TDR Preparation Discussion

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ePIC Collaboration Meeting — Tracking Workfest
Argonne National Laboratory — January 10, 2024

Preliminaries

The EIC Project includes both the facility and the (project) detector,

The next formal decision step in the project, CD-(2)3, requires a (pre-)TDR.

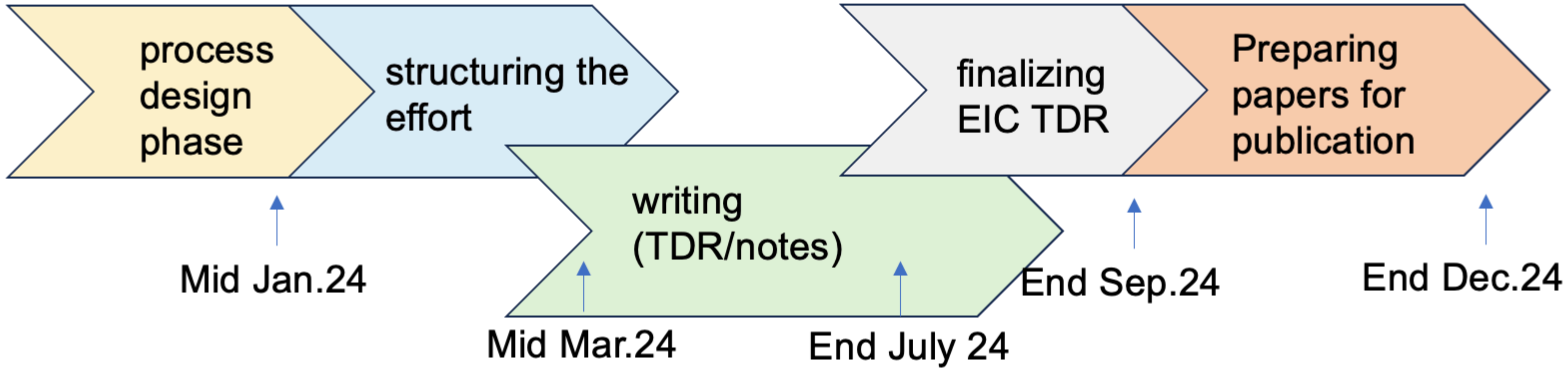
It takes little imagination that the formal (pre-)TDR will be a rather vast document driven by the EIC Project; (our) assumption is that the experiment component will be written to purpose on an aggressive timeline in (continued) close collaboration between the project and collaboration.

John Lajoie presented a preview of the timeline and proposed approach to the collaboration during the ePIC General Meeting past December 14, 2023 — c.f. https://indico.bnl.gov/event/21120/

TDR Strategy and Publications

- In 2024 the ePIC collaboration will produce:
  - The ePIC contributions to the EIC TDR
    - The EIC TDR is the top priority
      - Chapters on *Physics Goals and Requirements* and *Experimental Systems*
      - Not just the document, but the simulations and detector R&D that form the basis
      - Requires close cooperation between the collaboration and the project!
- An ePIC Detector Design paper:
    - Derived and expanded from the *Experimental Systems* TDR chapter
- An ePIC Physics Performance paper:
    - Derived and expanded from the *Physics Goals and Requirements* TDR chapter
- Both to be published in a scientific journal (such as NIMA, JINST, or PRC)
- These publications will serve as a focus in developing the ePIC Membership and Publication policies.

This strategy will be a focus of discussion and refined at the Jan 2024 collaboration meeting.



Reproduced from John Lajoie’s presentation past December 14, 2023 — https://indico.bnl.gov/event/21120/

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What Is Coming Up – TDR

We will start the process of writing a draft TDR later this year, and then this will continue towards a first version of a TDR in 2024.

Working model will be similar as we used to create the CDR, Elke/Rolf with engagement of ePIC leadership, and a mix of the project CAMs and EPIC WG representatives. At the late phases the editing rights will become more restricted. We plan to use where we can input from the CDR, YR, proposals, technical notes, etc.

Chapter 2: Physics Goals and Requirements *(should be short, < 50 pages)*
- 2.1 EIC Context and History (like CDR 2.2 or YR section 1)
- 2.2 The Science Goals of the EIC and the Machine Parameters (like CDR 2.3)
- 2.3 The EIC Science (follow YR structure)
- 2.4 Scientific Requirements

Chapter 3: Interaction Region 6 Overview (Elke/Rolf contributing)

Chapter 8: Experimental Systems *(can be long such that we can use as standalone detector TDR)*
- 8.1 Experimental Equipment Requirements Summary (like CDR 8.2)
- 8.2 General Detector Considerations and Operations Challenges (YR 10, CDR 8.3)
- 8.3 EIC Detector
- 8.4 Detector R&D Summary
- 8.5 Detector Integration
- 8.6 Detector Commissioning and Pre-Operations

Chapter 11: Commissioning (Elke/Rolf contributing)

Appendix-B: Integration of a Second Experiment (mainly emphasizing feasibility, luminosity sharing, polarization with two experiments, and first-order checks of magnets/acceptance)

Reproduced from Elke Aschenauer and Rolf Ent’s presentation past July 27, 2023 — https://indico.cern.ch/event/1238718

(Draft) TDR – more details on section on Experimental Systems

8.1 Experimental Equipment Requirements Summary (like CDR 8.2)

8.2 General Detector Considerations and Operations Challenges (YR 10 and CDR 8.3)

- 8.2.1 Beam Energies, Polarization, Versatility, Luminosities (like YR 10.1)
- 8.2.2 Rates and Multiplicities (like CDR 8.3.1)
- 8.2.3 Interaction Region Integration, Vacuum and Backgrounds (like CDR 8.3.2)
- 8.2.4 Systematic Uncertainties (like YR 10.5)

8.3 EPIC Detector **CAM(s) and ePIC collaboration contact(s)**

- 8.3.1 Magnet **For each subsection end with R&D and design maturity**
- 8.3.2 Tracking
- 8.3.3 Electromagnetic Calorimetry
- 8.3.4 Hadronic Calorimetry
- 8.3.5 Particle Identification
- 8.3.6 Far-Forward Detectors
- 8.3.7 Far-Backward Detectors
- 8.3.8 Polarimetry and Luminosity Detector
- 8.3.9 Readout Electronics and Data Acquisition
- 8.3.10 Software, Data Analysis and Data Preservation **(EICUG SWG?)**

8.4 Detector R&D Summary

8.5 Detector Integration **(Walt, Rahul, Tim/Christian, Fernando, Roland, Dan, Elke, Rolf)**

- 8.5.1 Experimental and Assembly Hall Infrastructure (like CDR 8.7.1, YR 13.1)
- 8.5.2 Interaction Region and Protection (include also YR 13.2)
- 8.5.3 Support Frames and Installation Fixtures *(new, ask Roland and Walt to draft)*
- 8.5.4 Detector Alignment (like YR 13.4)
- 8.5.5 Schedule and Installation (like CDR 8.7.2, YR 13.3)
- 8.5.6 Access and Maintenance (like CDR 8.7.3, YR 13.5)
- 8.5.7 System Engineering and Interface Controls *(links to later global Section 12 on System Engineering)*

8.6 Detector Commissioning and Pre-Operations

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For the (narrower) purpose of tracking, it seems natural to consider an existing tracking subsystem TDR to initiate our discussion.

ALICE-TDR-017

CERN-LHCC-2013-024
02 December 2013

Technical Design Report for the Upgrade of the ALICE Inner Tracking System

The ALICE Collaboration

J. Phys. G: Nucl. Part. Phys. **41** (2014) 087002 The ALICE Collaboration

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Detector performance — ITS2 outline (chapter-7):

- Experimental conditions, requirements, detector specifications
- Simulation tools and models, reconstruction tools
- Track and vertex reconstruction performance
- What-if scenarios, including failure / redundancy questions

Figure set from the ITS2 TDR — Chapter 7

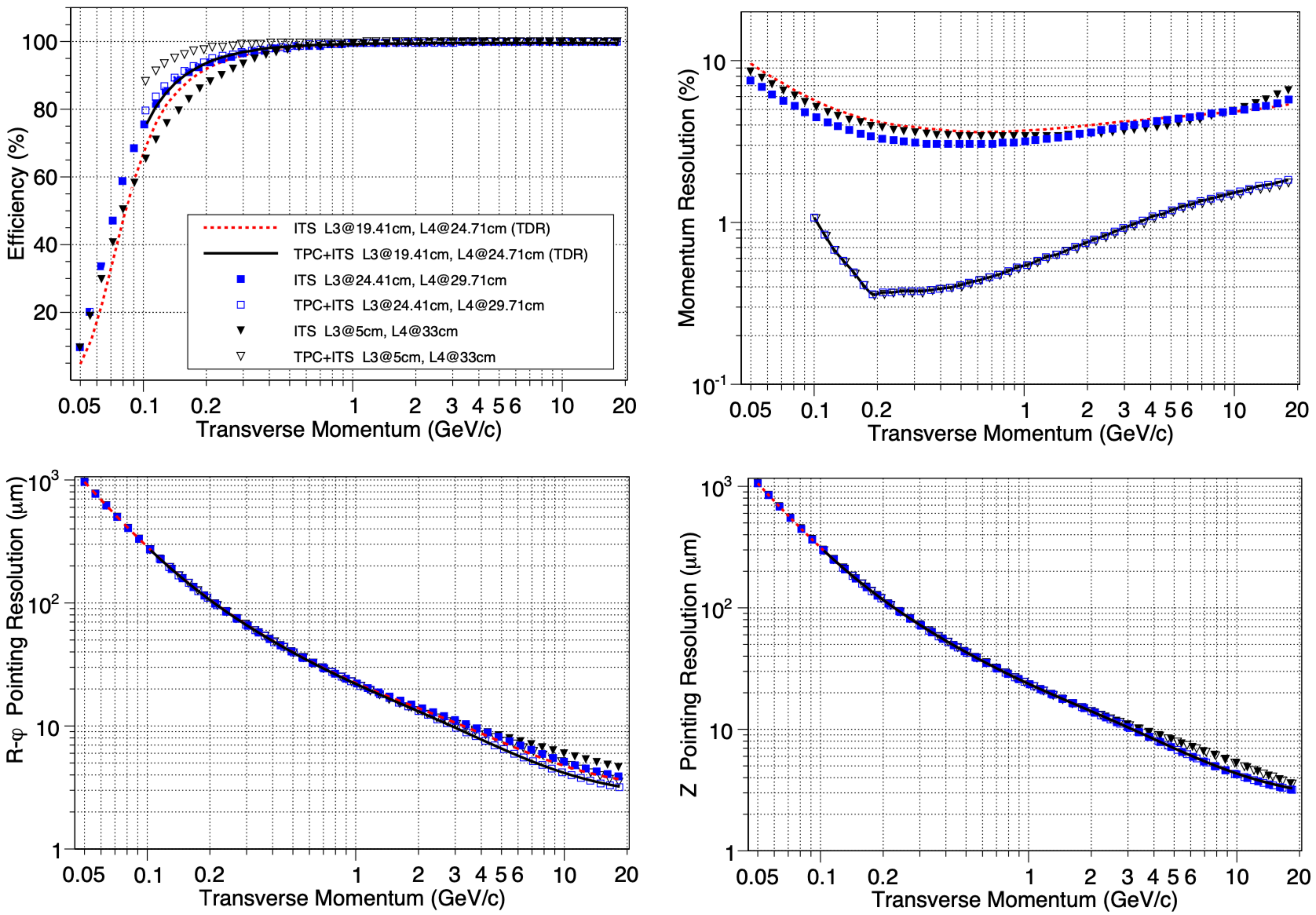

Figure 7.1: Performance of the ITS stand-alone and TPC+ITS combined reconstruction for different radial positions of the ITS layers.

A quadrant of key performance metrics. Note that total momentum, k_T, etc are more natural reconstructables for EIC purposes.

Figure set from the ITS2 TDR — Chapter 7

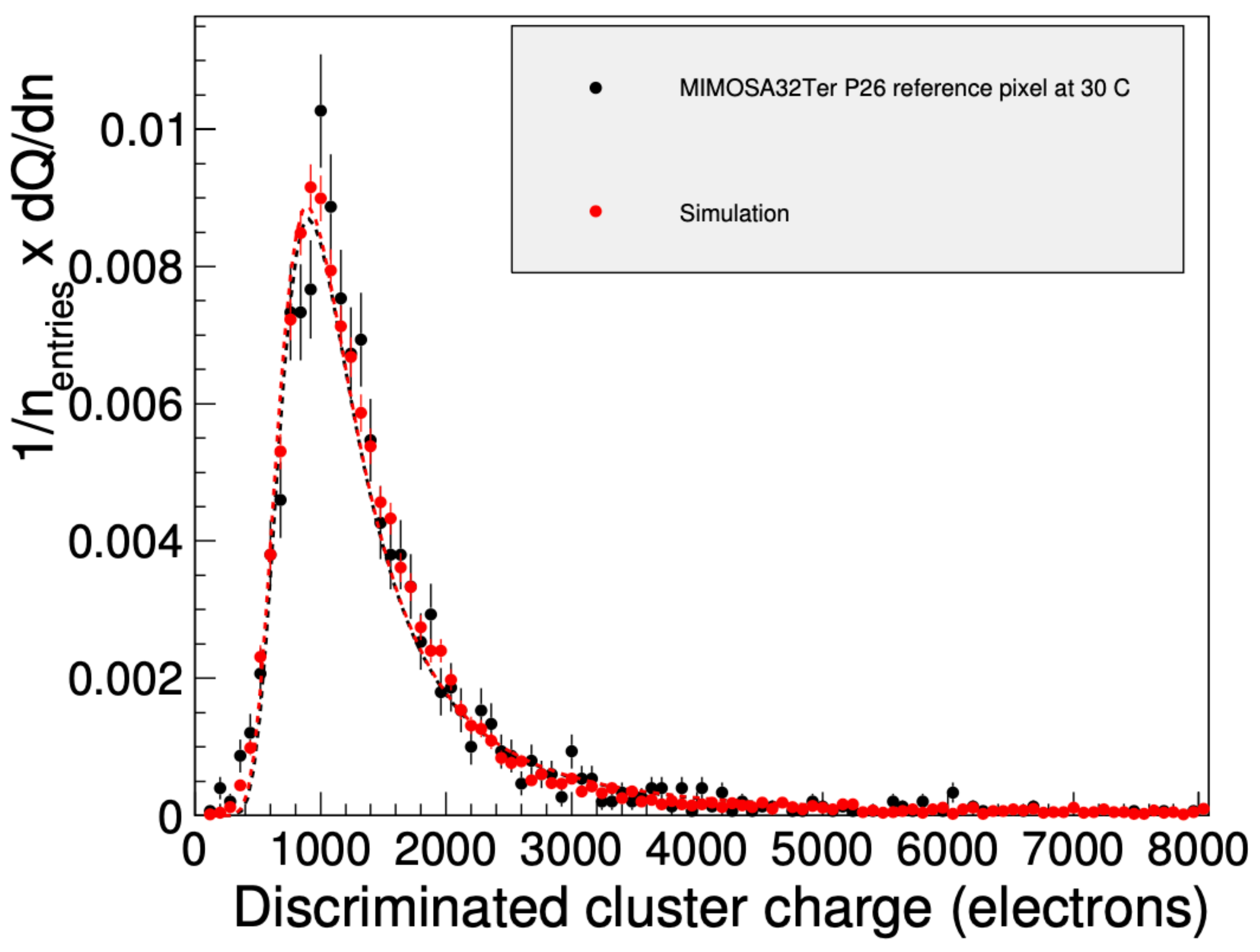

Figure 7.2: Comparison of cluster charge from tuned simulation and test beam measurement for MIMOSA-32Ter P26 reference pixel at 30 °C.

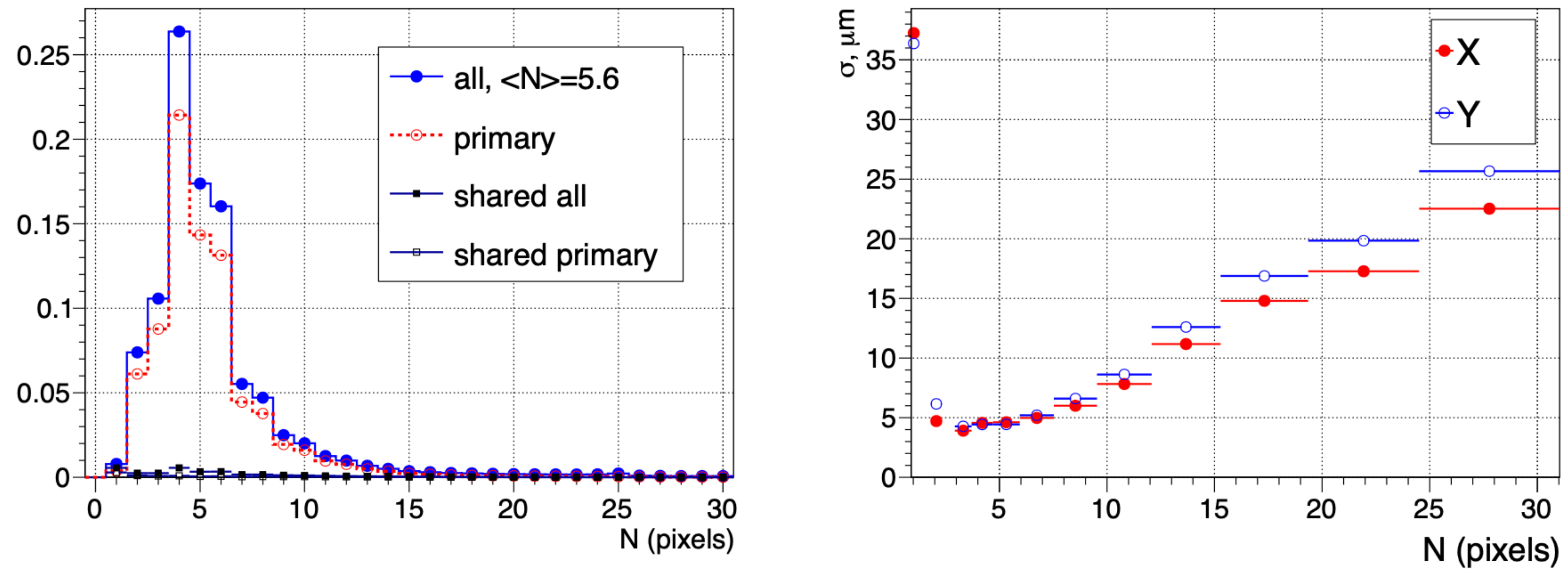

Figure 7.3: Cluster size distributions for all the charged particles and for primary charged particles (empty red circles). The term *shared* denotes hits that contribute to more than one cluster (left). Resolution on x (red full circles) and z (blue empty circles) directions as a function of the cluster size (right).

Comparison(s) and correspondence of simulation results with beam measurements.

Figure set from the ITS2 TDR — Chapter 7

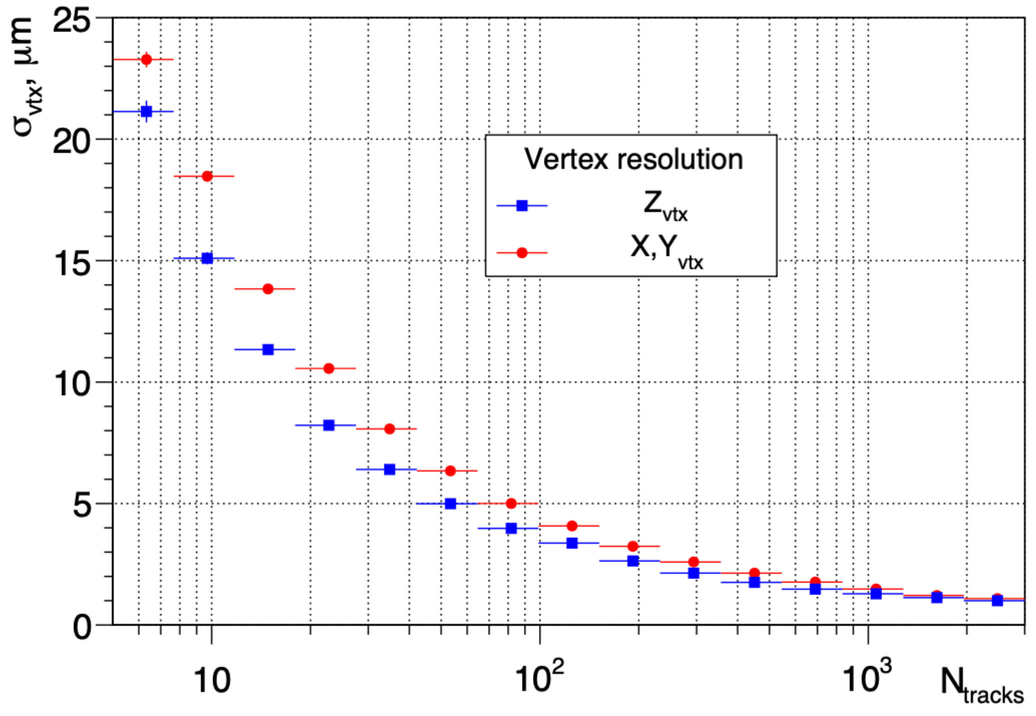

Figure 7.4: Resolution on the primary vertex reconstruction as a function of the number of tracks used to determine the primary collision coordinates.

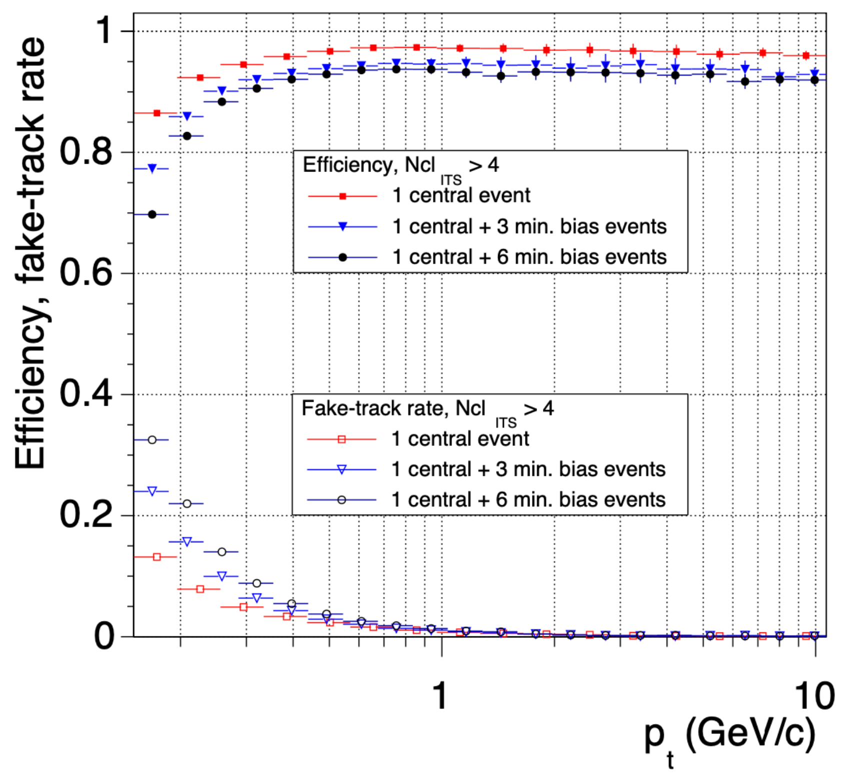

Figure 7.5: Track-matching efficiency between the TPC and upgraded ITS for different levels of event pileup.

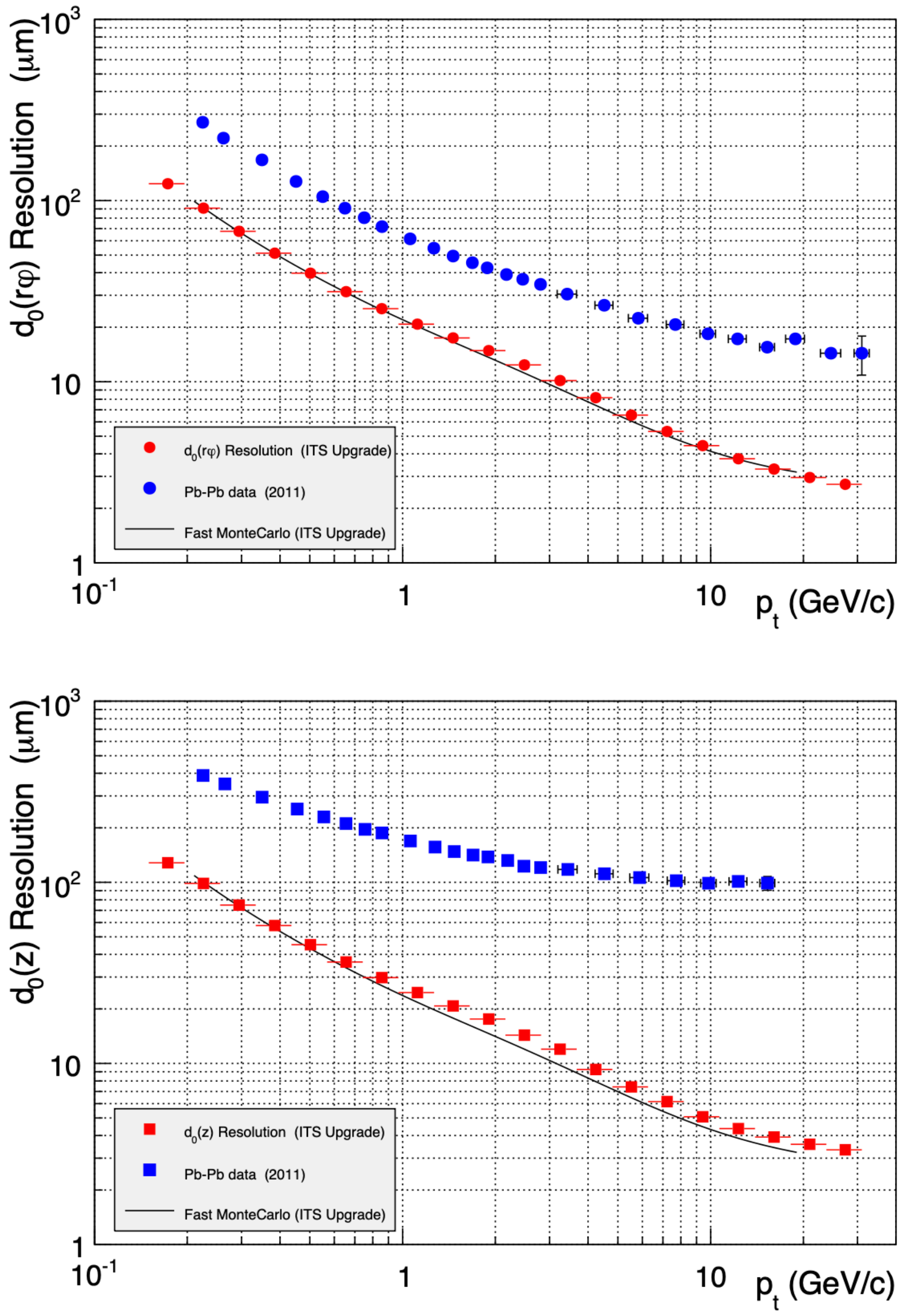

Figure 7.6: Impact-parameter resolution for primary charged pions as a function of the transverse momentum for the current ITS and the upgraded ITS in the transverse plane (upper panel) and in the longitudinal direction (lower panel).

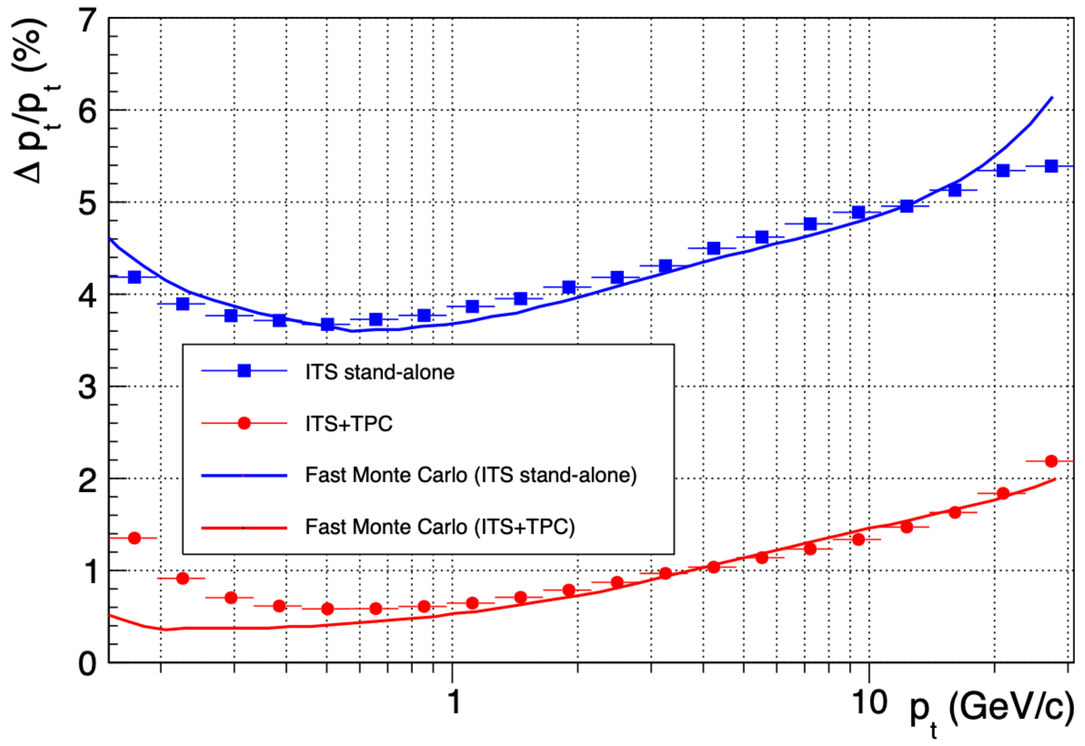

Figure 7.7: Transverse momentum resolution as a function of p_T for primary charged pions for the upgraded ITS. The results for the ITS stand-alone and ITS-TPC combined tracking mode are shown.

Detailed metrics, in the case of ITS2 demonstrating improvement from the proposed upgrade.

Figure set from the ITS2 TDR — Chapter 7

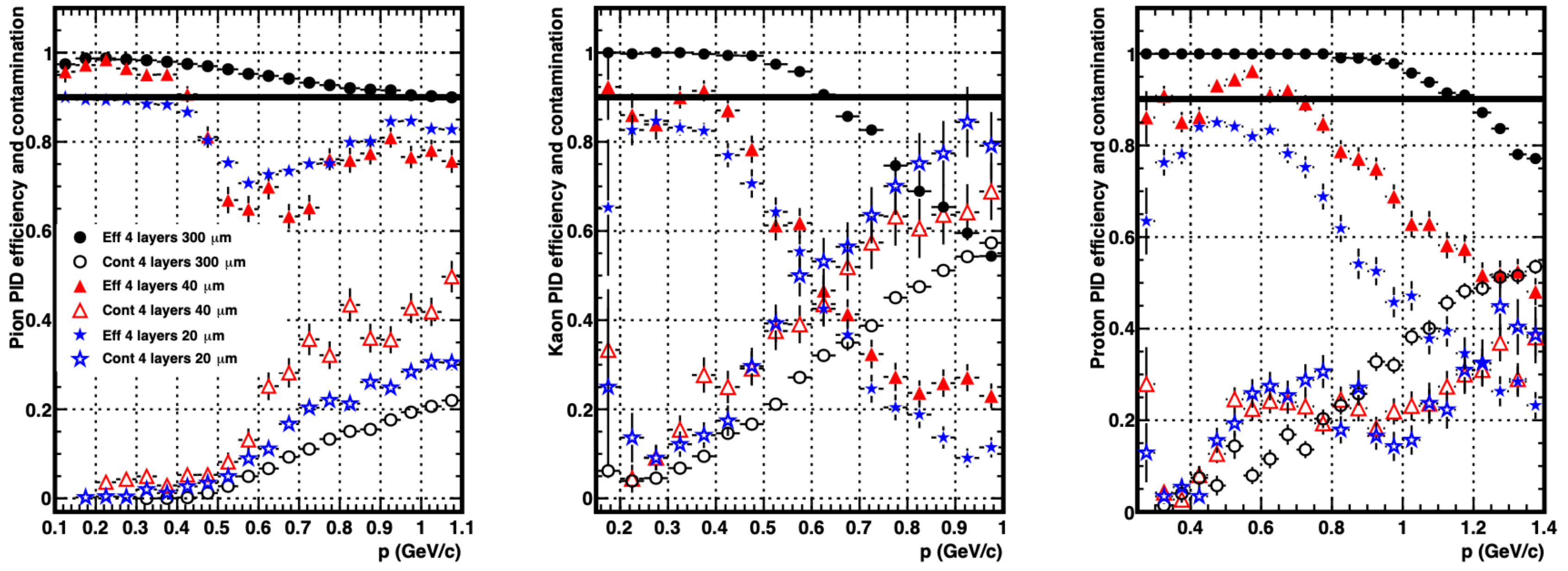

Figure 7.8: PID efficiency (closed symbols) and contamination (open symbols) as a function of the particle momentum assuming the relative abundances of π^+, K^+ and p as obtained from preliminary Pb–Pb data at $\sqrt{s_{NN}} = 2.76$ GeV for different configurations: four layers 300 μm thick (black circles), four Outer Layers 40 μm thick of pixel detectors (red triangles) and four layers 20 μm thick silicon detectors (blue stars). Pions, kaons, and protons are shown in the left, middle and right panels respectively. In all plots, a line corresponding to a PID efficiency of 90 % is drawn as a reference.

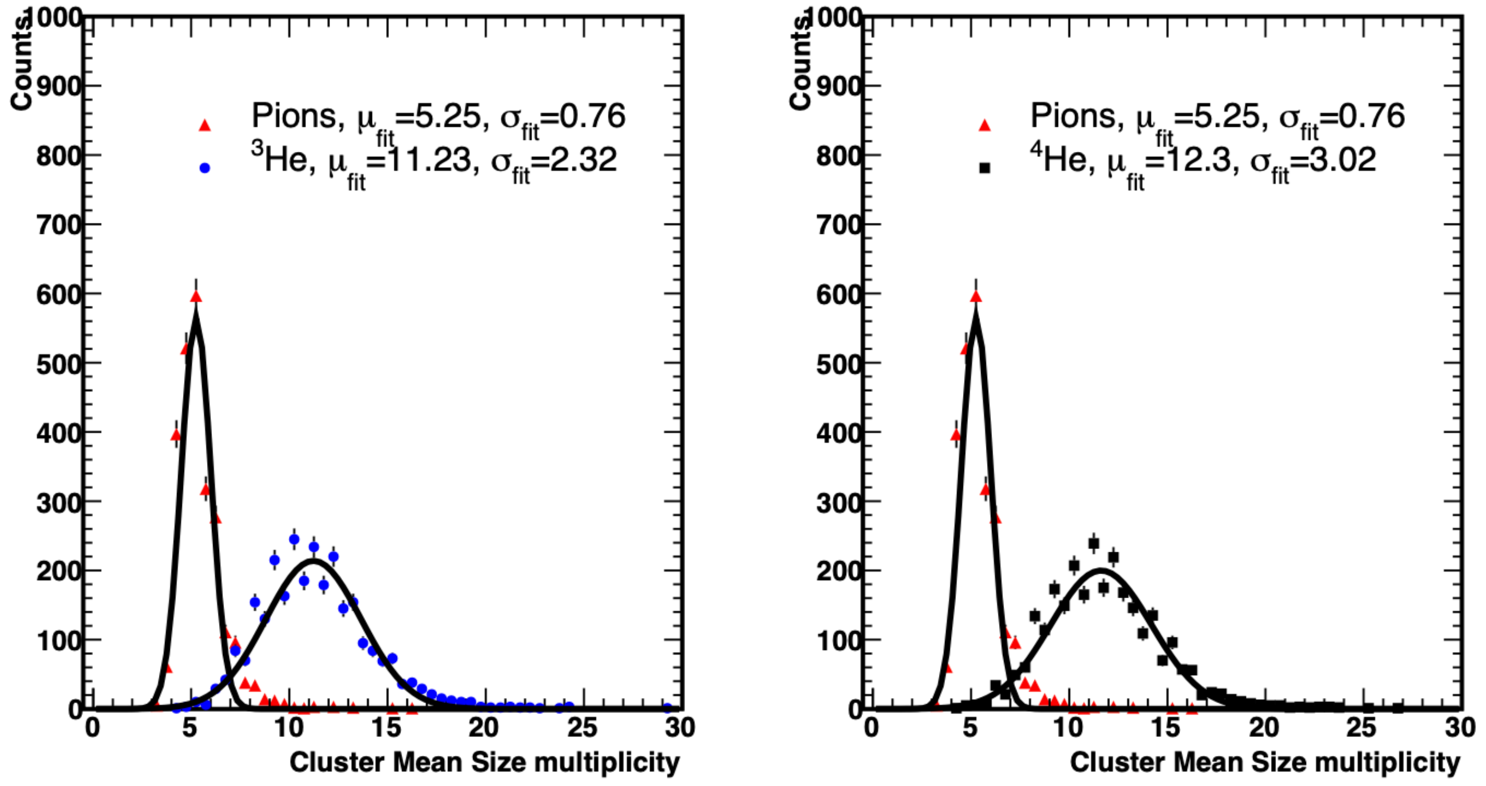

Figure 7.9: Multiplicity distribution of the mean value of the cluster size for pions (red triangles) and ^{3}He (blue dots) in the 6.1 GeV/c to 6.2 GeV/c momentum range (left). Multiplicity distribution of the mean value of the cluster size for pions (red triangles) and ^{4}He (black squares) in the 6.1 GeV/c to 6.2 GeV/c momentum range (right). In both figures, a Gaussian fit is superimposed to the distributions and the μ and σ values of the fits are reported in the legend.

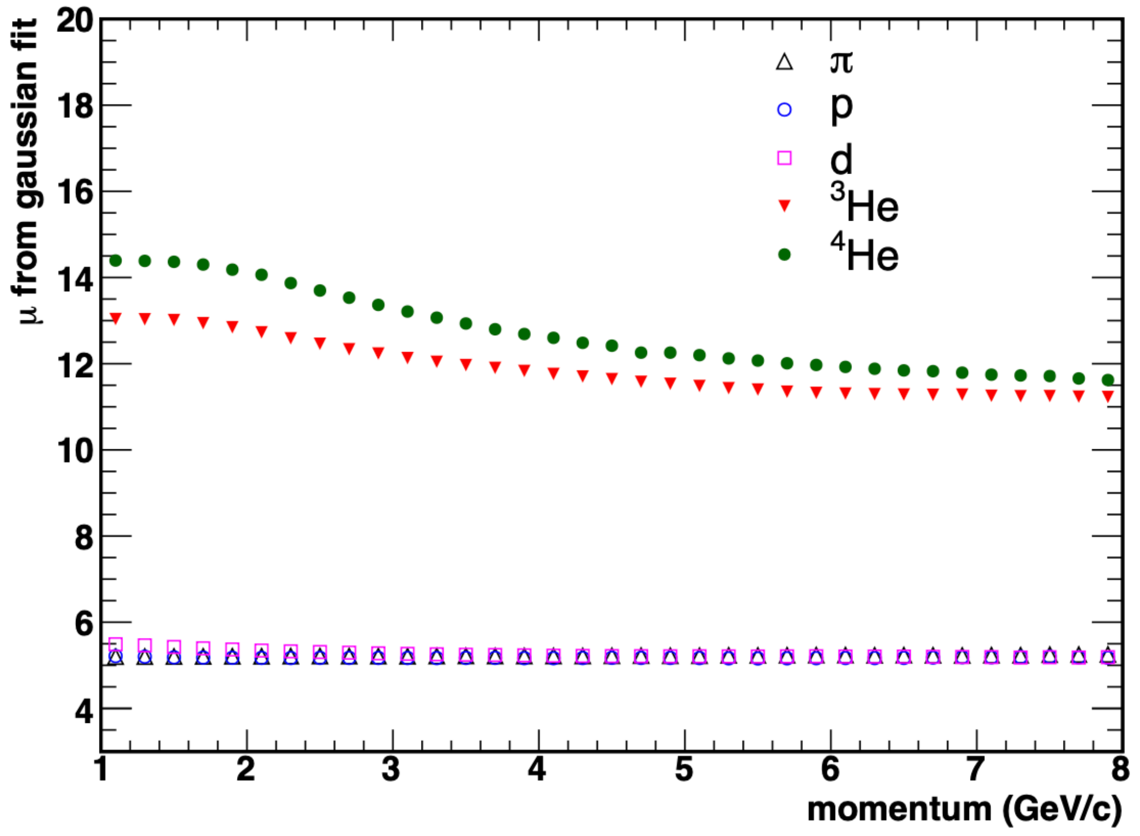

Figure 7.10: Mean values extracted from the Gaussian fit to the cluster size multiplicity distribution as a function of the momentum for the different simulated particle species (pions – black triangles, protons – blue circles, deuterons – magenta squares, ^{3}He – red triangles, and ^{4}He – green dots).

These figures would seem not so likely to have direct analogues / companion figures for EIC

However, PID is obviously essential at the EIC. Joint tracking and PID session may advance this area.

Figure set from the ITS2 TDR — Chapter 7

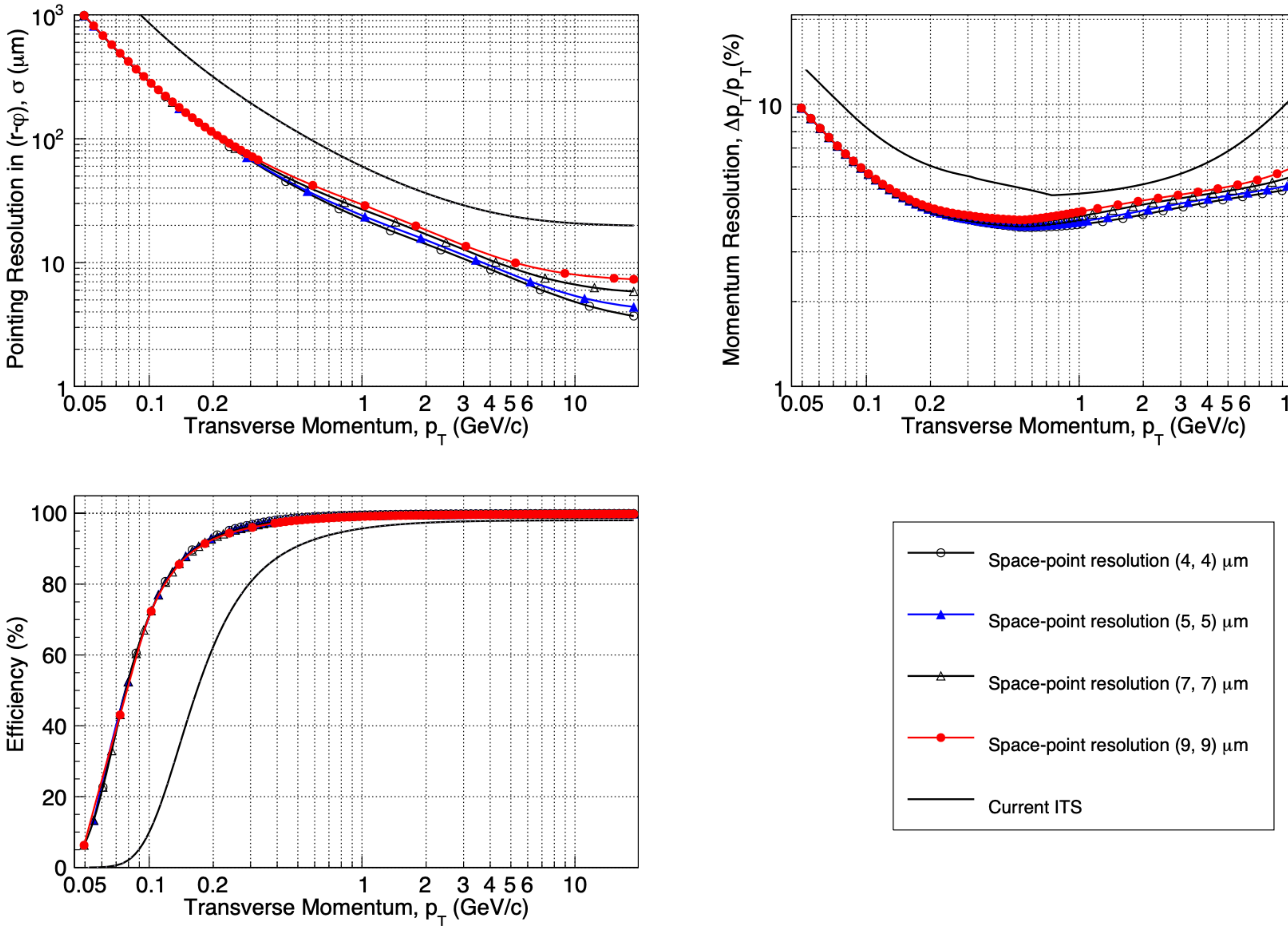

Figure 7.11: Pointing resolution, momentum resolution, and tracking efficiency obtained with the stand-alone upgraded ITS reconstruction assuming different space-point resolutions. For comparison, the performance of the current ITS is shown as well.

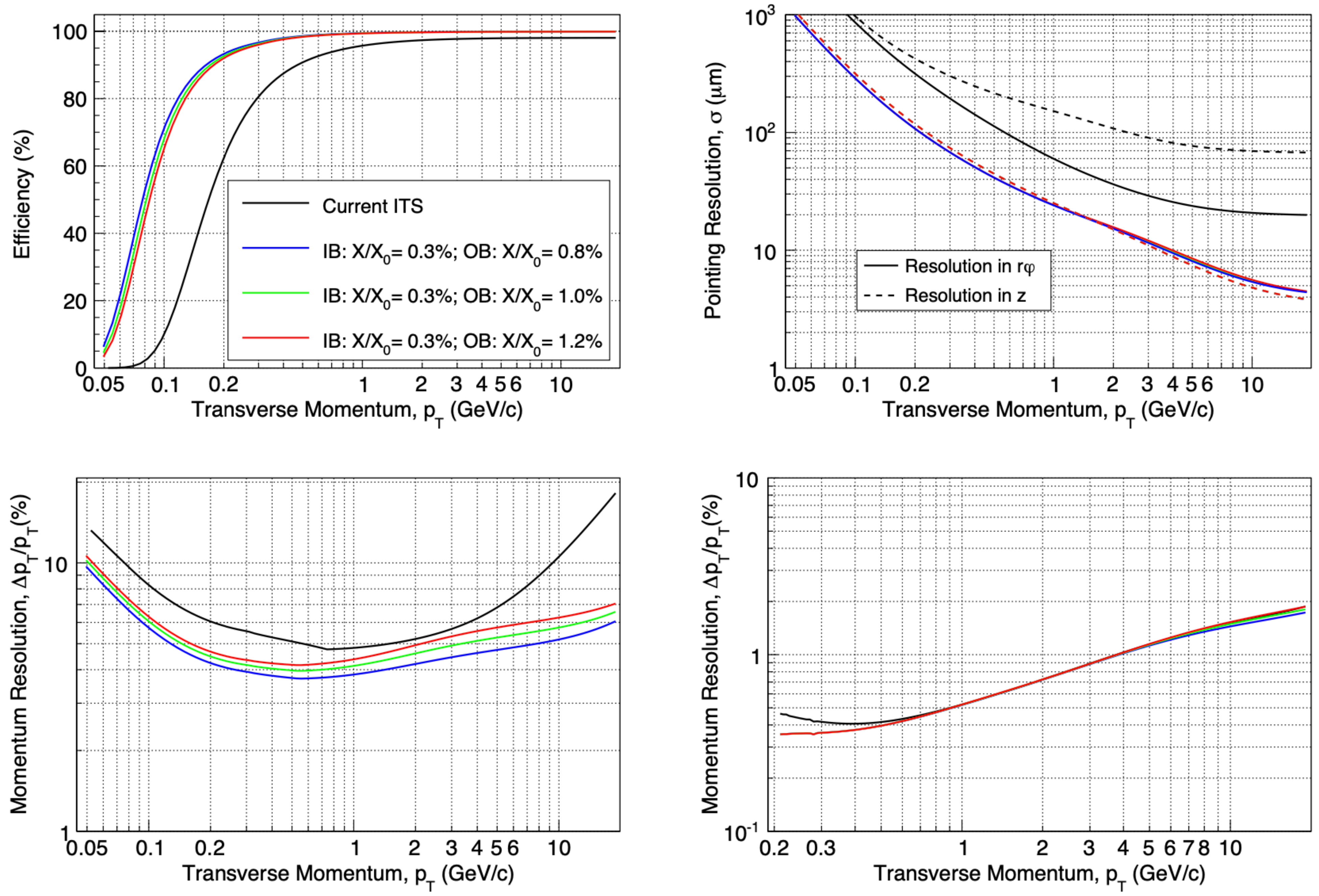

Figure 7.12: Top panels: Stand-alone tracking efficiency (left) and pointing resolution (right) for charged pions as a function of the transverse momentum for the current ITS and different material-budget options for the upgraded detector. Bottom panels: transverse momentum resolution for charged pions as a function of p_T for the current ITS and different material-budget options for the upgraded detector (the results for the ITS stand-alone and ITS+TPC combined tracking are shown on the left and on the right, respectively).

Projected performance ranges for variations in instrument metrics.

Figure set from the ITS2 TDR — Chapter 7

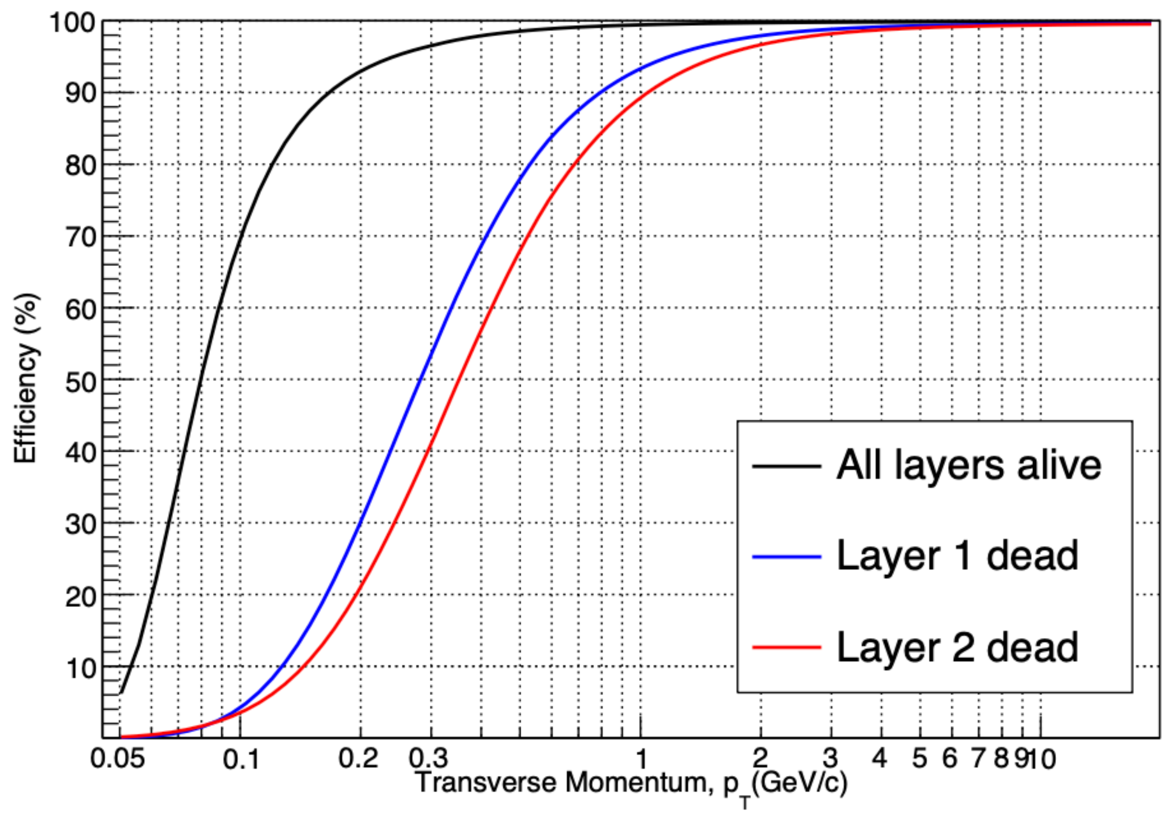

Figure 7.14: Tracking efficiency for the upgraded ITS. The two worst scenarios for the tracking efficiency where layer 3 (red) or layer 2 (blue) is dead is compared to the case of all layers working properly.

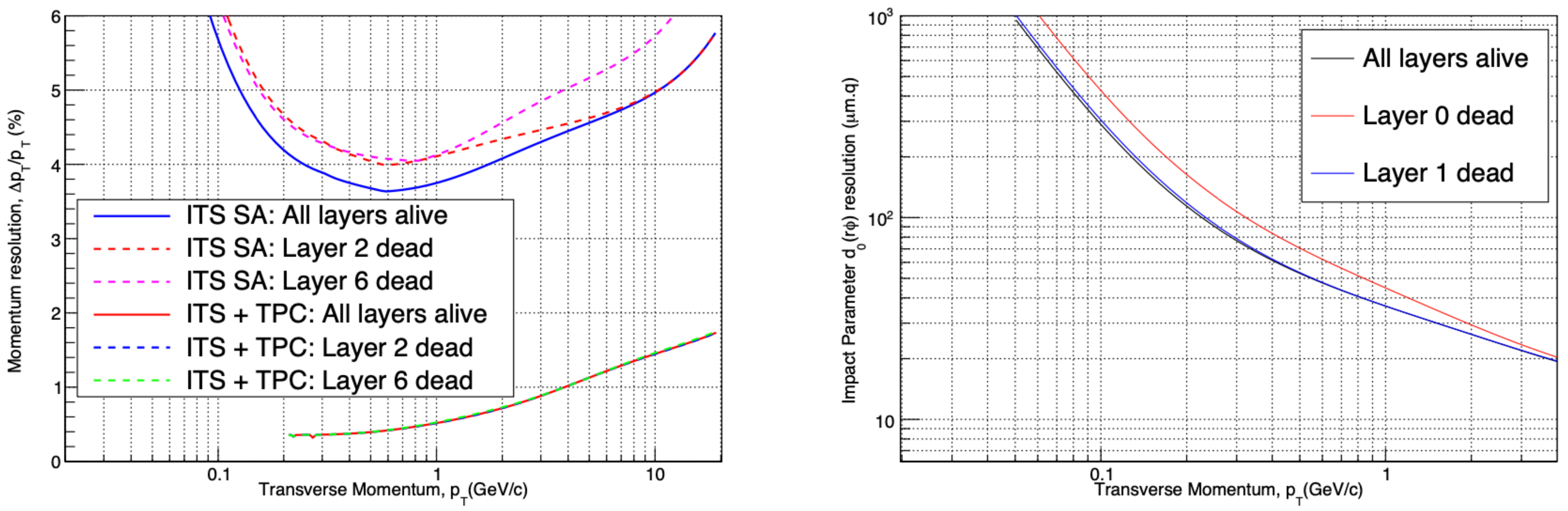

Figure 7.15: Momentum (left) and impact parameter (right) resolution for the upgraded ITS. The worst scenarios for the momentum (left) and impact parameter (right) resolution are compared to the case of all layers properly working. The momentum resolution for combined ITS and TPC tracking stays practically unchanged.

Demonstrations of redundancy and associated performance impact.

Detector performance — ITS2 outline (chapter-7):

- Experimental conditions, requirements, detector specifications
- Simulation tools and models, reconstruction tools
- Track and vertex reconstruction performance
- What-if scenarios, including failure / redundancy questions

Some of my (ES) notes towards the EIC TDR:

- Semi-inclusive (spin-)structure functions are key physics and often a function of transverse momentum k_T and $k_\perp$ (not p_T)
- Consider track-pair resolutions (invariant mass) and possibly resolutions within jets; VM production, heavy-flavor, etc.
- Tracking into PID subsystems will need / benefit from collaboration with the PID working group(s)
- Consider effects of mis-alignments, missing layers
- Consider detector response, noise, and (other) backgrounds

- There are no standalone tracking-specific requirements for the MPGD+TOF subsystem(s) in terms of resolution
- Workforce challenges/issues
- Discussion now, shared document to “specify figures”, follow-up subsequent tracking WG meeting(s)