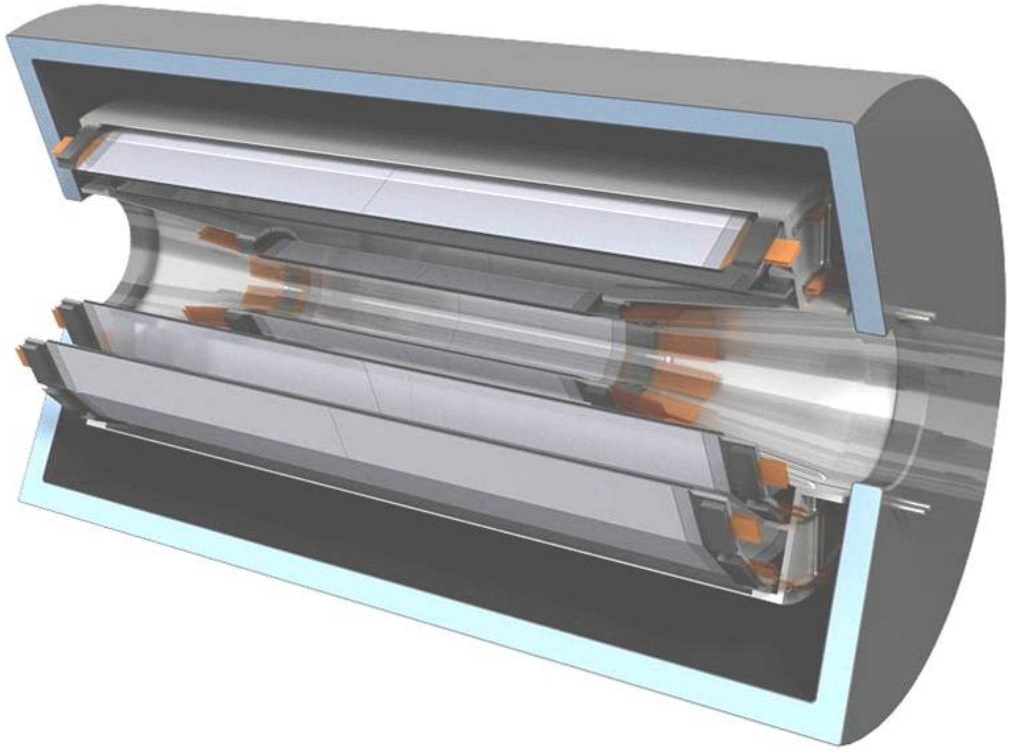
ILD vertex detector

ILD technical coordination meeting



ILD-VTX conveners
Marcel Vos (IFIC Valencia),
Auguste Besson, Akimasa Ishikawa

Reminder of the requirements

Total area: O(1) x 10^5 mm^2

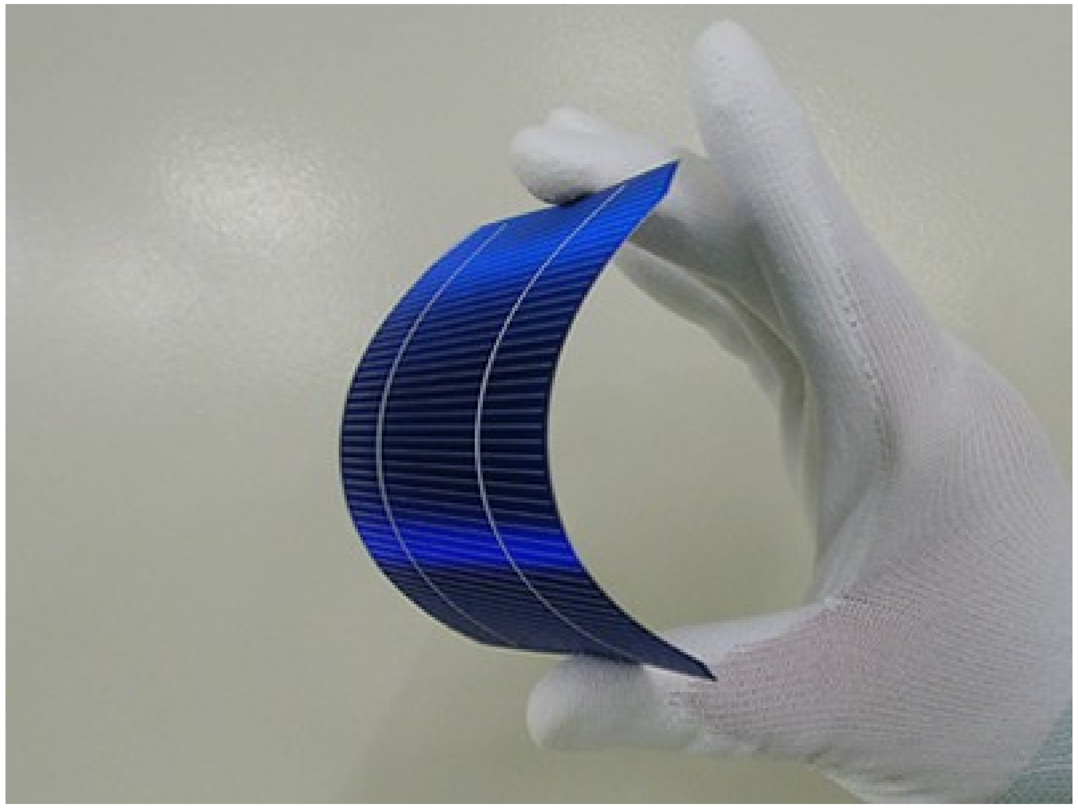
Smallest sub-detector in ILD

Spatial resolution: ~3 μm

Better than any other sub-system

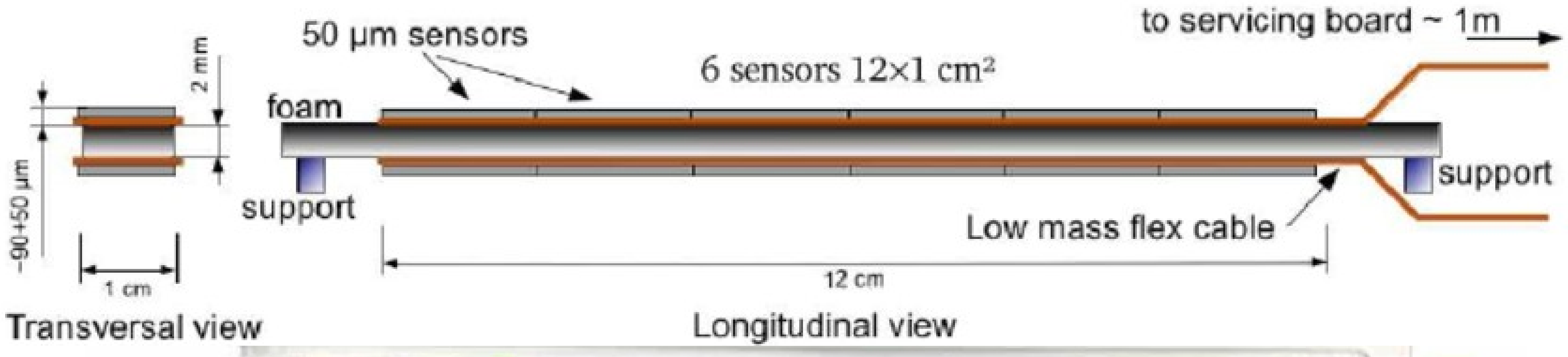
Material: 0.12-0.15% X_0 / layer

Very little material to ensure stiffness

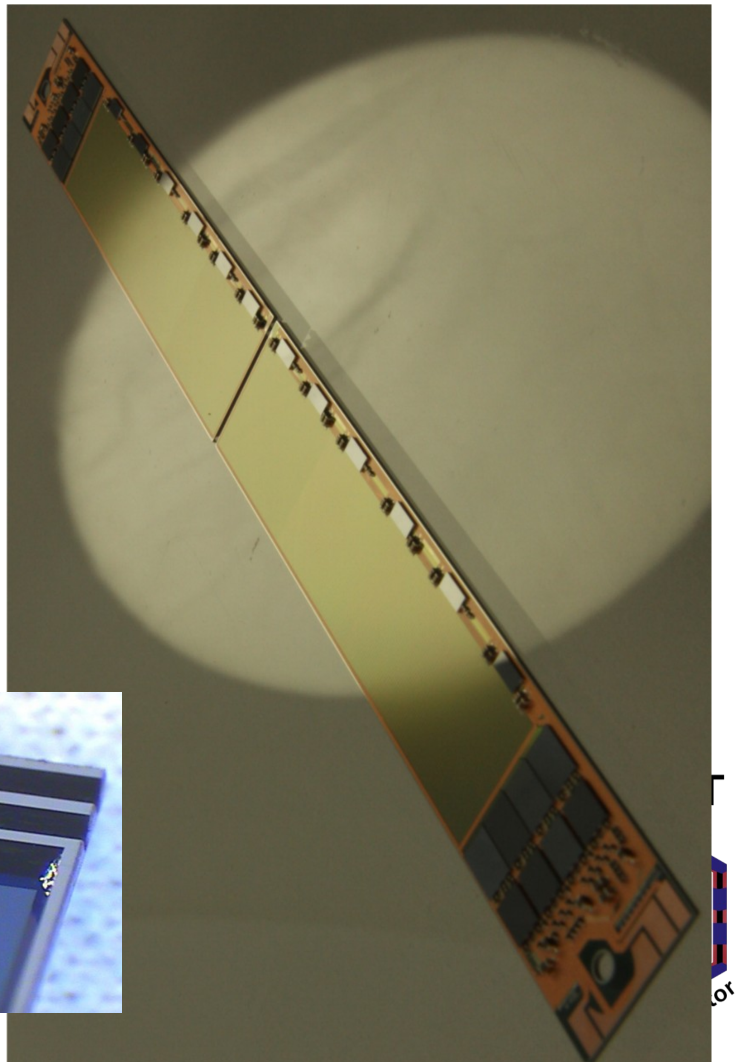


Challenge: keep detector stable to the micron-level long enough for track-based alignment to reach sufficient precision

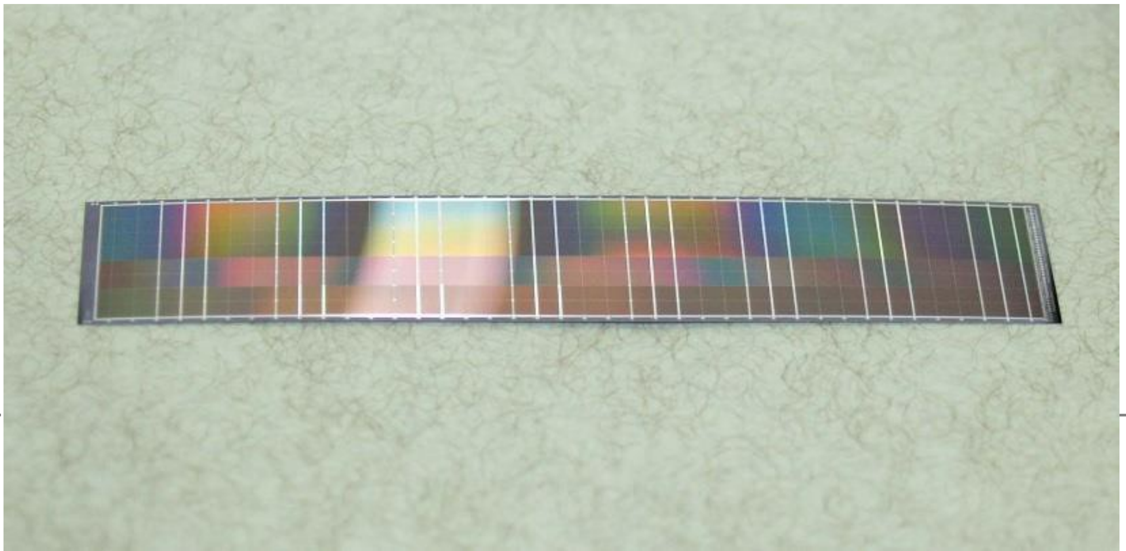
Approaches to mechanics



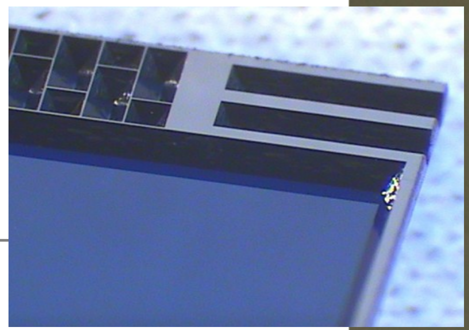
CMOS and SOI chips naturally have an a area of 1-2 cm^2
Buttable chips and stitching can provide larger active areas
Multiple chips supported by a SiC foam in the PLUME concept



Large-area sensors: DEPFET and FPCCD sensor sizes are limited by wafer size and yield only



Single sensor typically 1 x 6 cm^2



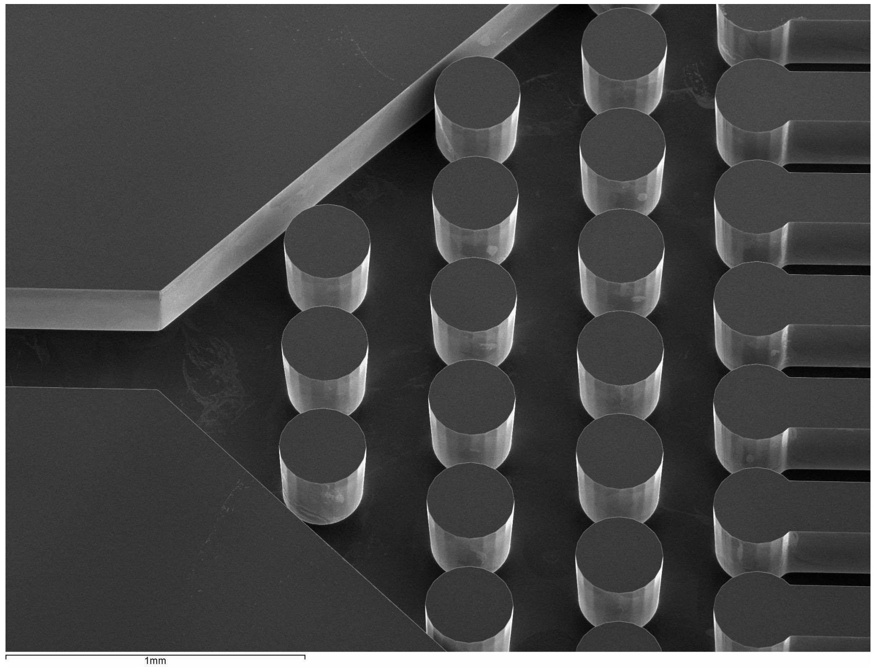
Approaches to cooling

Power-pulsing
(reduce average power budget by factor 100)

Air cooling
(shown to work over small prototypes)

Liquid (bi-phase CO_2) cooling
(CCDs require cold operation)

Micro-channel cooling
(feasibility with DEPFET process demonstrated)



7. Does your subdetector plan to use power-pulsing?
   Probably for DEPFET/CMOS, No for FPCCD
10. If power-pulsing is used, what is the effective live-time percentage?
   Typically 2-3%

Vertex detector alignment

Vertex detector alignment to distinguish several levels:

- global alignment of entire detector: 6 DOF
- layer-level alignment: 6 x 6 DOF
- ladder-level alignment: 6 x O(200) DOF
- chip-level alignment: 6 x O(200) x O(20) DOF

Full characterization moreover has (V-dependent) Lorentz angle, mobilities, etc.

Pre-installation metrology to constrain initial internal alignment to micron-level (CMM)

Global or layer-level movements monitored with hardware system (laser, interferometer)

Ultimately, alignment is track-based

Outline the strategy for alignment and calibration of your subdetector.
Assembly: optical survey
Global alignement with data: Z peak ?
Internal alignment in each layer/ ladder -> overlap regions of few 100s microns : all data including beam background tracks ?
2. What calibration and alignment parameters need to be measured with particles (either from collisions or cosmics) for your subdetector?
Ideally: 3 shift position / 3 rotation angles for each chip + possible distorsions per chip
3. What precision is needed on the calibration and alignment parameters for your subdetector? What is the basis for this assessment?
Sigma_ip = $5 \oplus 10/p$ (um) ➔ typically um level alignment or below (FPCCD).

DEPFET

Stability

Engineering design goal: minimal distortions during operation

- **Fast (< hours) internal distortions nearly impossible to correct**

  Must be avoided by careful design, excellent control of conditions

- **Position to be reproduced as well as possible after intervention**

  (power up/down, cooling ramp, magnet ramp, push-pull!)

  Impossible to maintain global/layer alignment to the μm level

  Ladder internal alignment OK?

12. On which time-scales do you anticipate that the alignment and/or calibration of your sub-detector will be stable? In particular would it be reasonable to assume that data collected over multiple running periods in multiple years can be used collectively to refine the overall calibration or alignment?

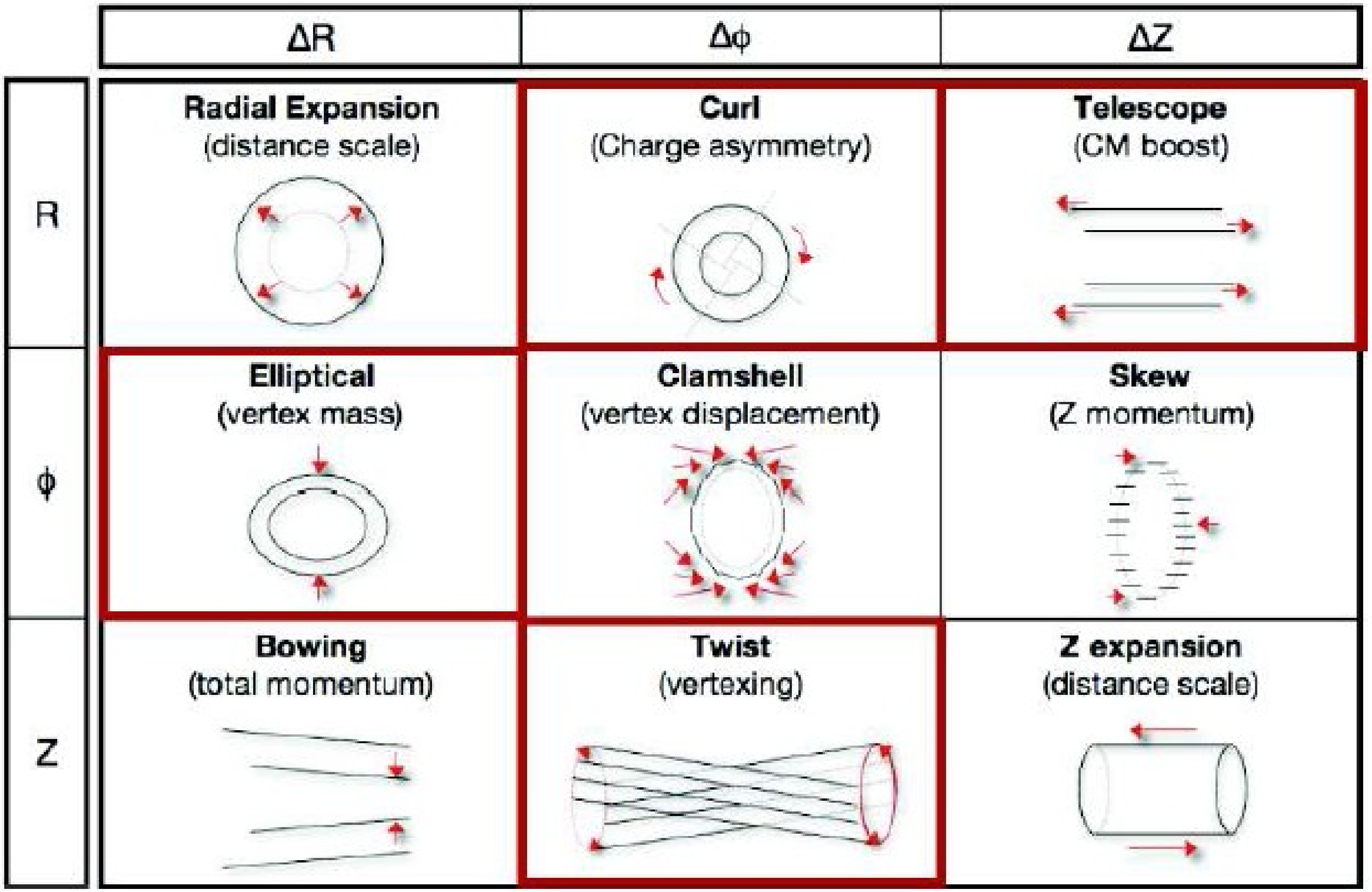
    Global alignment to be repeated often, full alignment on time scale of months.

    Push-pull is likely to upset the mechanics to a level that alignment constants must be re-derived!

11. Is data with the magnetic field needed for your sub-detector?

    Yes

Distorsions – weak modes



[8] C. Escobar, "Track based alignment of the ATLAS Silicon Tracker," *PoS*, vol. VERTEX2008, p. 026, 2008.

Some distortions lead to large effects in track-hit residuals, but other – weak modes – exist that are hard to constrain in track-based alignment

Alignment sample

Sample needed to constrain all - including weak - modes:

Alignment likes special tracks (traversing entire detector, Z-mass constraint)

Cosmics are useful for ~horizontal ladders, but rate is very low

Halo muons are useful for FTD, not for VXD

Z-pole running yields sample with mass constraint

Prefer high momentum tracks (>5 GeV for layer-to-layer alignment if MS < 3 μm)

Few 1000 tracks/overlap region (~1% of acceptance) required for layer alignment

4. How many usable particles per sub-detector element are needed to establish the calibration and alignment constants at the above level of precision?
   few 1000s tracks per overlapping region (1% of sensor)
5. What particles and kinematic criteria are needed?
   high momentum charged particles, but using low momentum tracks might be mandatory to enhance statistics.
6. What is the smallest solid-angle subtended by an individual sub-detector element?
   Technology dependent: surface is from few cm^2 to ~15 cm^2 → $\Omega = S / R^2$
   - Pixels: $\Omega \sim 0.002^2 / 1.6^2 \sim 0.000002$ steradians
   - Layer 1 chip: $\Omega \sim 2^2 / 1.6^2 \sim 2$ steradians
   - Layer 1 ladder: $\Omega \sim 15^2 / 1.6^2 \sim 90$ steradians
8. Are cosmics useful for the alignment/calibration of your sub-detector?
   Yes, they are useful to deal with weak modes. However statistics is too low for internal alignment.
9. Are beam halo muons useful for the alignment/calibration of your sub-detector?
   No. (they are useful for FTD, though)

Cosmic muons / pair background

Cosmic muon flux:

- 1 muon/cm²/minute
- Angular distribution: ~cos²θ

Excellent tracks, connecting both detector halves

Key in Belle VXD alignment

Useful in a small detector with power-pulsing, but not sufficient to rely only on cosmics

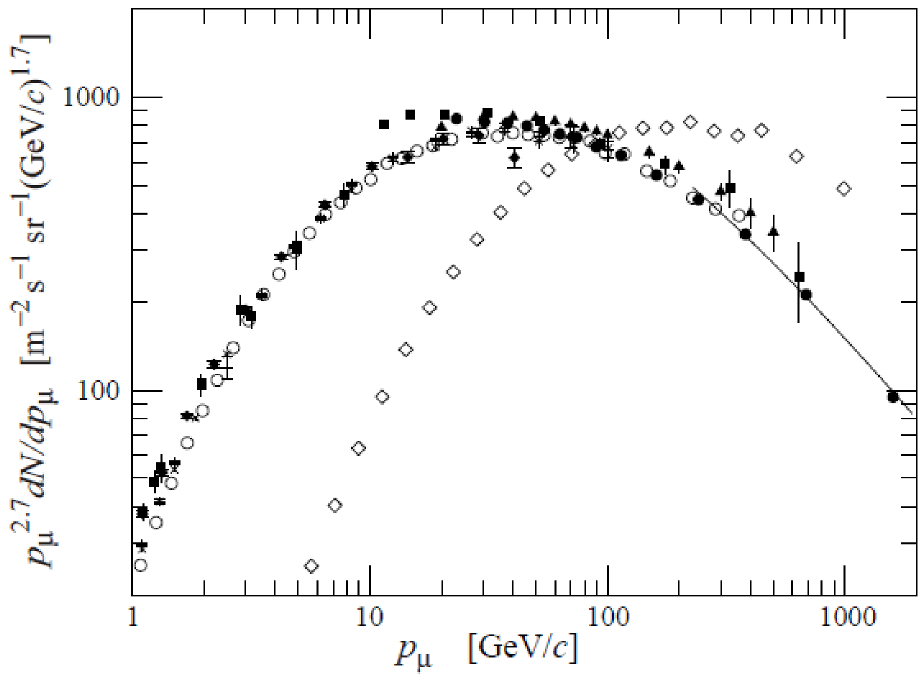
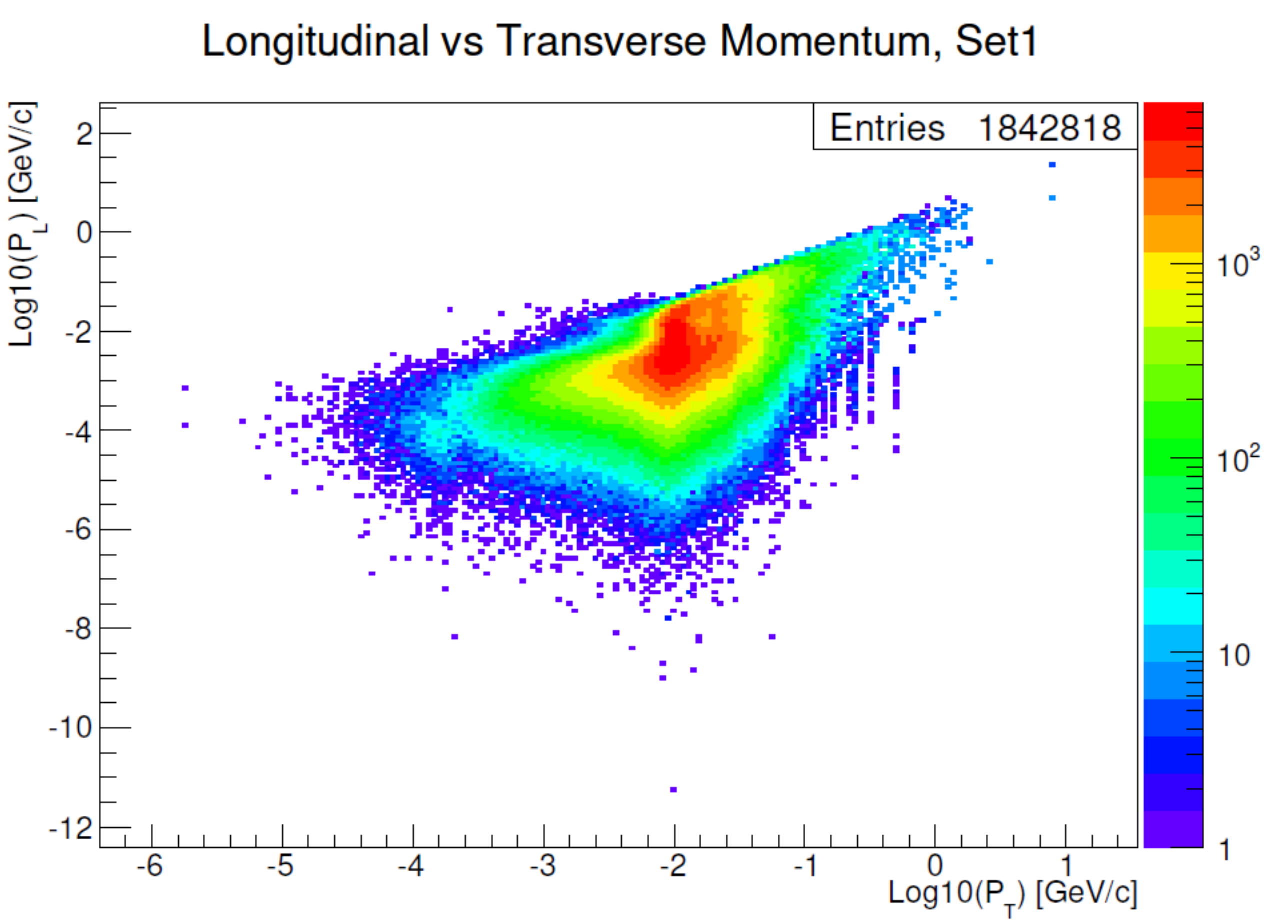


Figure 24.4: Spectrum of muons at $\theta = 0°$ (♦ [41], ■ [46], ▼ [47], ▲ [48], ×, + [43], ○ [44], and ● [45] and $\theta = 75°$ ◊ [49]) . The line plots the result from Eq. (24.4) for vertical showers.



Rate of tracks from pair background is large (background hits dominate the VXD occupancy)

Sufficiently hard to traverse multiple layers

Not the best tracks for alignment, but their number may make up for that!

VTX alignment

This will be the first we build a detector with this spatial resolution

This will be the first time we build a detector with this material budget

Keeping the sensitive elements exactly where they are during operation - to 1 μm-level precision – with so little material is a very serious challenge

We will learn to what degree the internal alignment is conserved through major interventions (such as push-pull) as we move towards full-scale mock-ups

13. Do you foresee particular challenges in the alignment and calibration of your subdetector?

Mechanical stability over time (roll-in, magnet-rampf, temperature effect, power pulsing, humidity, season effect)
Weak modes are hard to constrain and require substantial statistics.