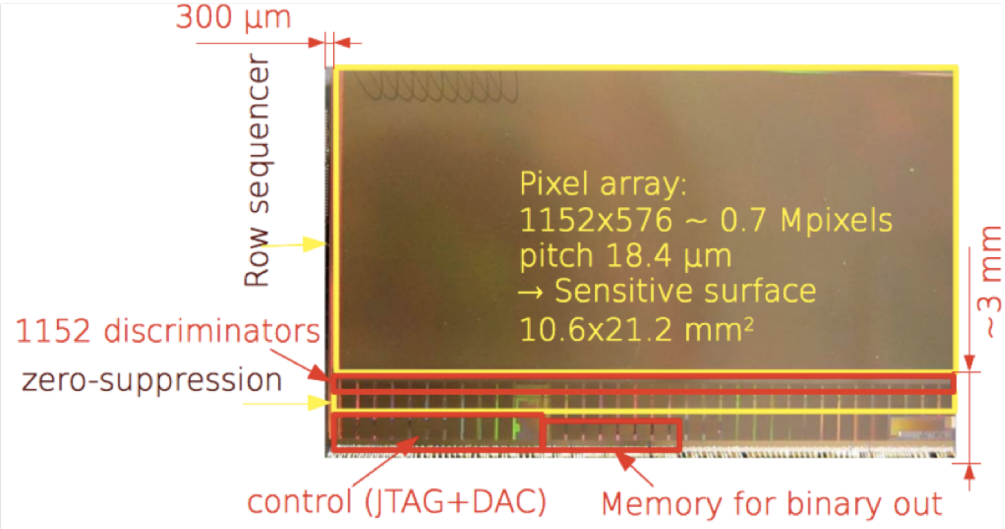


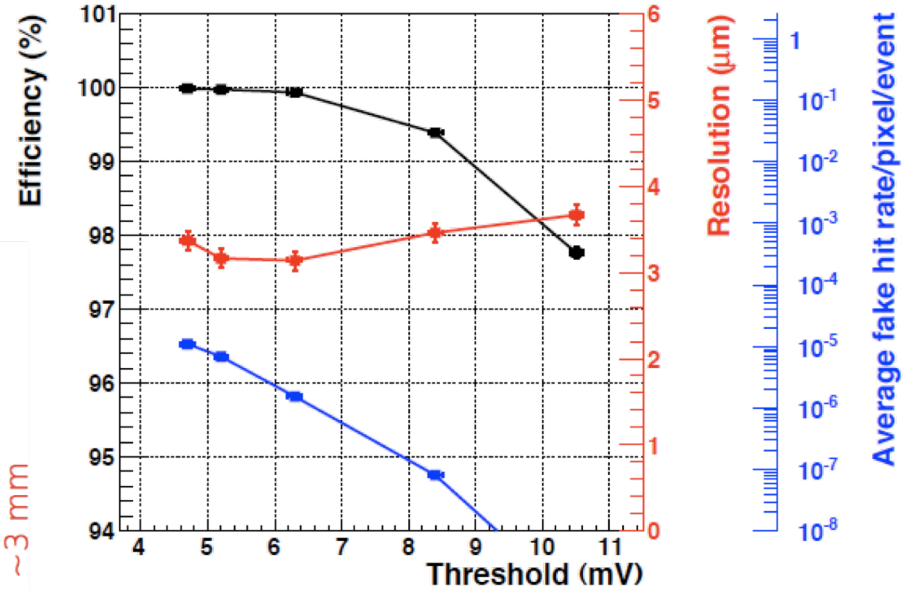
Side view

8 Mpixels
3 µm, 100 µs
10 g, 9 Watts

MIMOSA-26 recap'

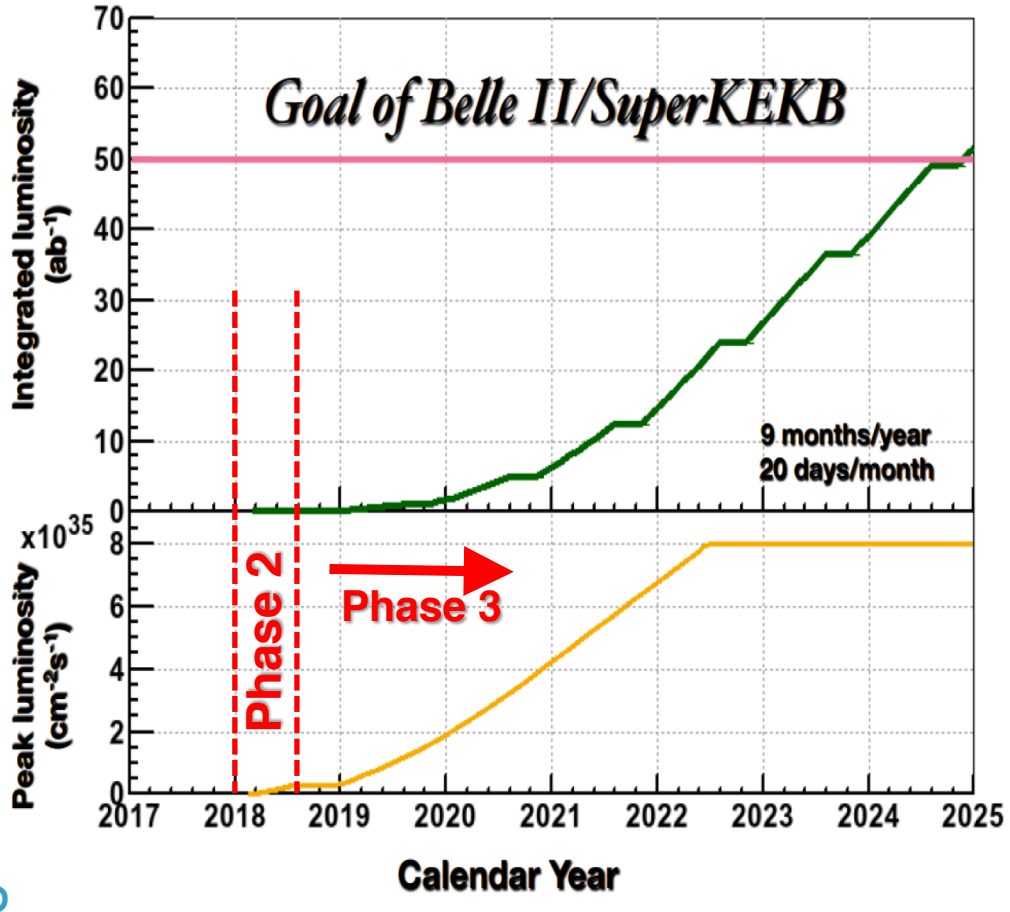
- Sensor designed in 2009
  - Technology 0.35 µm
  - binary & zero-suppressed output
  - 115 µs integration, 700 mW dissipation
  - Equips beam telescopes
  - Used in NA-61, NA-63, hadrontherapy (FIRST, QAPIVI)





SuperKEKB commissioning

- Overall goal of the new super-B-factory
  - Accumulate 50x data of previous B-factories => luminosity 8×10^{35} $cm^2.s^{-1}$
- A first phase in 2016
  - First beams
  - No Belle II detector but some instruments @ IP
- 2018: initial collisions
  - Almost full Belle II detector
  - Goals:
    - Instantaneous lumi 10^{34} $cm^2.s^{-1}$
    - Integrated lumi ~20 fb^{-1}



Beam induced bkg @ e+e- colliders

- Luminosity strategy from KEKB ➔ SuperKEKB
  - Currents x2
  - Vertical beam size /20
  - Crossing angle x4

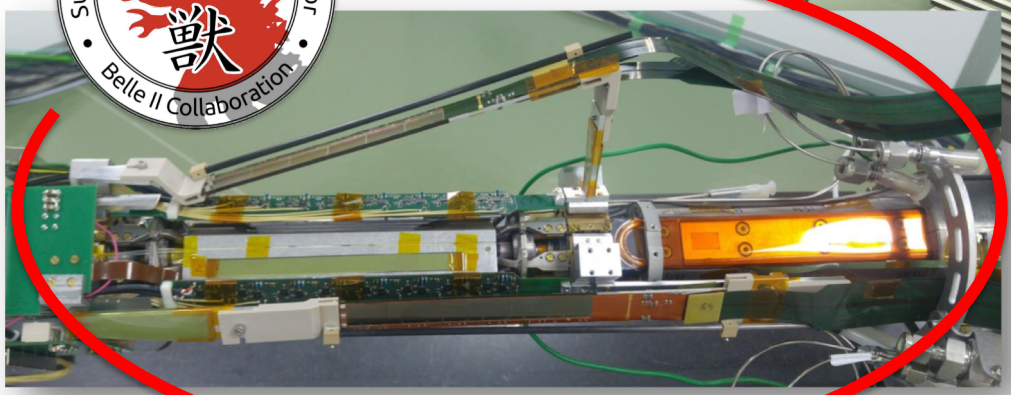
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

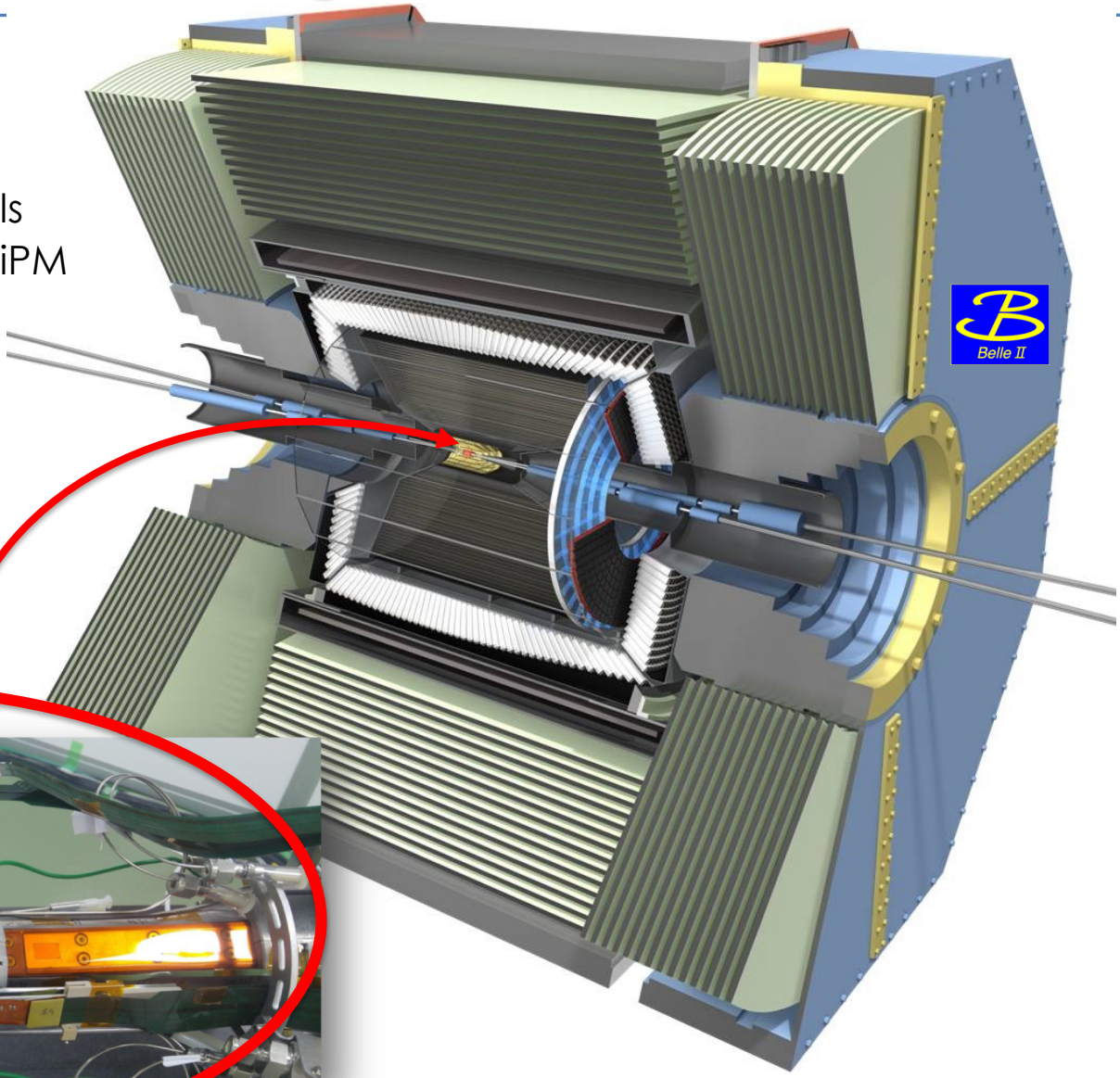
- Various background sources
  - Single beam effects
  - Touschek: intra-beam scattering
    - Prob $\propto I^2_{bunch} \times N_{bunch} / (\sigma_x \times \sigma_y) / E^3_{beam}$
  - Beam gas (vacuum residue)
    - Prob $\propto I^2 \times$ pressure
  - Synchrotron radiation
    - Power $\propto E^4_{beam}$ / curvature
  - Radiative Bhabha scattering
  - Pair creation by two photon interactions

➢ Need for
- Control background before running full detector
- Validating MC-simulations for robust prediction level @ 80x higher lumi

Belle II commissioning

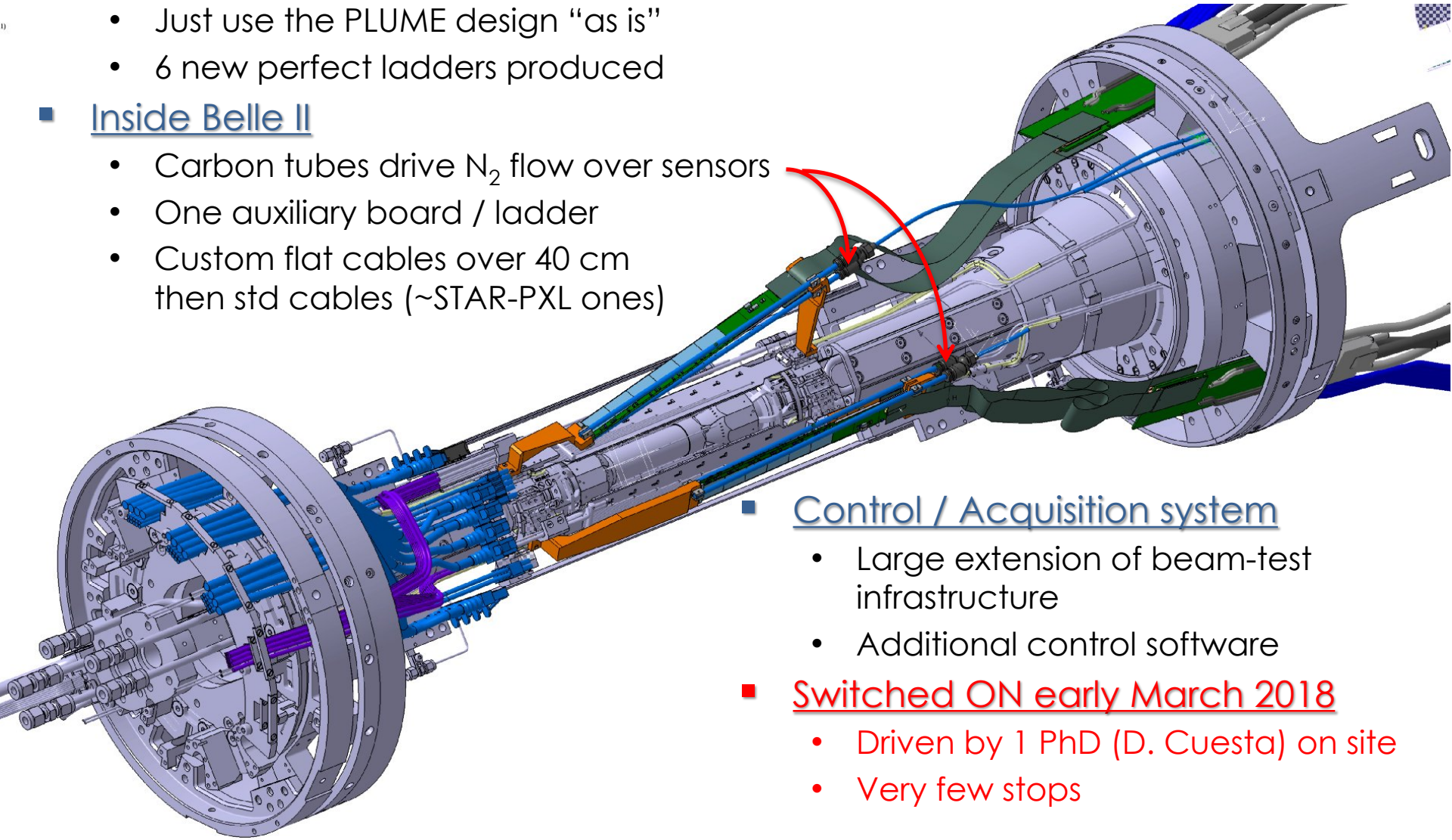
- Additional detectors
  - Diamond sensors
  - FANGS: ATLAS FE-I4 pixels
  - CLAWS: CALICE scint.+SiPM
  - PLUME
  - He3-tubes
  - Mini-TPC
  - PIN-diodes
- 1 sector of PXD+VXD





PLUME install & running in BEAST

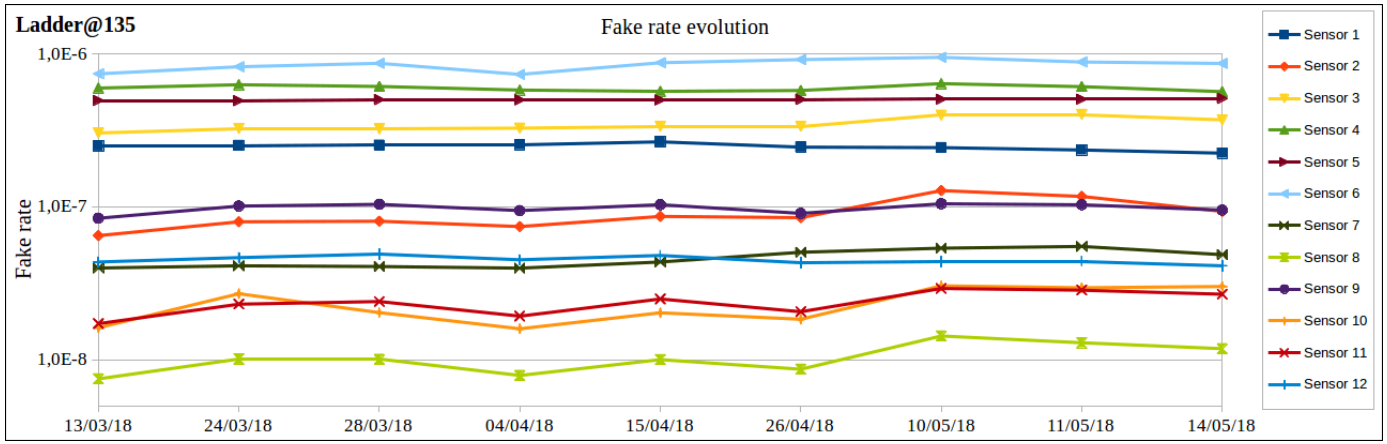
- Ladders
  - Just use the PLUME design "as is"
  - 6 new perfect ladders produced
- Inside Belle II
  - Carbon tubes drive N_2 flow over sensors
  - One auxiliary board / ladder
  - Custom flat cables over 40 cm then std cables (~STAR-PXL ones)



- Control / Acquisition system
  - Large extension of beam-test infrastructure
  - Additional control software
- Switched ON early March 2018
  - Driven by 1 PhD (D. Cuesta) on site
  - Very few stops

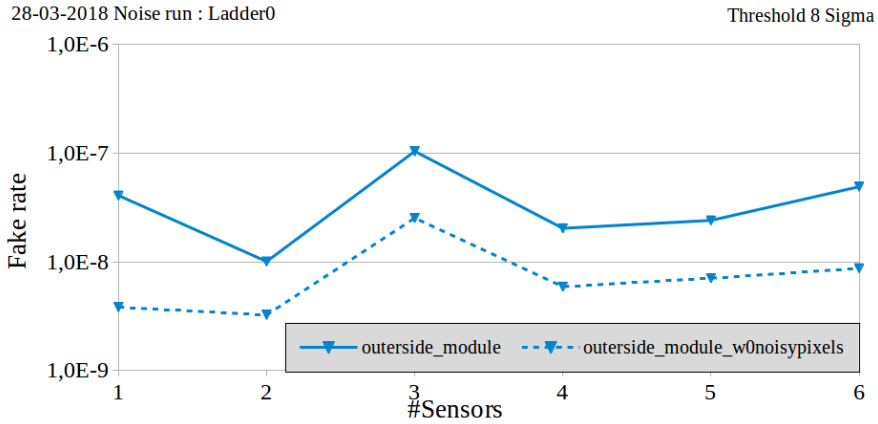
Sensor conditions

- Stable running conditions
  - Same threshold ~8x equivalent noise charge
- Fake hit rates

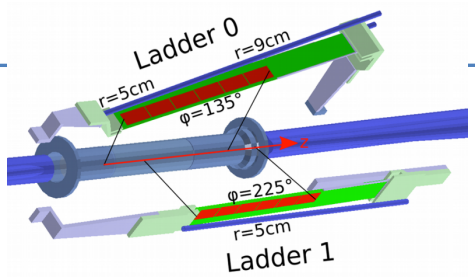


- Dominated by "noisy" pixels
- Controlled weekly

- Maintained below 10^{-7} pixel^{-1} by suppressing pixels with fake > 10^{-3} pixel^{-1} => few 10^{-5} of overall pixels

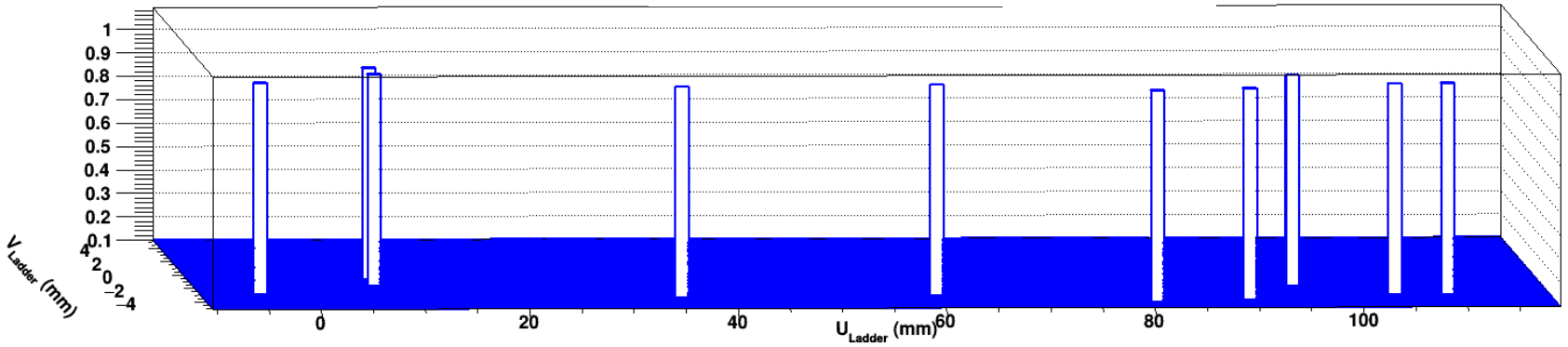


Events

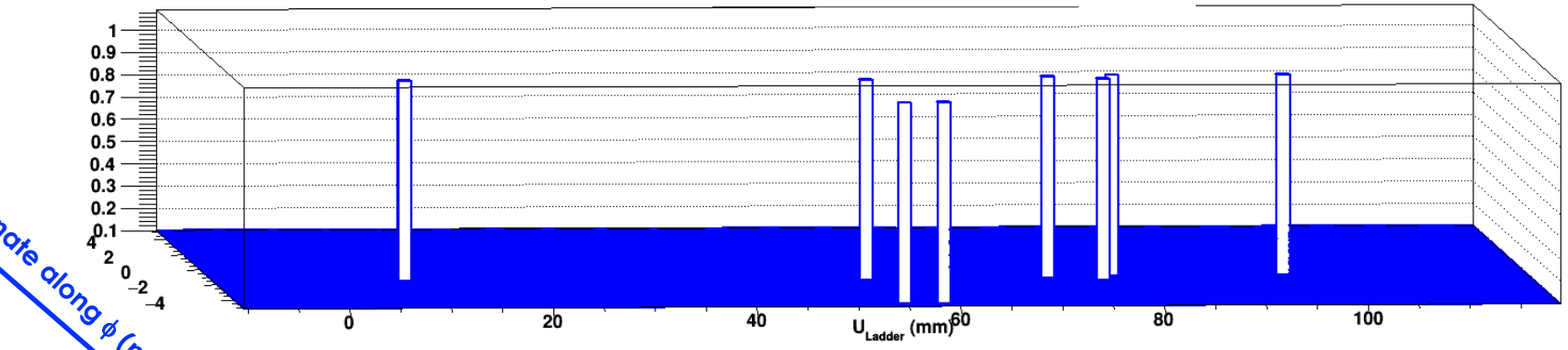


- A rather busy event in one ladder
  - Display of hit position (after clusterisation)

Outer side of layer



Inner side of layer

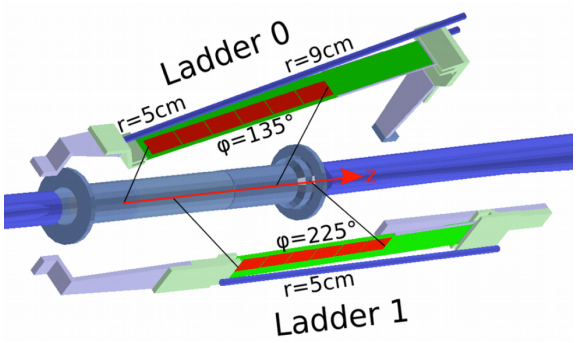


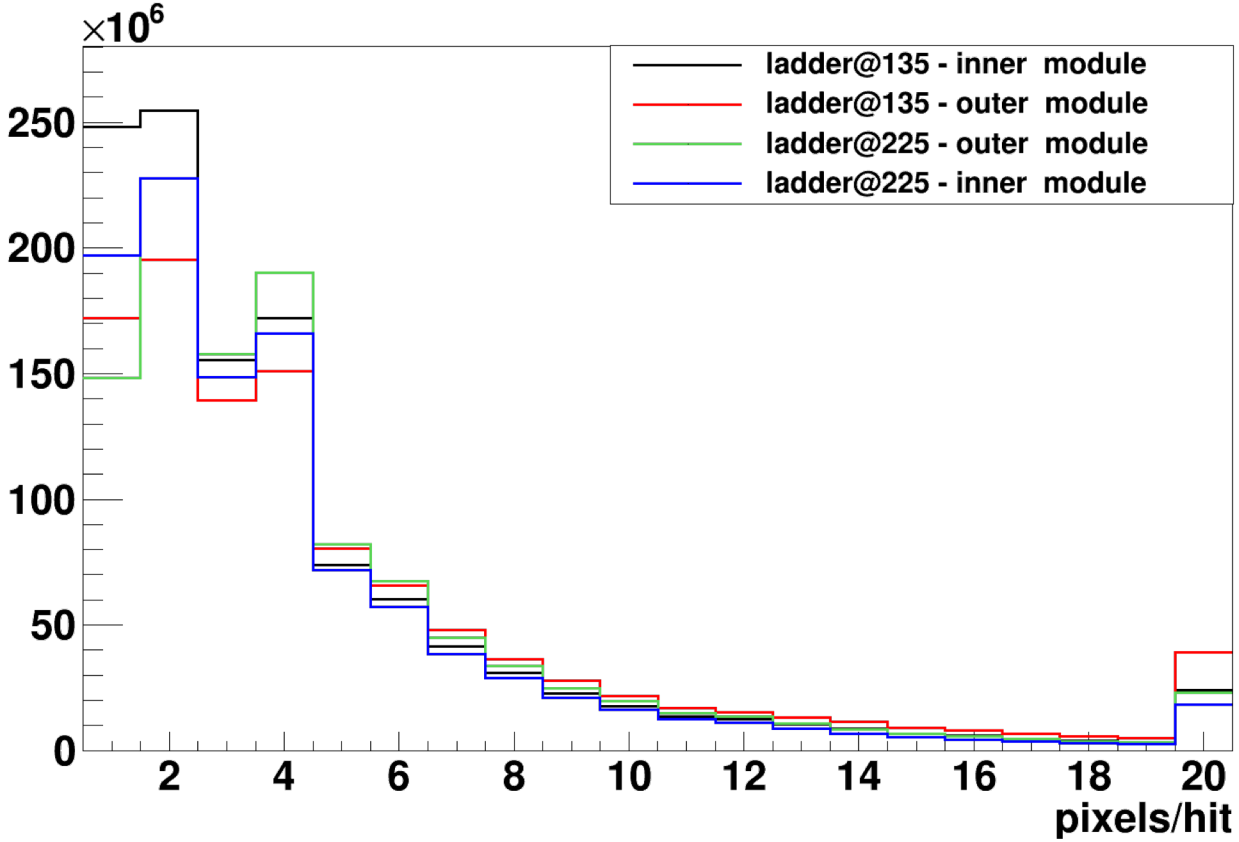
Coordinate along ϕ (mm)

Coordinate along beam (mm)

Basic analysis

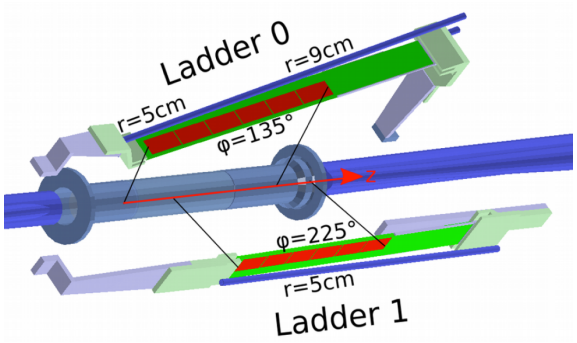
- Count rates
  - Online: no-clusterisation => pixel rates
  - Offline: after clusterisation => hit rates

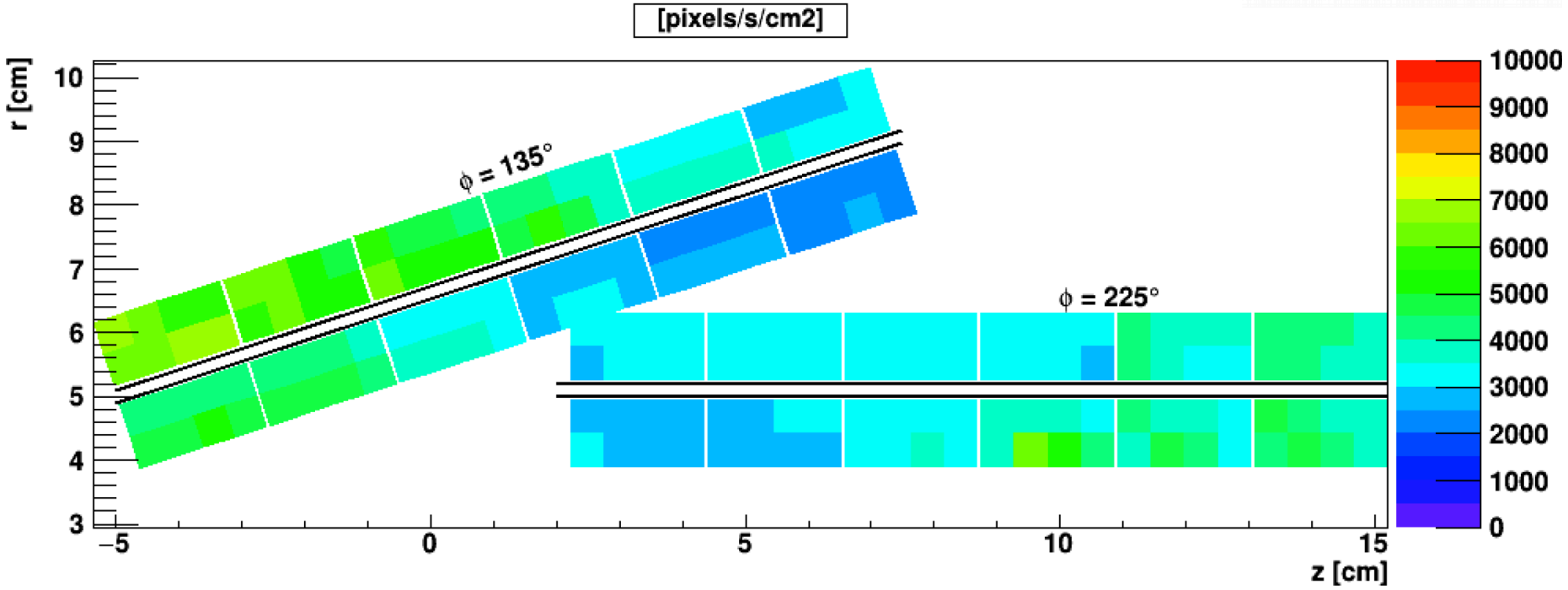




Basic analysis

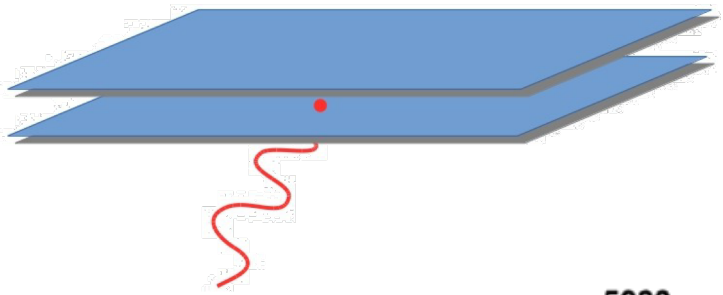
- Count rates
  - Online: no-clusterisation => pixel rates
  - Offline: after clusterisation => hit rates
  - Both rates per second
    - Averaged over 10 Kframes for monitoring purpose
  - Additional monitoring during 4ms following injections
    - Rate history over 40 frames (115 µs time bin = integration time)

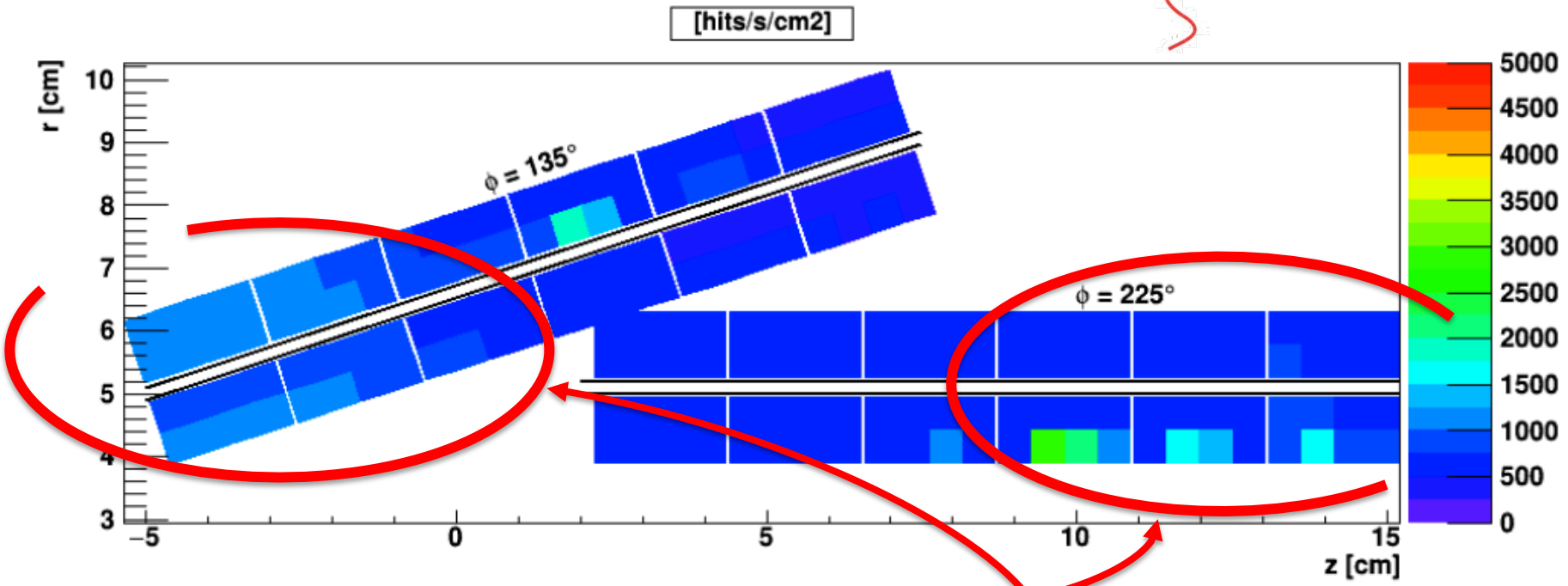




Double-sided benefits

- Low penetrating particles
  - Hit inner-side but don't make it to outer-side
  - Most probably photons ≲ 10-15 keV

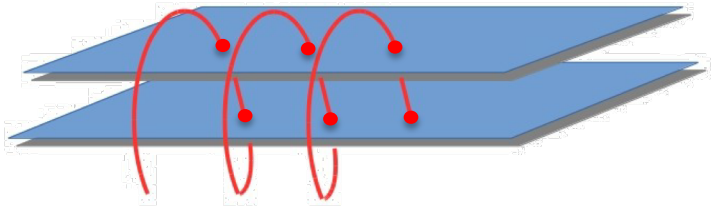


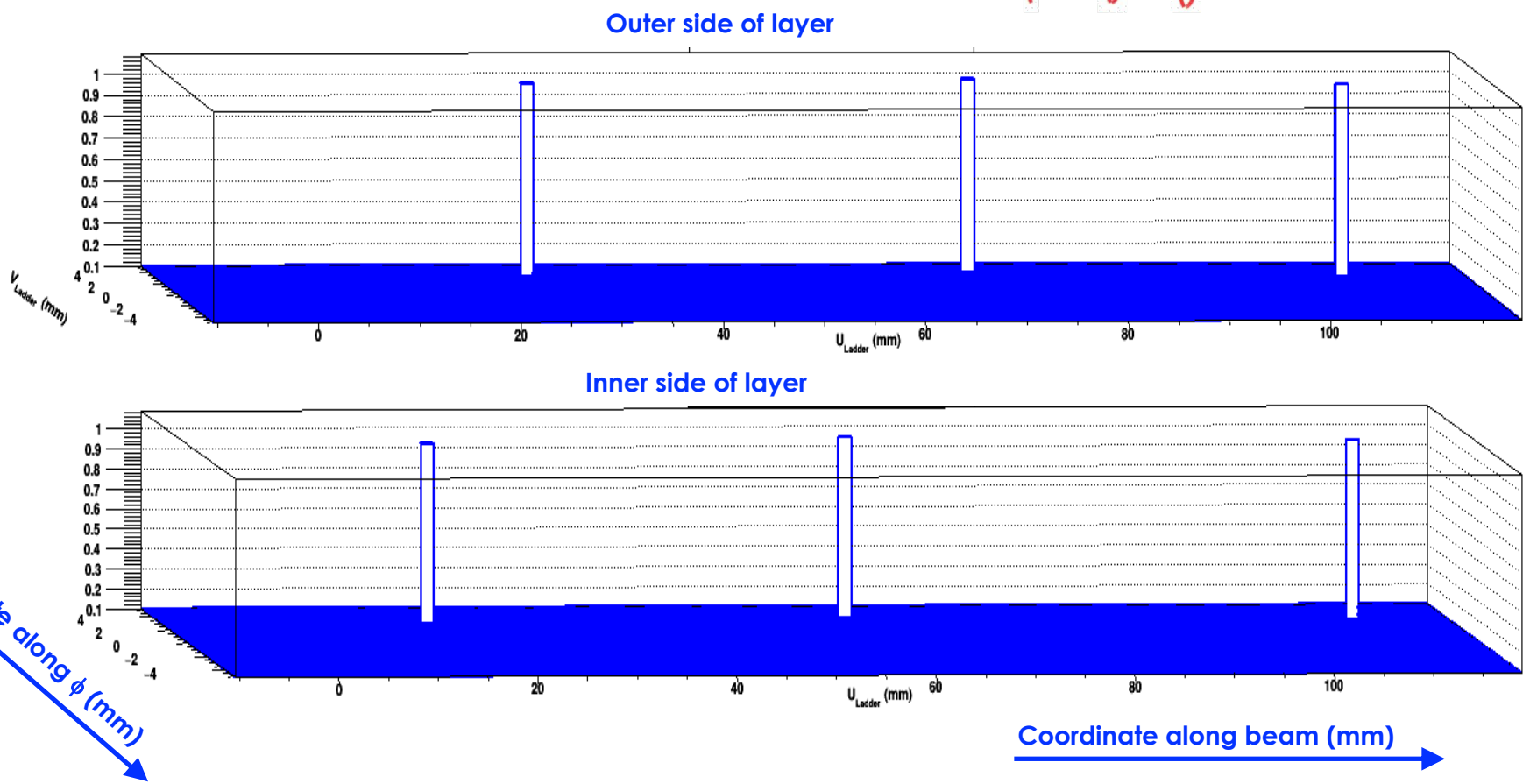


- Observed by differentiating rates on both sides
- Confirmed by other E_{loss} measurement detectors (FANGS, PXD, SVD)

Double-sided benefits

- Looping particles
  - Low momentum tracks produced around the layer radius





Conclusion & Prospects

- PLUME running at SuperKEKB within BEAST/Belle II
  - ON still day one ~2 months ago
  - Monitoring job: "so far so good"
  - Still at early stage in analysis for deeper insight in beam-backgrounds

  => Expect a rich beam-background talk at next LC-workshops from BEAST/Belle II

- PLUME heritage
  - Building & Installing PLUME inside Belle II was hard-work (16Mpixels)
    BUT few people involved over short-time ~3 years
    => PLUME is a robust, "ready-to-go" system

  - Still the 0.3 % X_0 layer to be commissioned and tested

  - Children?
    - FOOT targets fragmentation Xsections relevant for charge particle therapy
    - Flat double-sided area 8x8 cm^2 inspired by PLUME design
    - Exploiting MIMOSA-28 (STAR-PXL sensor)

Thanks to all contributors

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