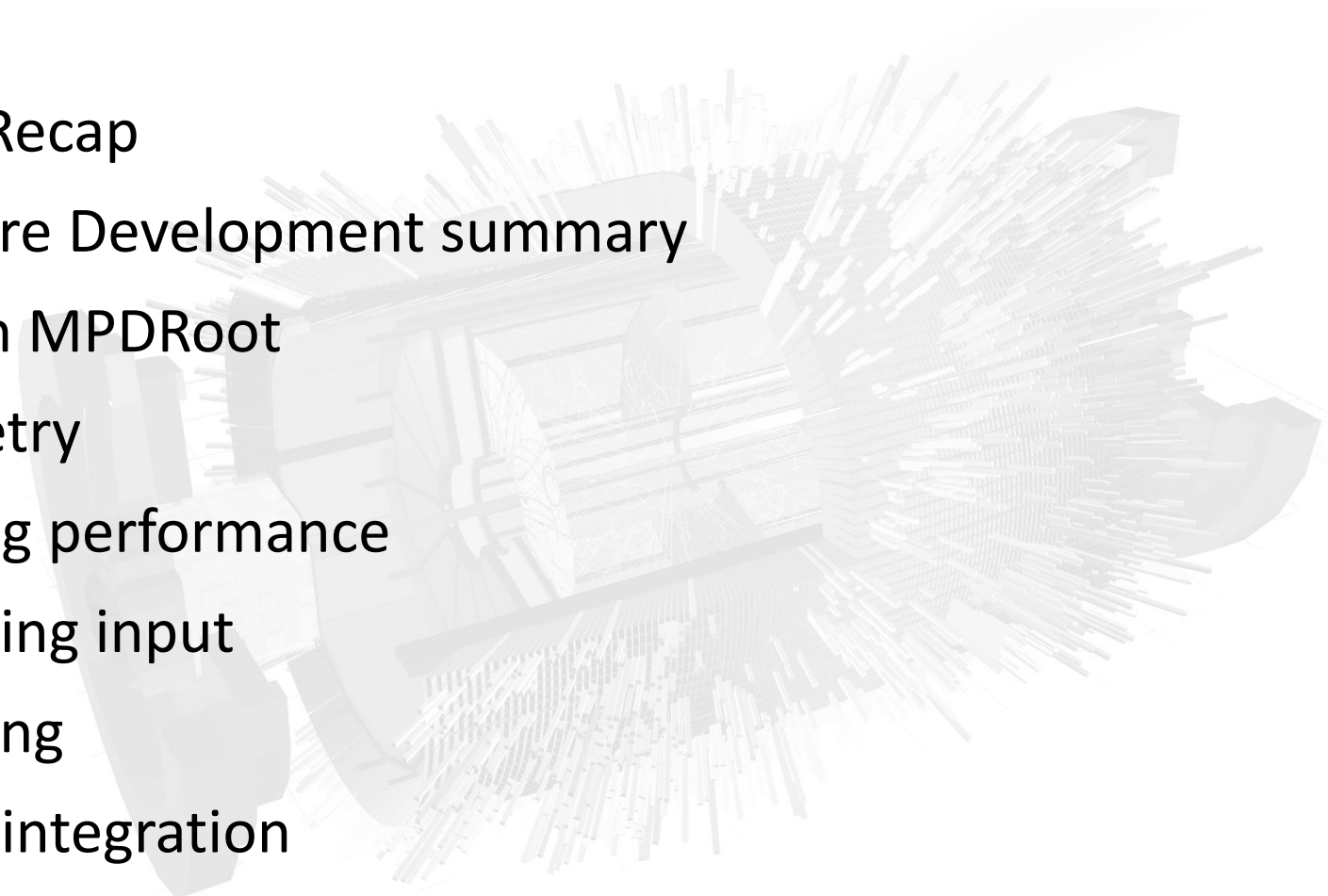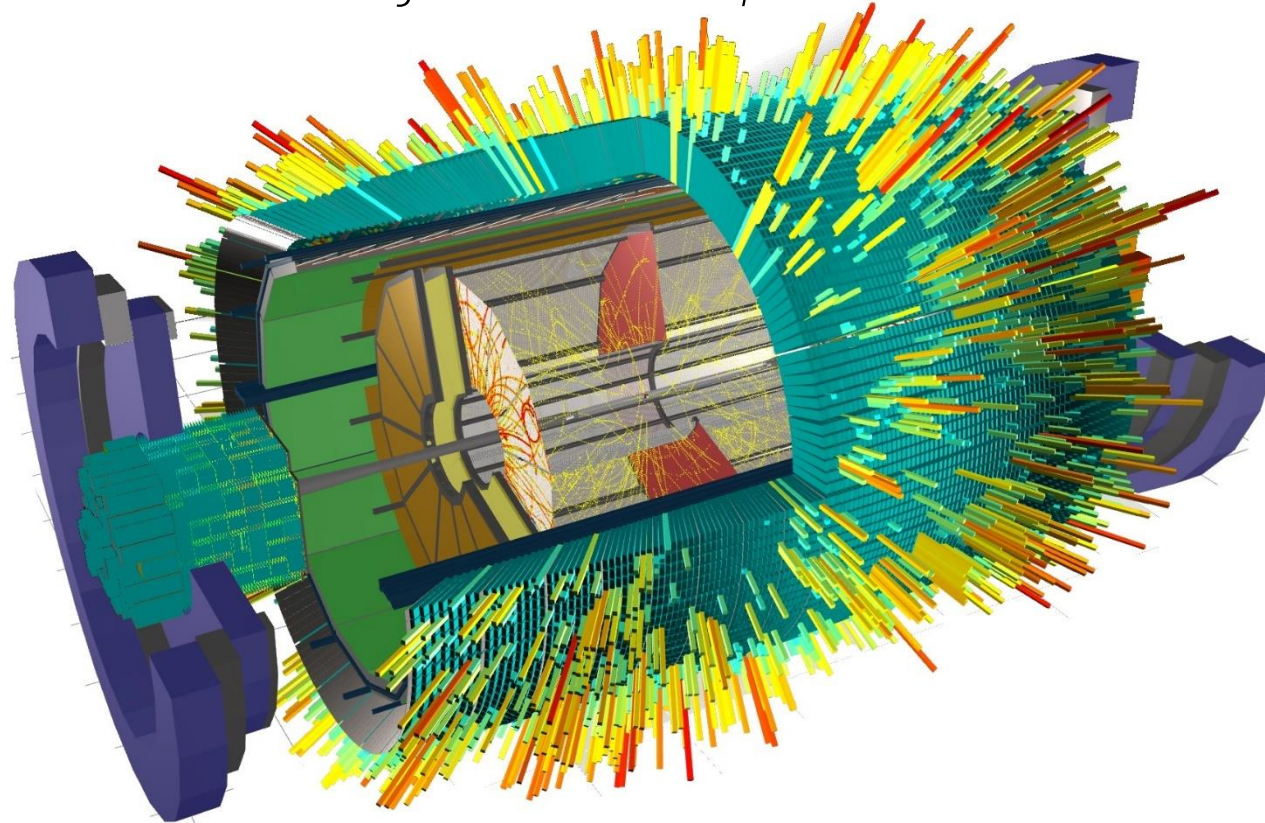# Progress of ACTS implementation in MPDRoot

HNATIC Slavomir

MPD Software Development Team

OUTLINE

- Quick Recap
- Software Development summary
- ACTS in MPDRoot
- Geometry
- Tracking performance
- Clustering input
- Vertexing
- Global integration
- Near future

QUICK RECAP (October 2024)

NICADIST
- separate build system
- dependencies handling

CVMFS
- software distribution
- unified environment

Project Management & Support/User Interaction

GITLAB
- codebase
- CI
- testing

SUPPORT
- helpdesk
- telegram channel

WEBSITE
- howtos
- docs
- general info

R & D

IF YOU THINK YOU CAN ASSIST US

Read the issues in Gitlab

https://git.jinr.ru/nica/mpdroot/-/issues

MPDRoot

| ANALYSIS | SIMULATION | RECONSTRUCTION |

MPD assembly

TPC installation: Autumn 2025

ONLINE EVENT DISPLAY
- experiment visualization
- slow control

DATA STORAGE & RETRIEVAL

DETECTOR CALIBRATION
- alignment
- noise level
- digitalization delay

Mass Production

| PWG REQUESTS HANDLING | DIRAC INTERWARE |

Computing Infrastructure
(MICC & friends)
- supercomputer
- clusters
- storage systems

RELEASES SINCE OCTOBER 2024
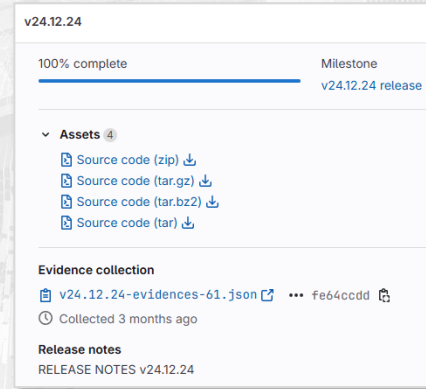
MOST IMPORTANT STUFF

New features
- Analysis updates (physicists)
- ACTS v40, v38.1, v38.1-ckf ports
- ACTS port refactorings, adjustments, fixes, custom patches

Latest dependencies
- ROOT 6.32.06
- GCC 13.2.0
- Boost 1.83.0
- FairRoot 18.6.10
- GEANT4 .... 11.2.1
- Python 3.12.4
- GSL 2.8
- Fedora 41

DETAILED INFO in RELEASE NOTES

git.jinr.ru/nica/mpdroot/-/releases

v24.12.24

100% complete — Milestone v24.12.24 release

∨ Assets 4
- Source code (zip)
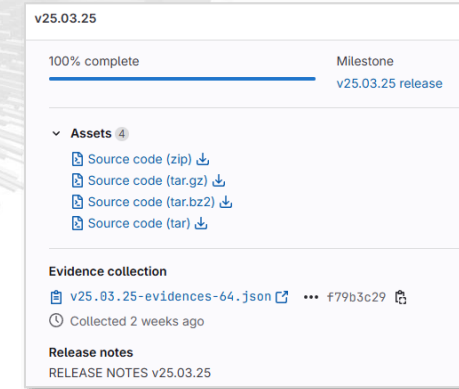- Source code (tar.gz)
- Source code (tar.bz2)
- Source code (tar)

Evidence collection
- v24.12.24-evidences-61.json ··· fe64ccdd
- Collected 3 months ago

Release notes
RELEASE NOTES v24.12.24

v25.03.25

100% complete — Milestone v25.03.25 release

∨ Assets 4
- Source code (zip)
- Source code (tar.gz)
- Source code (tar.bz2)
- Source code (tar)

Evidence collection
- v25.03.25-evidences-64.json ··· f79b3c29
- Collected 2 weeks ago

Release notes
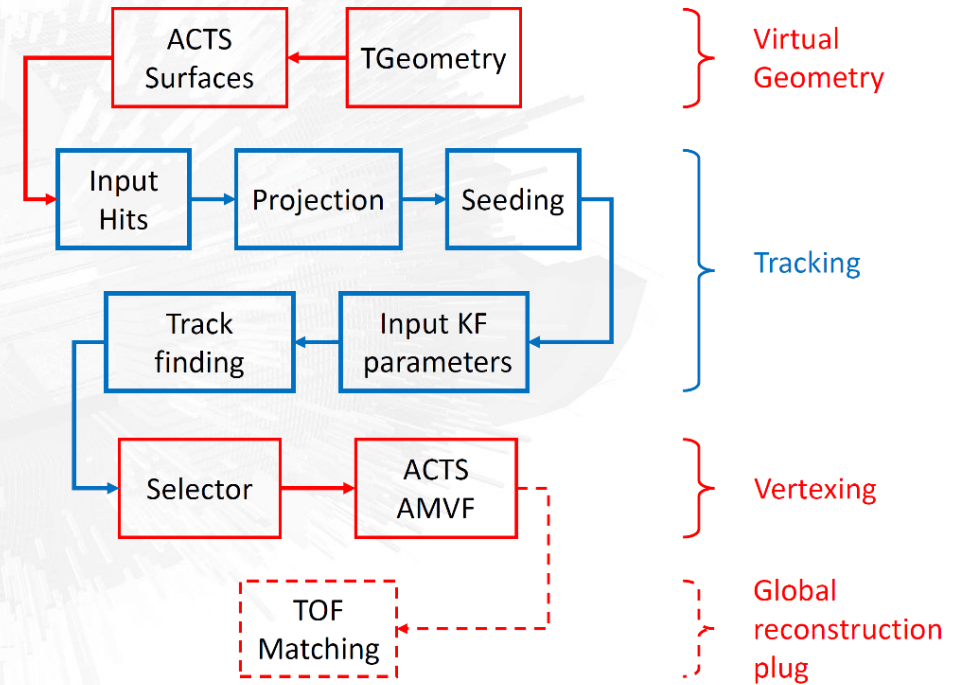RELEASE NOTES v25.03.25

ACTS TRACKER

CORE CONCEPTS

- Modern C++

- Performance focus:

  - compile time polymorphism (templates)

  - thread safe design

  - configurable algorithms

How to run in MPDRoot:

toolbox enter a9-nica-dev

module add mpddev ACTS

build mpdroot's dev branch

runReco.C with ETpcTracking::ACTS

Rapidly developed (frequent API changes)

- about 2 new releases per month

ACTS pipeline in MPDRoot

Virtual Geometry
- ACTS Surfaces ← TGeometry

Tracking
- Input Hits → Projection → Seeding
- Track finding ← Input KF parameters

Vertexing
- Selector → ACTS AMVF

Global reconstruction plug
- TOF Matching

ACTS GEOMETRY

CURRENT STATUS

Cylindrical virtual geometry
- Sectors & Layers
- Implemented by parsing the ROOT TGeo geometry and converting the TGeoNode volume into Acts Surface

MAJOR ISSUES

- poor conversion code (TGeoDetector)
- slowing down calculations
- memory consumption
- requires writing patch for ACTS on each new release
- frequently breaks down when other, seemingly nonrelated parts of ACTS geometry are rewritten
- mystical bugs, taking lots of time to investigate & fix
- does not significantly affect the tracking accuracy (the only positive thing)
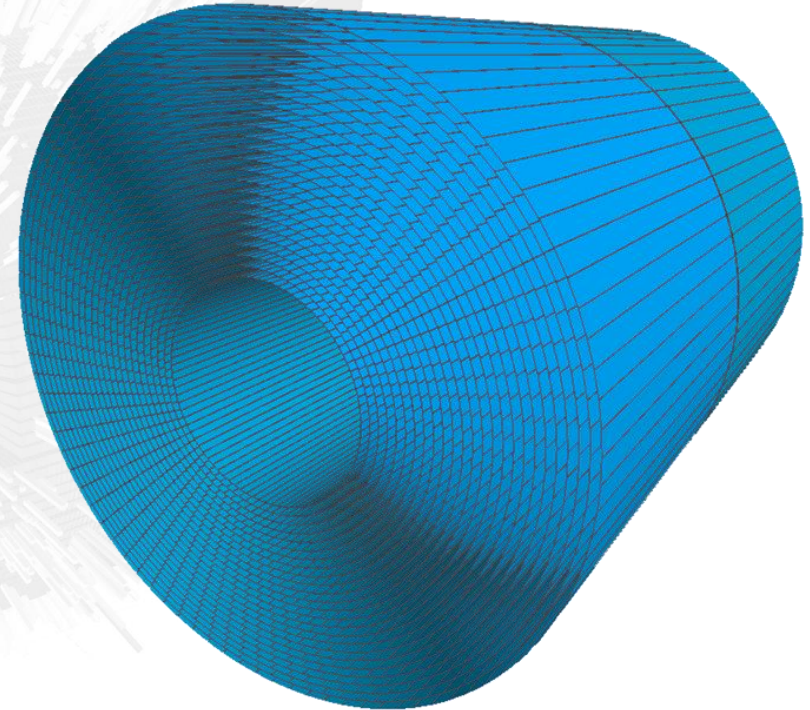
J.D. Osborn et al.
"Implementation of ACTS into sPHENIX Track Reconstruction."
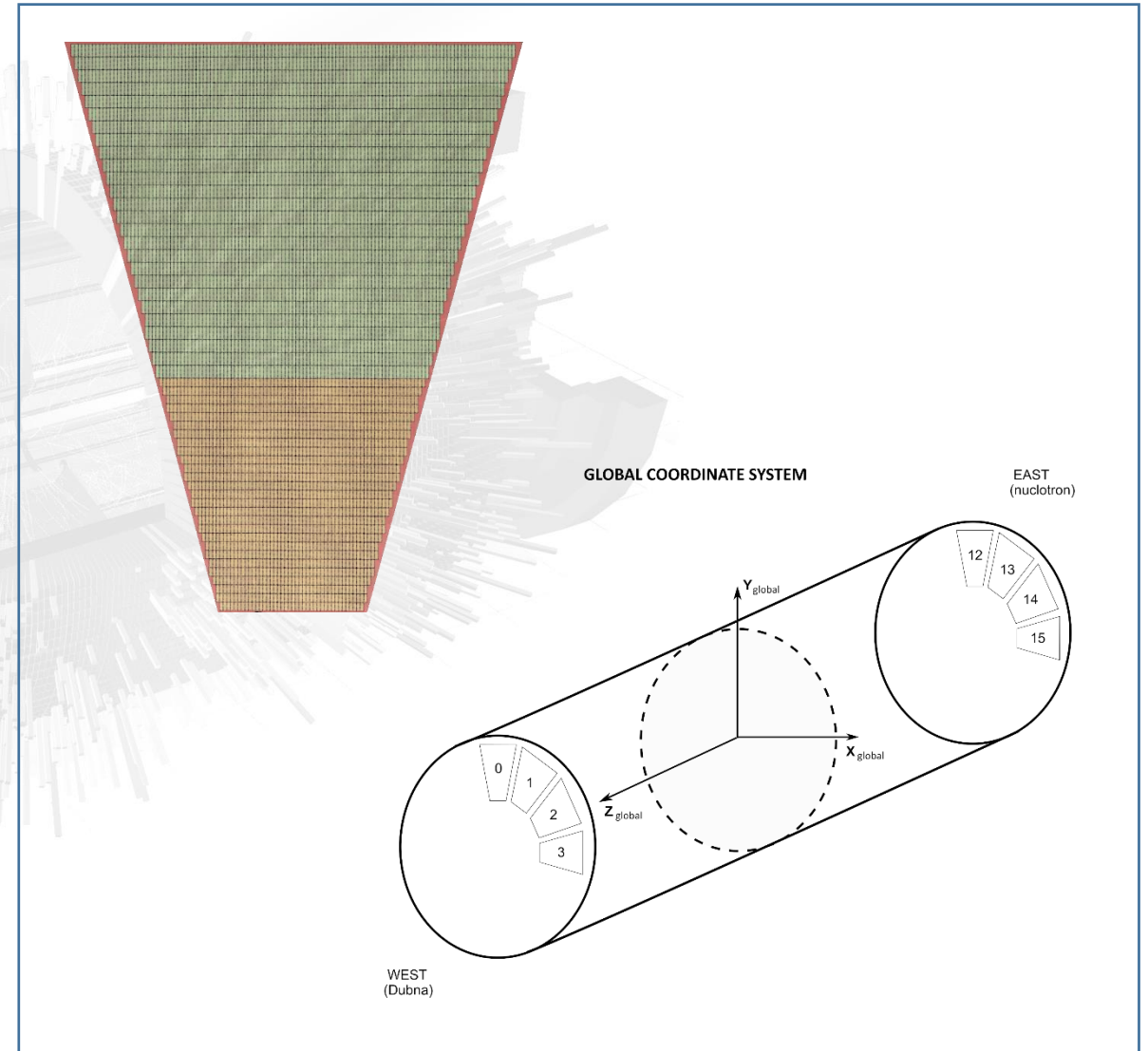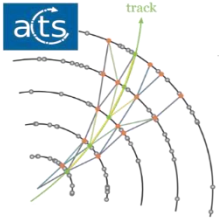Computing and Software for Big Science, 2021

ACTS GEOMETRY

SOLUTION

Getting rid of TGeo conversion
is **INEVITABLE** for the real experiment
- creating surfaces and volumes on our own
- gluing them together
- generating tracking geometry
 & plugging it into tracker

---

- some geometry R&D work already done by
  E.Kryshen & N.Burmazov (Thursday talk)

- must start from zero, can use some ideas
  (code not portable due to our technical reqs)

- TPC sector padrow based virtual geometry ideal

- Cylindrical geometry without TGeo conversion
  will still likely resolve all the worst geometry issues
  we have atm

GLOBAL COORDINATE SYSTEM

EAST
(nuclotron)

Y_{global}

X_{global}

Z_{global}

12
13
14
15

0
1
2
3

WEST
(Dubna)

TRACKING PERFORMANCE

- MLEM clustering; ACTS v36.0.0
- UrQMD
- 200000 events (2000 runs, 100 events per run)
- 9 minimum hits per track
- P_t > 0.1 GeV
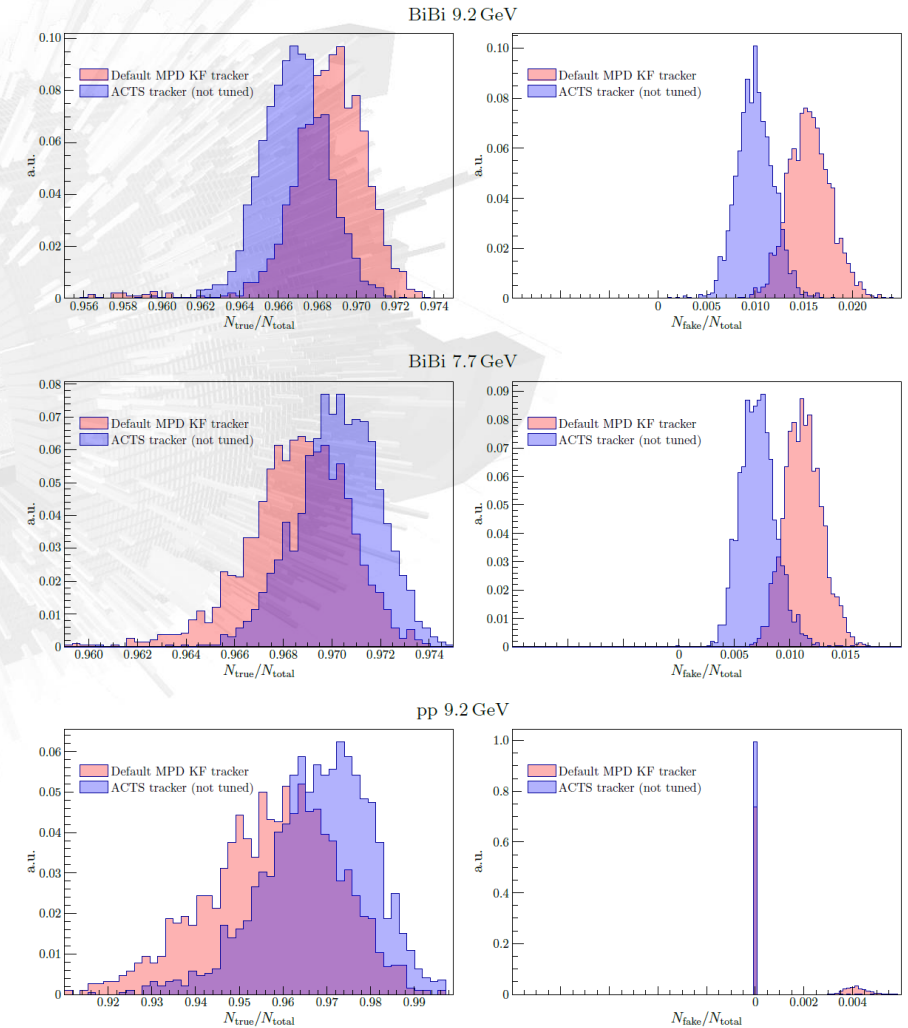
	Default tracker		ACTS tracker	
	true rate	fake rate	true rate	fake rate
BiBi 9.2 GeV	$\mu = 0.9686$ $\sigma = 0.00212$	$\mu = 0.01544$ $\sigma = 0.002012$	$\mu = 0.9668$ $\sigma = 0.001724$	$\mu = 0.00999$ $\sigma = 0.00189$
BiBi 7.7 GeV	$\mu = 0.9686$ $\sigma = 0.002107$	$\mu = 0.01122$ $\sigma = 0.001664$	$\mu = 0.9702$ $\sigma = 0.001772$	$\mu = 0.00713$ $\sigma = 0.001612$
pp 9.2 GeV	$\mu = 0.958$ $\sigma = 0.01426$	$\mu = 0.00128$ $\sigma = 0.002337$	$\mu = 0.968$ $\sigma = 0.00212$	$\mu = 2.5 \cdot 10^{-5}$ $\sigma = 3.5 \cdot 10^{-4}$

"Implementation of ACTS into MPDRoot"
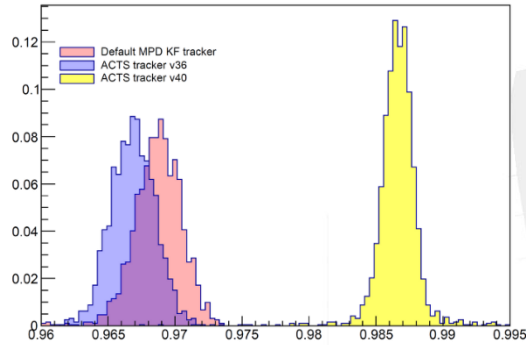S. Hnatic, J. Busa Jr., A. Bychkov, A. Krylov, V. Krylov, A. Moshkin, O.Rogachevsky

MMCP '24 Proceedings, PEPAN
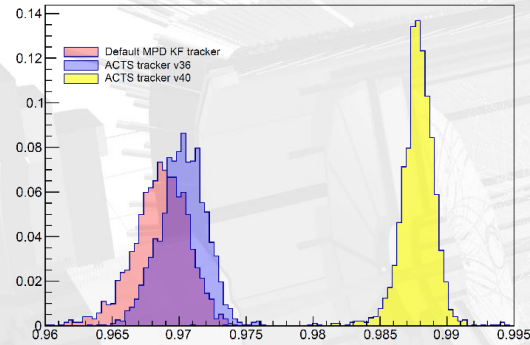
TRACKING IMPROVEMENT: v36 vs v40

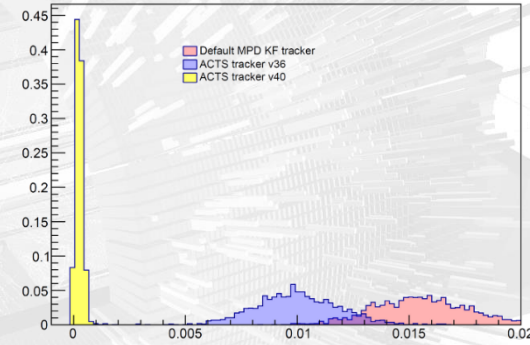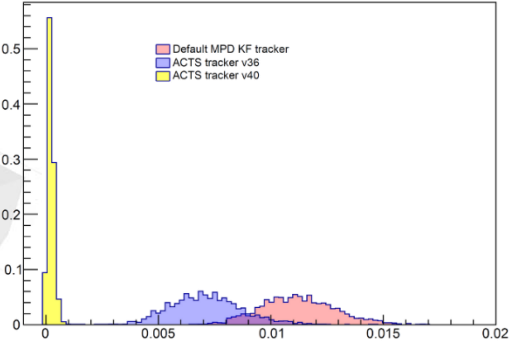CKF enhancements: better efficiency, far less fakes

Efficiency

Fake rate

BiBi 9.2 GeV

BiBi 7.7 GeV

BiBi 9.2 GeV

BiBi 7.7 GeV

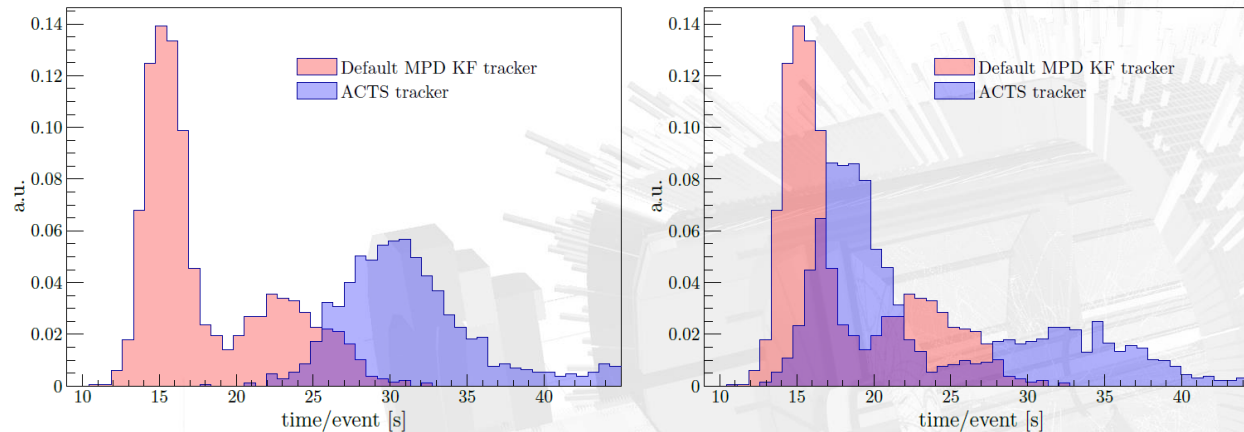|	Default tracker		ACTS tracker v36.0.0		ACTS tracker v40.0.0	
	true rate	fake rate	true rate	fake rate	true rate	fake rate
BiBi 9.2 GeV	$\mu = 0.9686$ $\sigma = 0.00212$	$\mu = 0.01544$ $\sigma = 0.002012$	$\mu = 0.9668$ $\sigma = 0.001724$	$\mu = 0.00999$ $\sigma = 0.00189$	$\mu = 0.9866$ $\sigma = 0.001779$	$\mu = 0.00026$ $\sigma = 0.000172$
BiBi 7.7 GeV	$\mu = 0.9686$ $\sigma = 0.002107$	$\mu = 0.01122$ $\sigma = 0.001664$	$\mu = 0.9702$ $\sigma = 0.001772$	$\mu = 0.00713$ $\sigma = 0.001612$	$\mu = 0.9878$ $\sigma = 0.001427$	$\mu = 0.000225$ $\sigma = 0.000168$

COMPUTING SPEED

BiBi 7.7GeV

Fast clusterhitfinder by V.Krylov – initially written for online event display processing

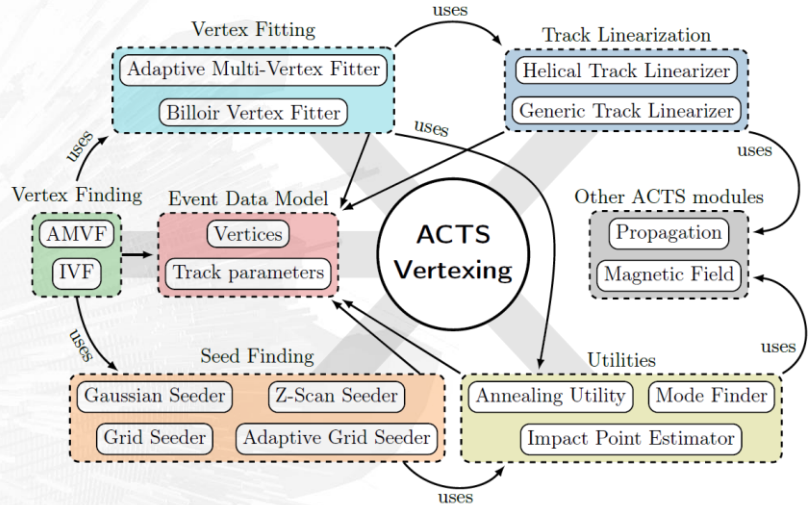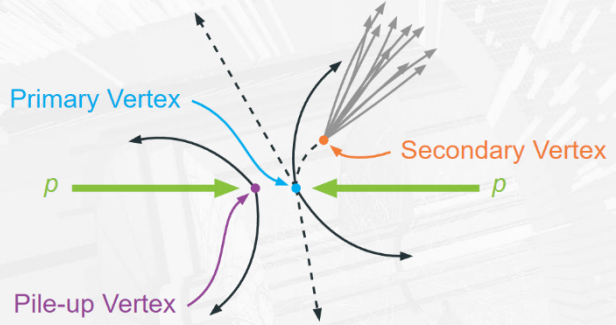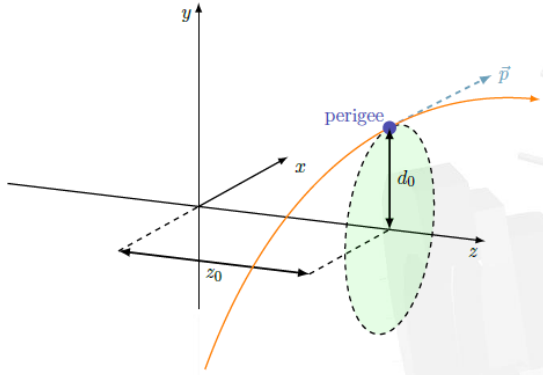| MLEM + DEFAULT KF	μ = 18.12 s / event	σ = 4.281 s / event
MLEM + ACTS v36	μ = 31.12 s / event	σ = 2.273 s / event
FAST (v0.2.0b) + ACTS v36	μ = 23.41 s / event	σ = 7.481 s / event

FAST (v0.2.0b) + ACTS v36 … lower efficiency than MLEM + DEFAULT KF

FAST v2.0.8 + ACTS v40.0.0 port - ready in ~1month … should have higher efficiency

ACTS calculation speed should be faster with native geometry

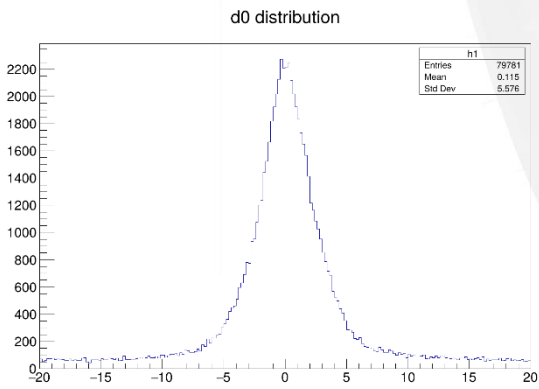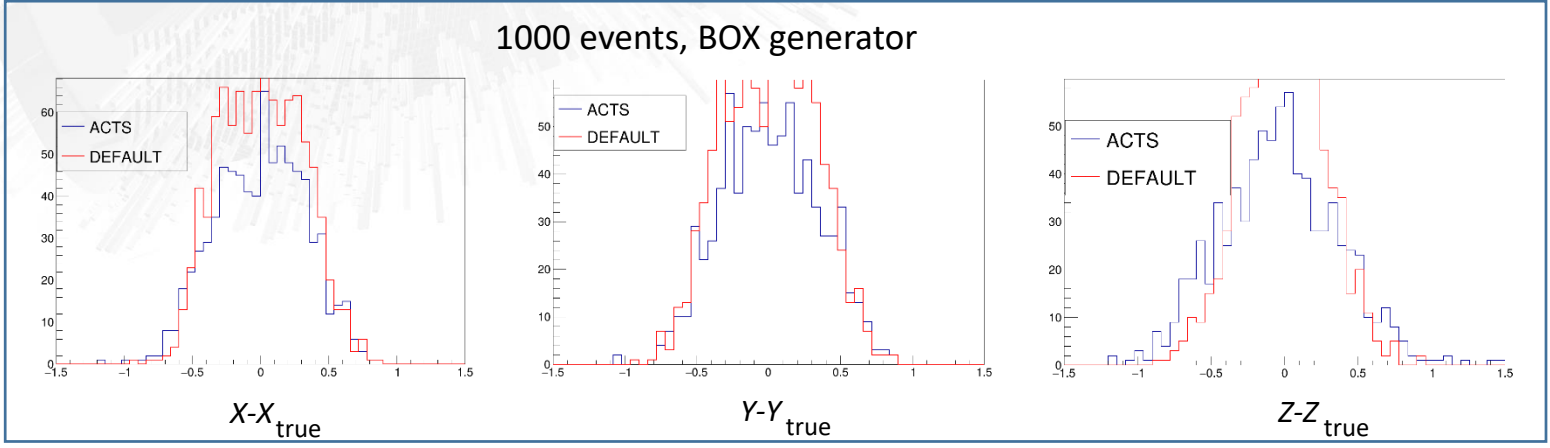# PRIMARY VERTEXING

ACTS VERTEXING SUITE

PERIGEE TRACK PARAMETRIZATION
Track selection: $|d\_0| < 2$mm

- many tunable parameters

d0 distribution

1000 events, BOX generator

$X-X_{\text{true}}$

$Y-Y_{\text{true}}$

$Z-Z_{\text{true}}$

GLOBAL INTEGRATION

TPC outputs → MATCHING ← TOF inputs

CURRENT TOF MATCHING STATUS

- no generic API access

- tight coupling to old classes (**no good**)

- inputs taken only as MpdTpcKalmanTrack type

- brings MpdKalmanFilter, MpdKalmanHit

  etc with it….

ACTS TRACKING OUTPUT API

TrackProxy class

- reference surface

- track parameters at reference surface

  (loc0,loc1, theta, phi, q/p, t)

- momentum, charge, direction vector

- hits, chi2, etc…

Need for **generic API for TOF Matching**
its inputs must be independent from tracker implementation!

FUTURE

NEXT 2-3 MONTHS
- Fast clustering v2.0.8 ACTS integration
- New ACTS geometry

AFTERWARDS
- TOF matching (finalize integration into global reco)
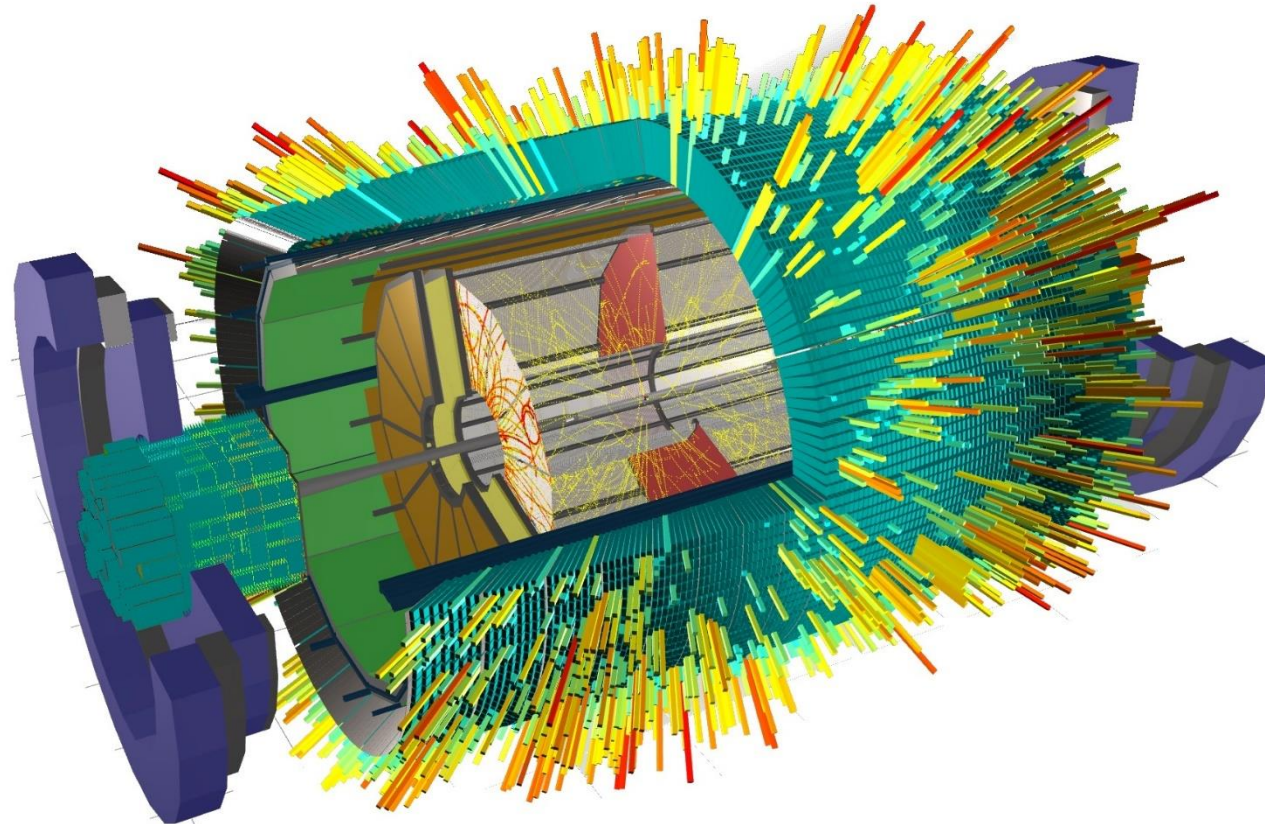- Testing & feedback from physicists

MISC
- Investigate & fix crashes on cluster
- Disconnected tracks
- Statistics visualization

SOFTWARE DEVELOPMENT
- up to date with latest packages (Acts, ROOT, …)
- regular release schedule
- automated tests
- cleanup
- refactoring

Thank You !

Q & A

MPD Software Development & Computing Team

Rogachevsky O. .... Coordinator

Krylov V., Krylov A. .... Online MPD Event Display

Moshkin A., Pelevanyuk I. .... Mass Production

Bychkov A. .... Detector Simulation

Kuzmin V. .... Detector Alignment

Podgainy D., Zuev M. .... Supercomputing

Alexandrov E., Alexandrov I. .... Databases

Balashov N. .... Gitlab Support

Belyakov D. .... Network Infrastructure

Belecky P., Kamkin A., Hnatic S. .... Acts Tracker

Busa J. .... Build System

Hnatic S. .... Architecture