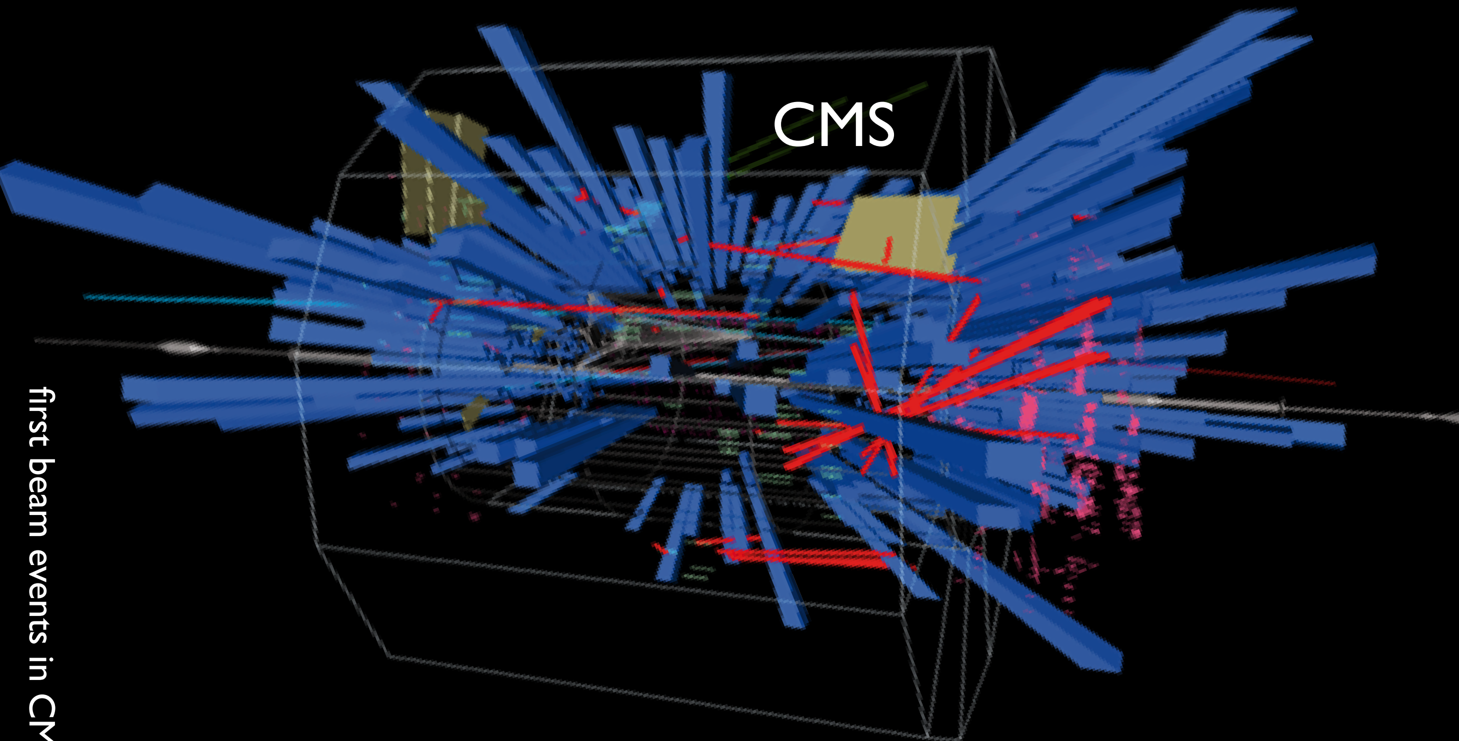
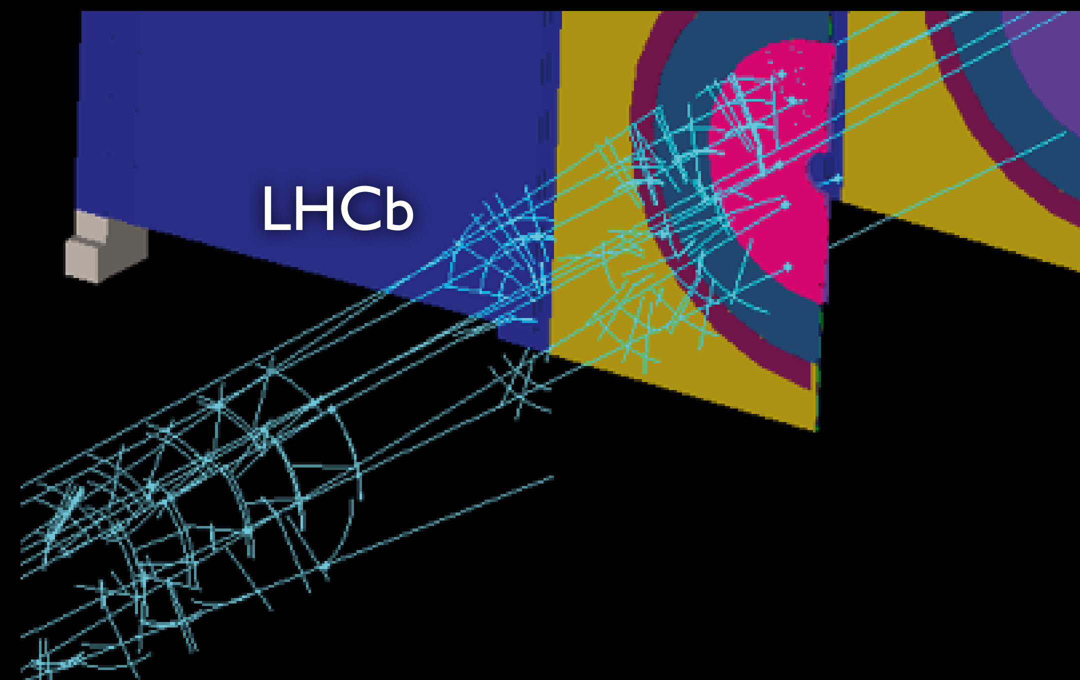
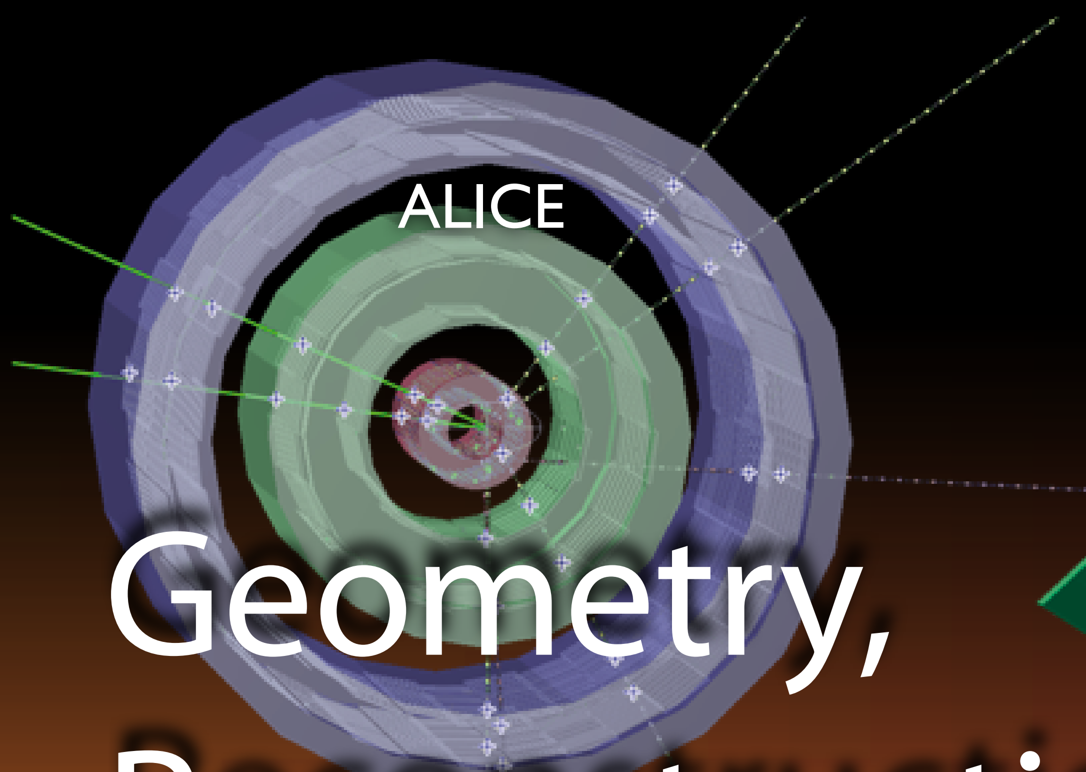
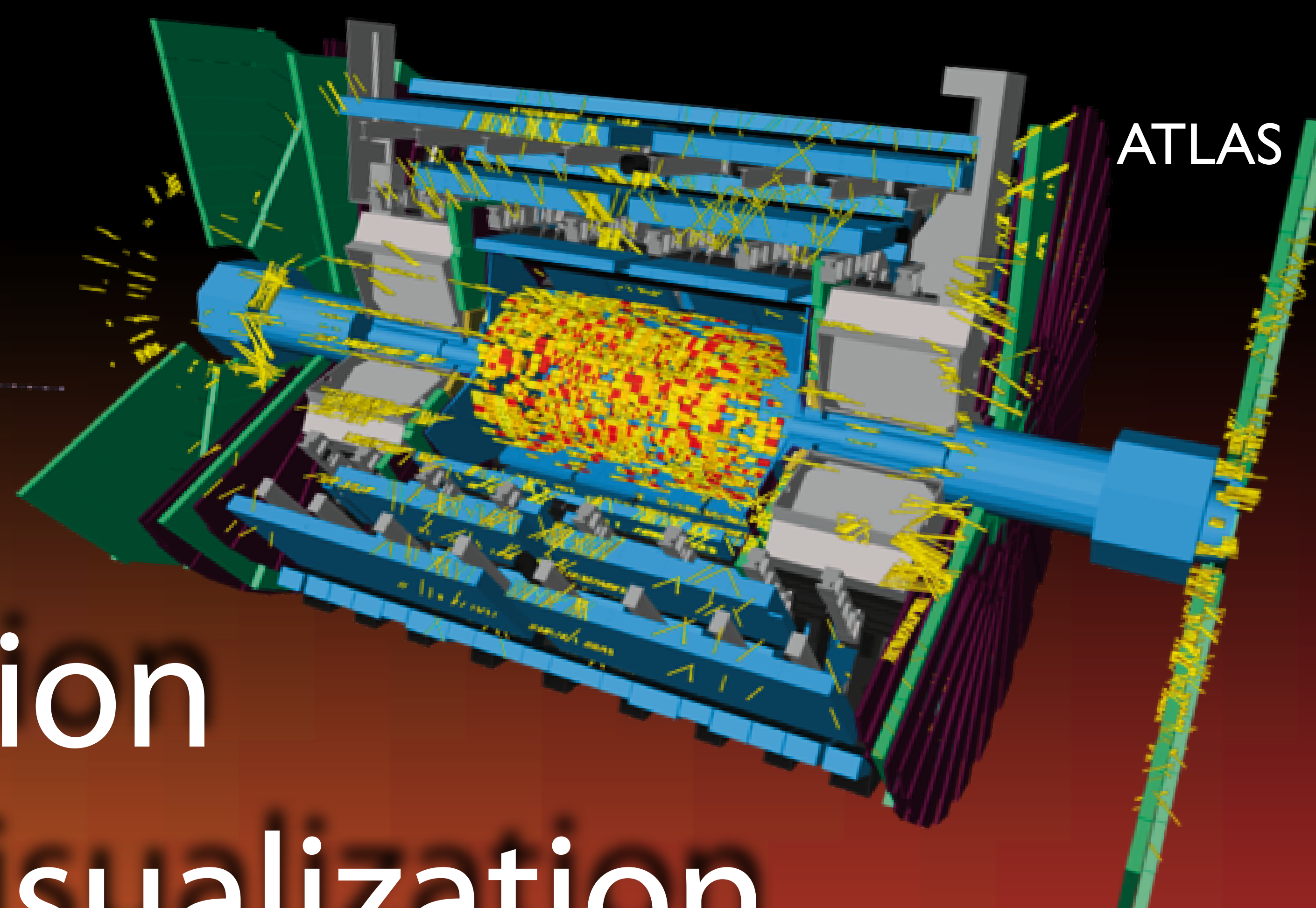
Markus Elsing









first beam events in CMS, LHCb, ALICE and ATLAS

Geometry, Reconstruction and Event Visualization

Outline

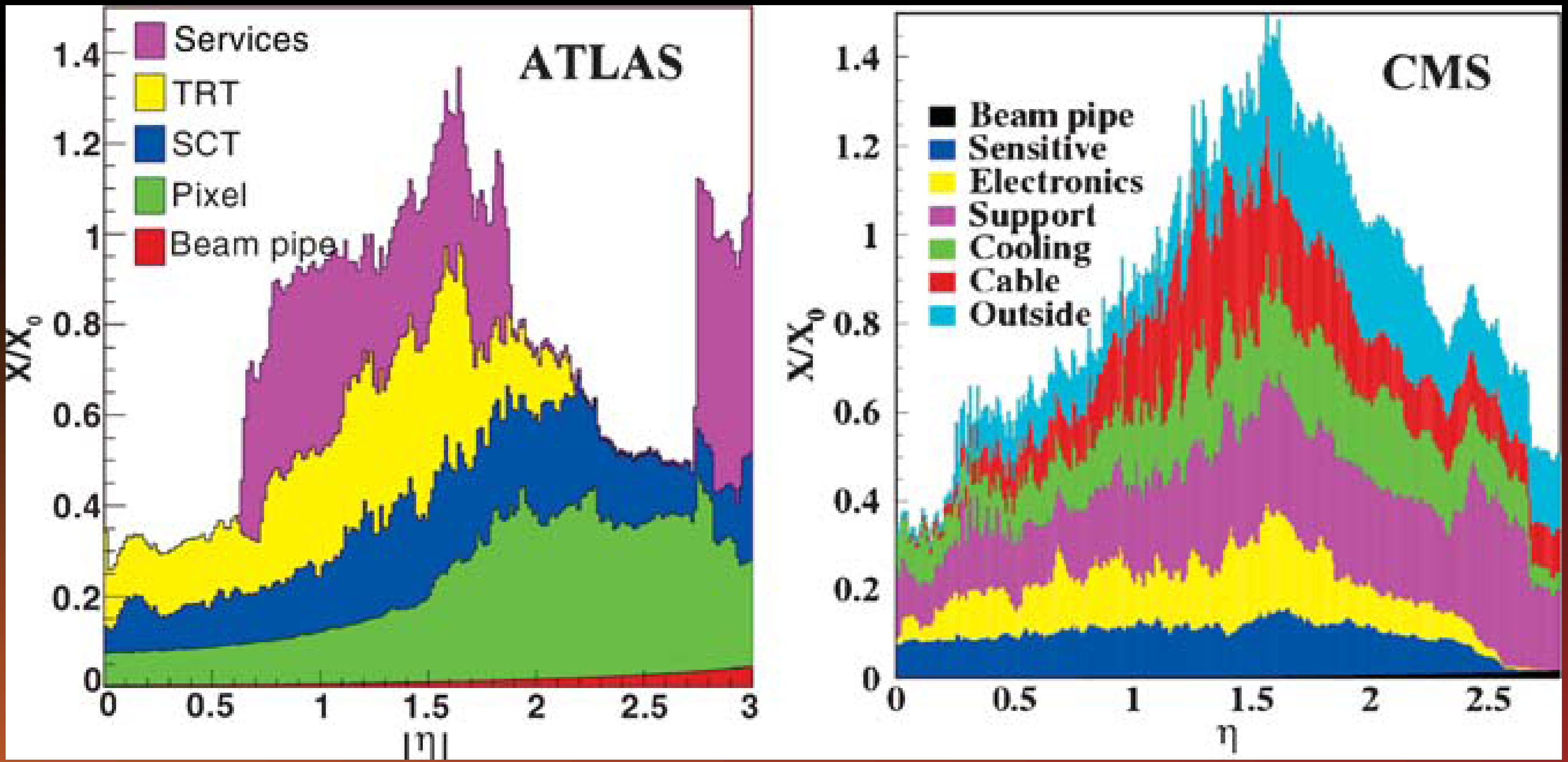
- recent developments on aspects of offline software
  - ➡ I will restrict myself and give a LHC centric view
- geometry developments
  - ➡ use-cases for full and fast geometries
- reconstruction tools
  - ➡ highlight some interesting developments and methods
- interactive event displays
  - ➡ usage for commissioning and offline analysis of real data
- I will not cover e.g. developments for Linear Collider
  - ➡ more information: talk #375 on Marlin, poster #373 on ILCSoft, ...

Detector Description

- LHC detectors are complex
  - ➡ experiments developed gemoetry models, translation into G4, G3...
  - ➡ huge number of volumes
  - ➡ ATLAS/CMS significantly more material in trackers than e.g. CDF and D0

	model	placed volumes
ALICE	Root	4.3 M
ATLAS	GeoModel	4.8 M
CMS	DDD	2.7 M
LHCb	LHCb Det.Des.	18.5 M

- physics requirement:
  - ➡ control material close to beam pipe at % level



Realistic Detector Description

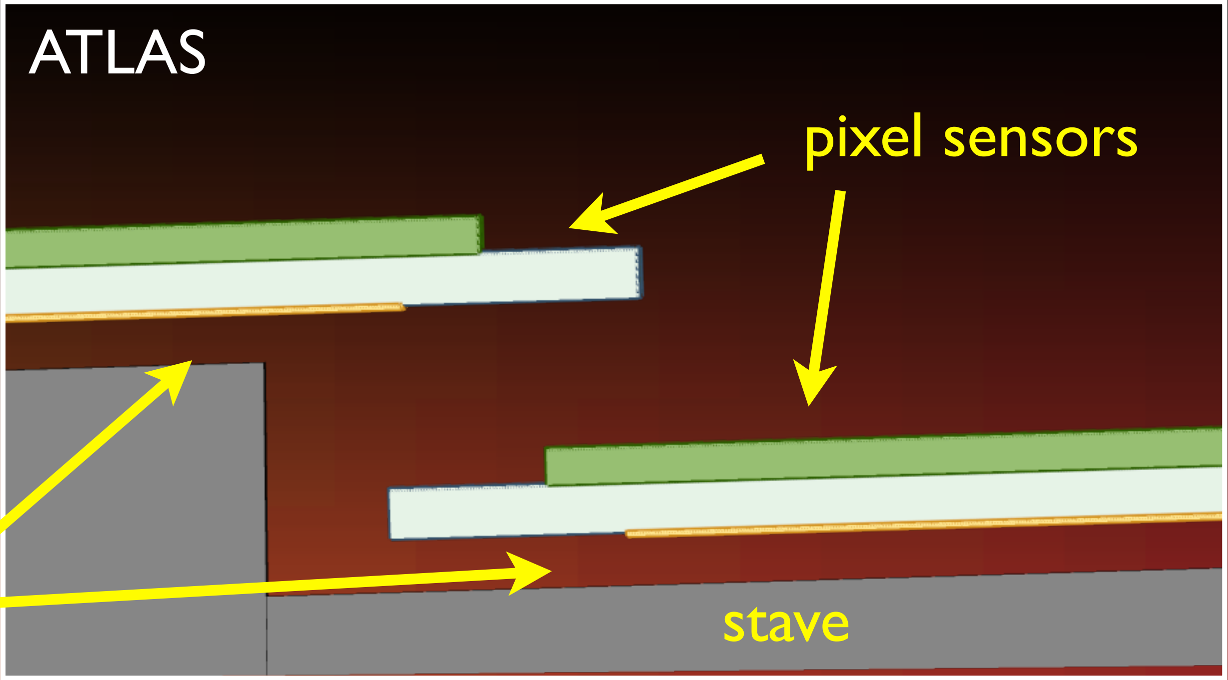
- huge effort in experiments
  - ➡ implement very detailed description
  - ➡ put each individual detector part on balance and compare with model
  - ➡ example: measured CMS and ATLAS tracker compared to simulation

ATLAS	estimated from measurements	simulation
Pixel package	201 kg	197 kg
SCT detector	672 ±15 kg	672 kg
TRT detector	2961 ±14 kg	2962 kg

CMS	estimated from measurements	simulation
active Pixels	2598 g	2455 g
full detector	6350 kg	6173 kg

Preliminary

- large MC productions to study effects of
  - ➡ detector material (e.g. additional material in tracker)
  - ➡ misalignment
  - ➡ very active field over past years in experiment physics challenges
- example: misalignment in G4
  - ➡ implement clearances in geometry
  - ➡ avoid G4 volume clashes

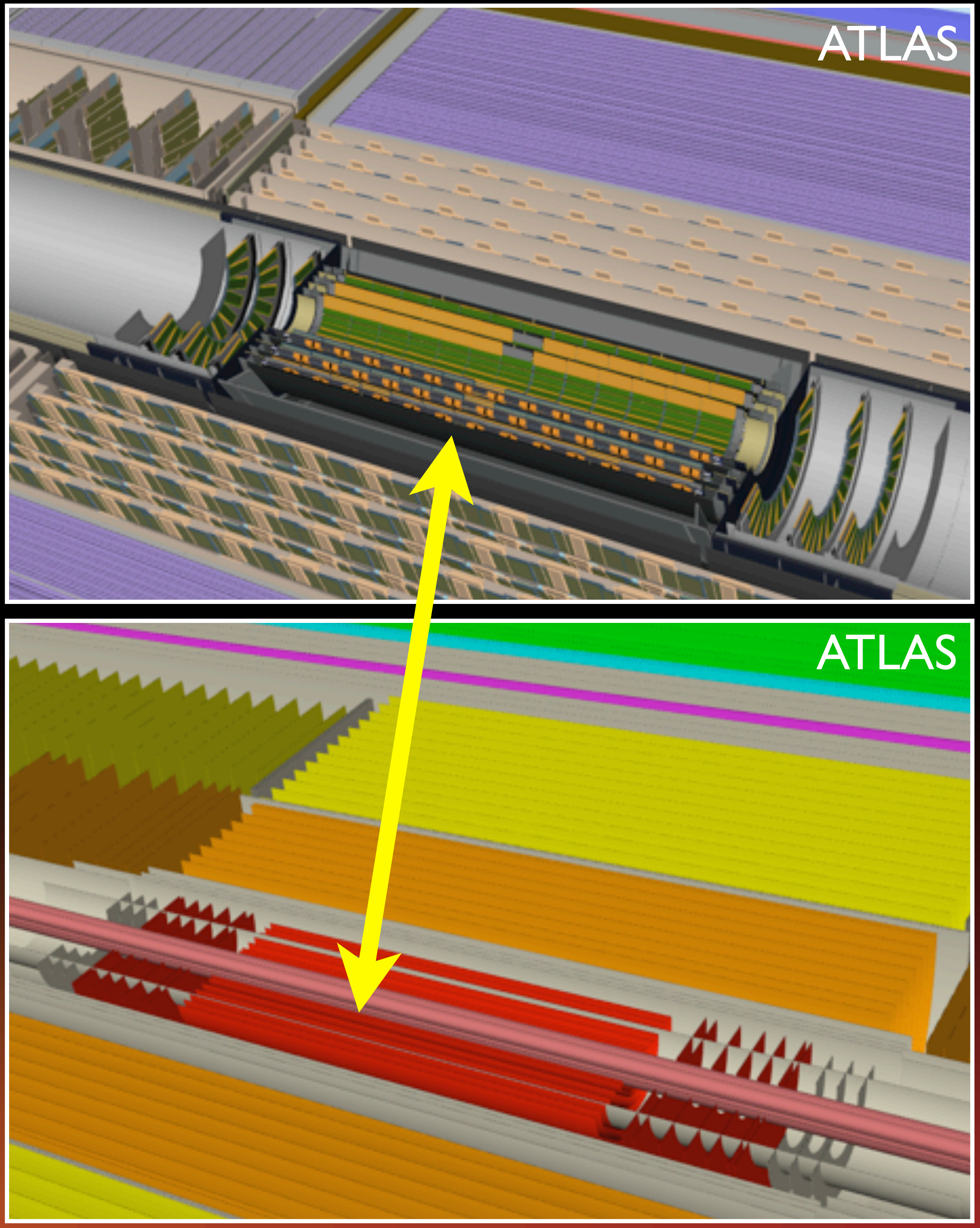


Full and Fast Tracking Geometries

- complex G4 geometries not optimal for reconstruction
  - ➡ simplified tracking geometries
  - ➡ material surfaces, field volumes (CMS)
- reduced number of volumes
  - ➡ blending material to surfaces/volumes
  - ➡ surfaces with 2D material density maps, templates per Si sensor...

	G4	tracking
ALICE	4.3 M	same *1
ATLAS	4.8 M	10.2K *2
CMS	2.7 M	3.8K *2
LHCb	18.5 M	30

*1 ALICE uses full geometry (TGeo)
*2 plus a surface per Si sensor

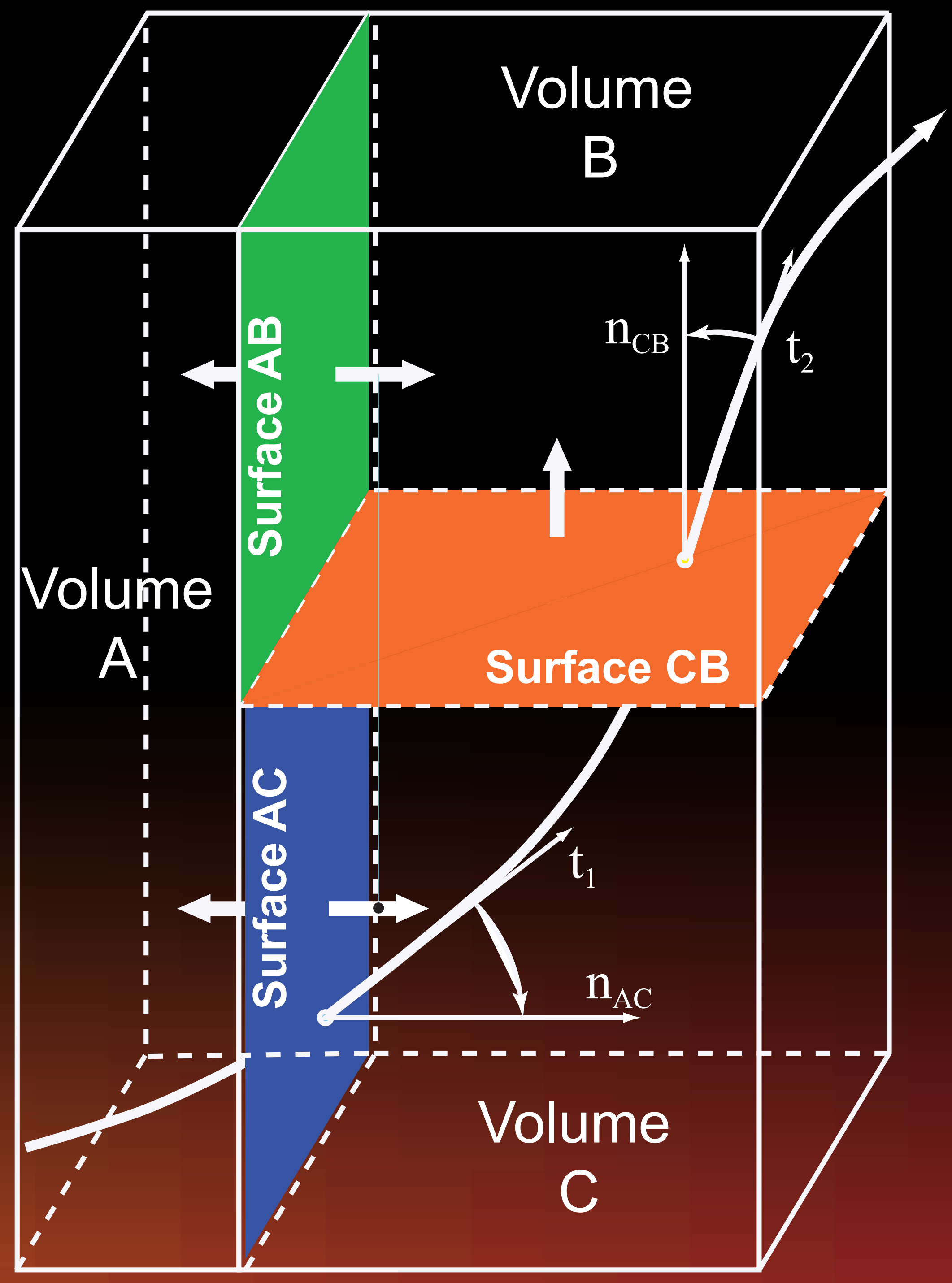


Embedded Navigation Schemes

- embedded navigation scheme in tracking geometries
  - ➡ G4 navigation uses voxelisation as generic navigation mechanism
  - ➡ embedded navigation for simplified models
  - ➡ used in pattern recognition, extrapolation, track fitting and fast simulation
- example:
  - ➡ ATLAS developed geometry of connected volumes
  - ➡ boundary surfaces connect neighboring volumes to predict next step

ATLAS	G4	tracking	ratio
crossed volumes in tracker	474	95	5
time in SI2K sec	19.1	2.3	8.4

(neutral geantinos, no field lookups)

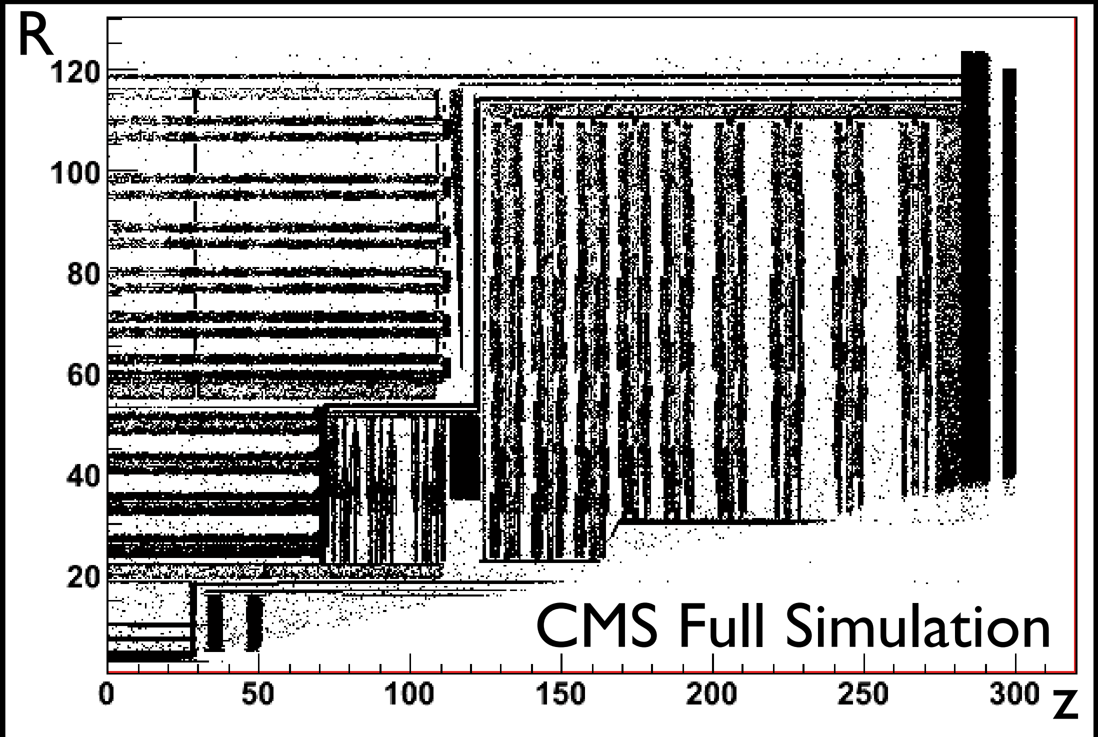


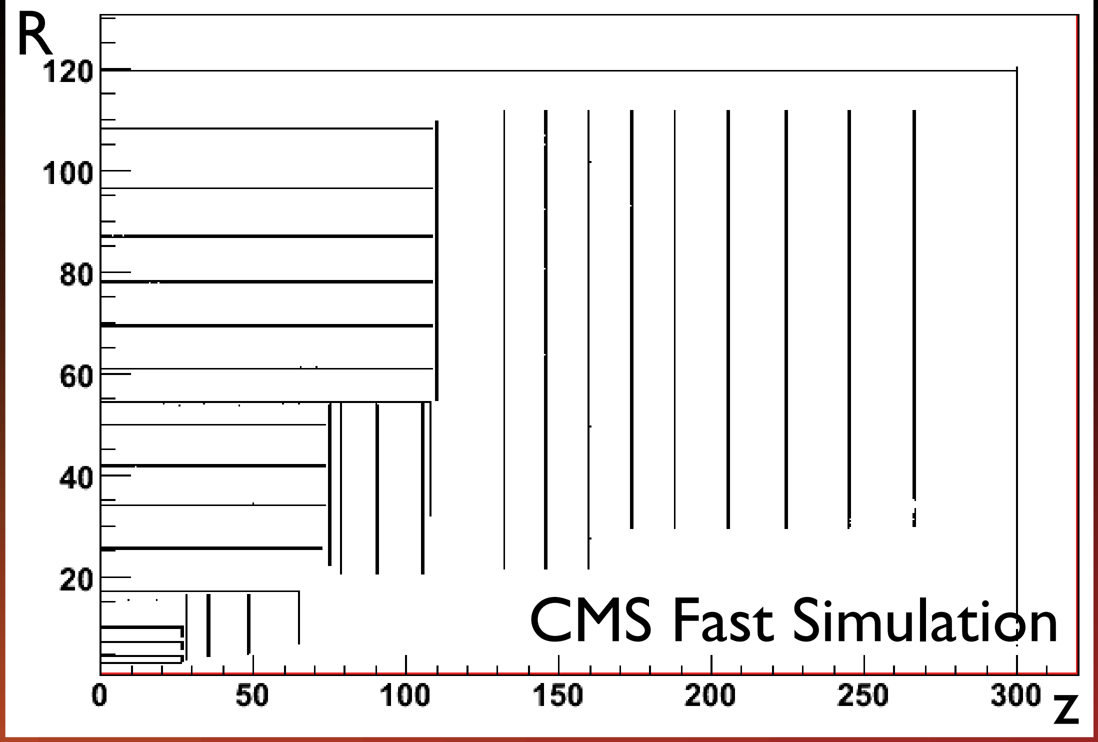
Fast Simulation

- fast simulation engines
  - ➡ fast calo. simulation (parameterization, showers libraries, ...)
  - ➡ simplified (tracking) geometries
  - ➡ simplify physics processes w.r.t. G4
  - ➡ output in same data model as full sim.
  - ➡ able to run full reconstruction (+trigger)

	G4	fast sim.
CMS	360	0.8
ATLAS	1990	7.4

- ttbar events, in kSI2K sec
- G4 differences: calo.modeling , phys.list, eta cuts, b-field

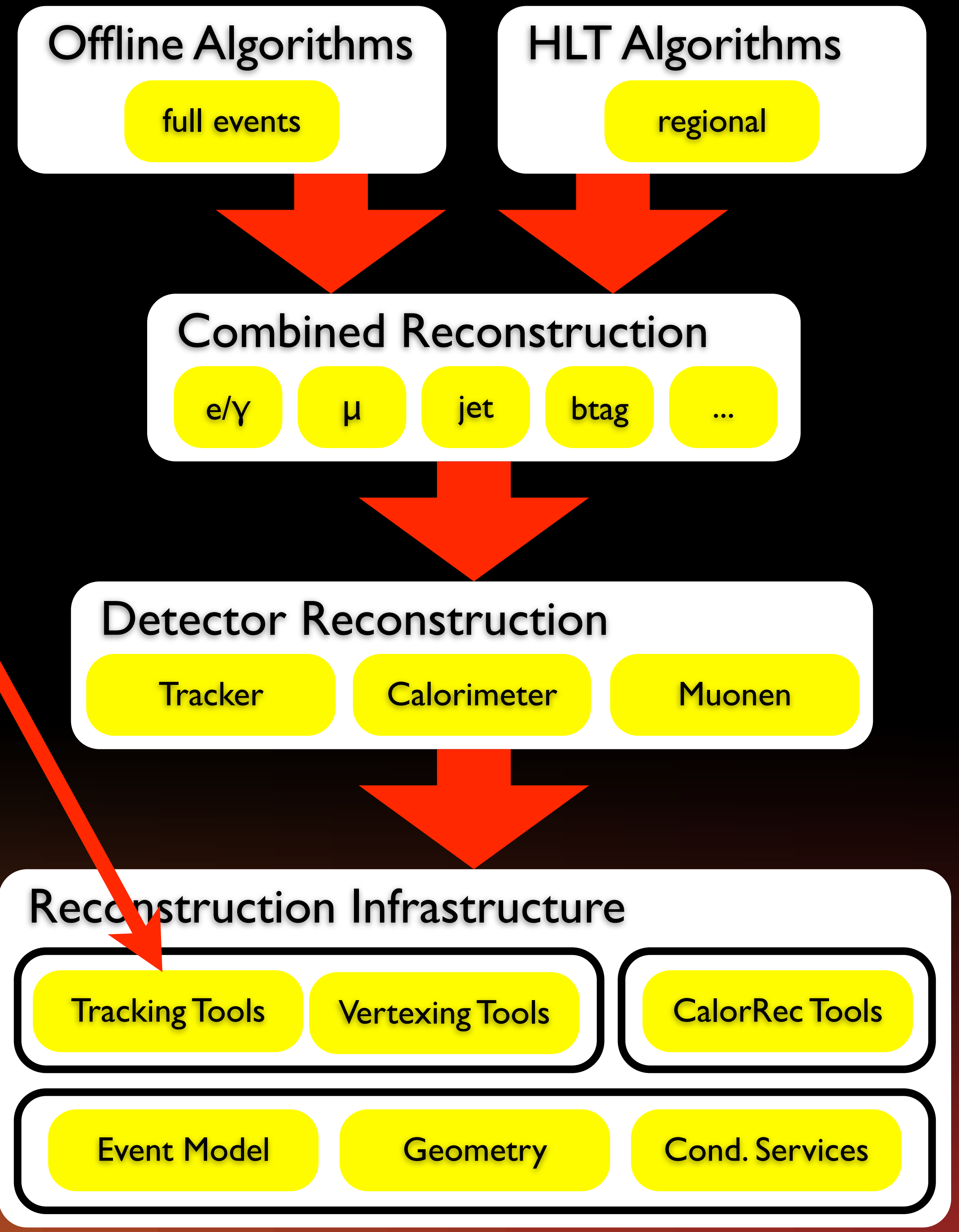




- CPU for full G4 exceeds computing models
  - ➡ simulation strategies of experiments mix full G4 and fast simulation

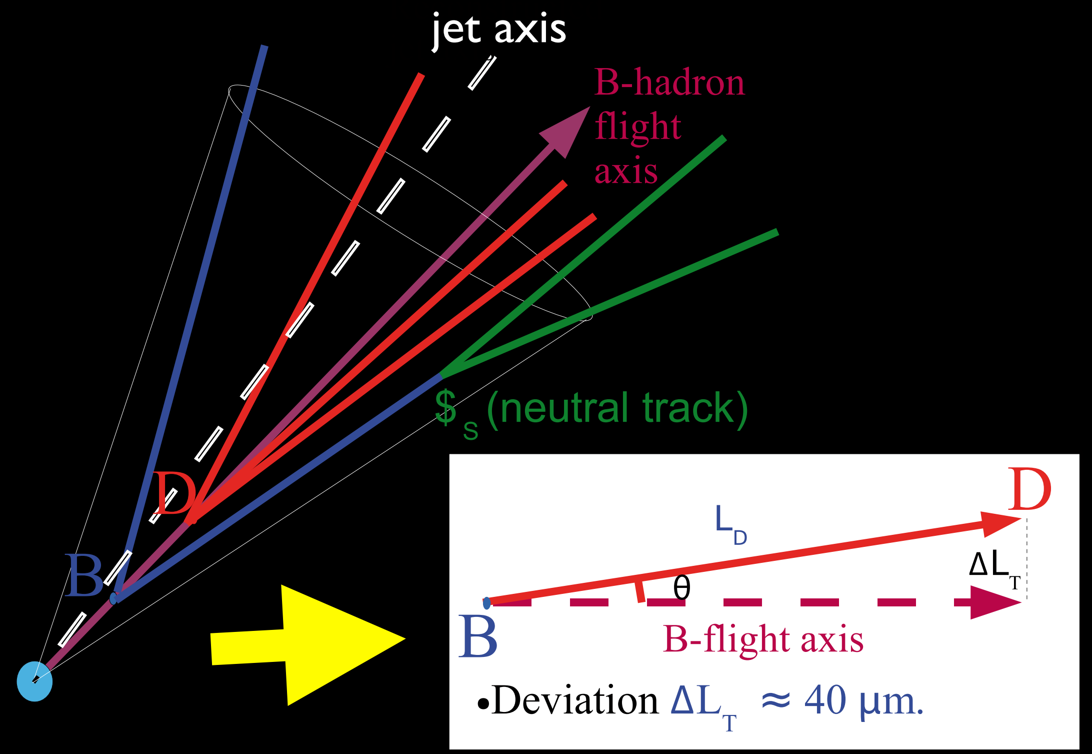
Reconstruction

- software organization follows common pattern
  - ➡ "natural" architecture
- similar layer of tracking and vertexing tools
  - ➡ fitters, propagation, geometry...
  - ➡ little sharing of code across experiments
- common code base for offline and High Level trigger (HLT) is a success
  - ➡ full and regional reconstruction using common reconstruction tools
  - ➡ different algorithm sequencing in HLT for early rejection
  - ➡ special code for time critical parts

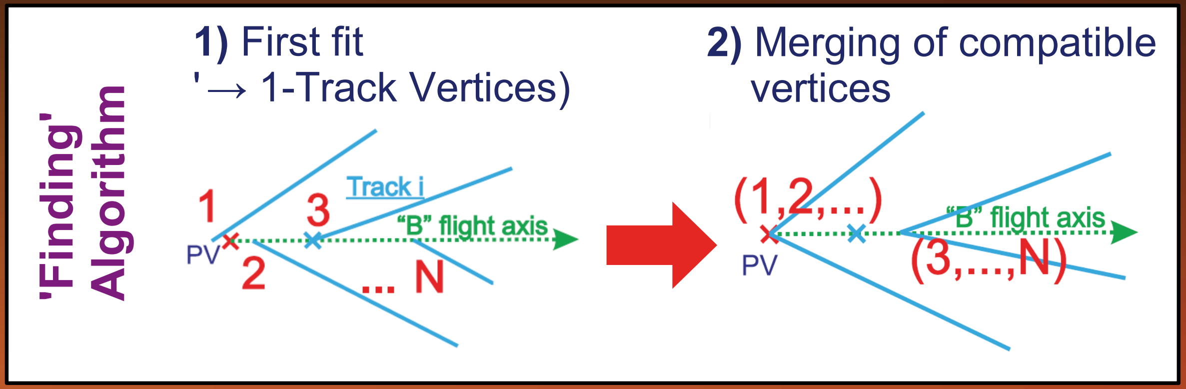


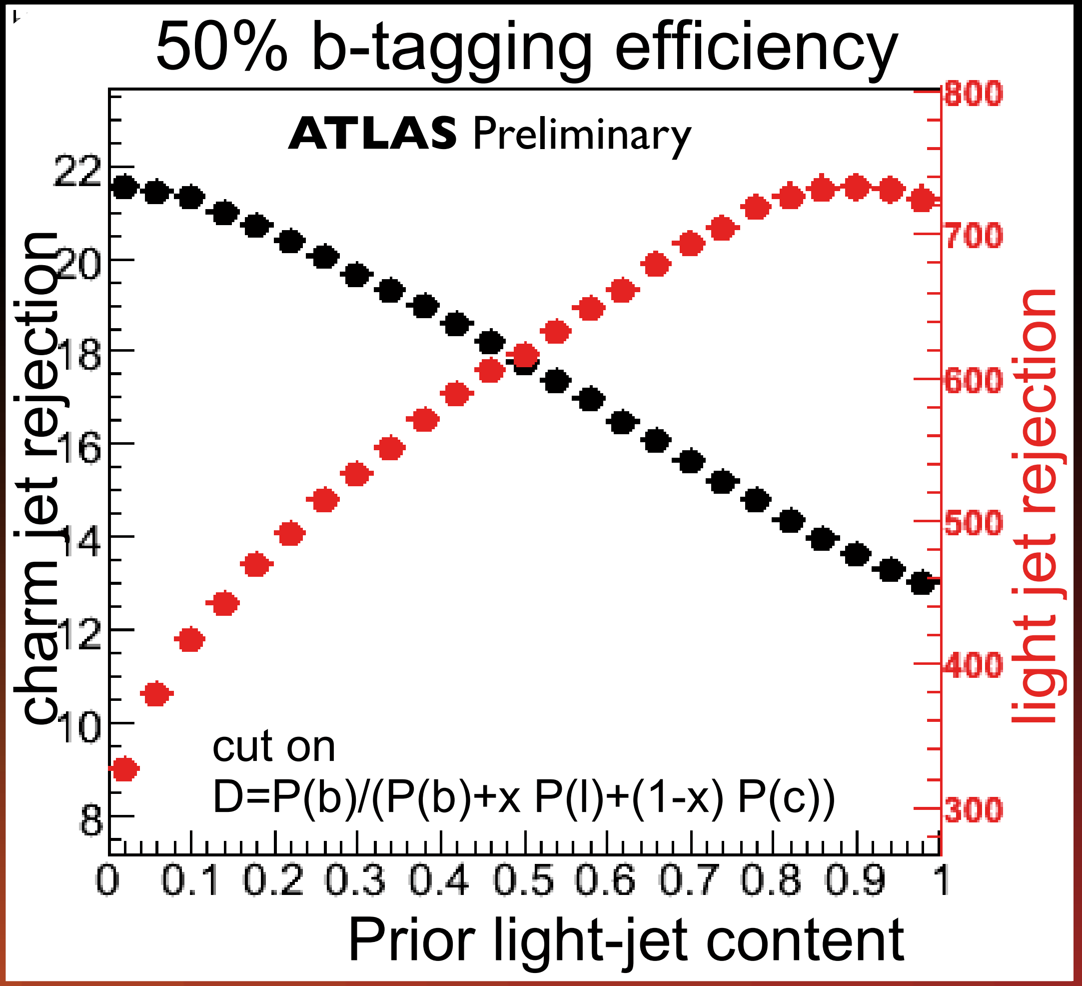
Jet-Fitter: b-Tagger

- conventional vertex tagger
  - ➡ fits all displaced tracks into a common geometrical vertex
- Jet-Fitter
  - ➡ b-/c-hadron vertices and primary vertex approximately on the same line
  - ➡ fit of 1..N vertices along B-hadron axis
  - ➡ mathematical extension of conventional Kalman Filter for vertex fitting



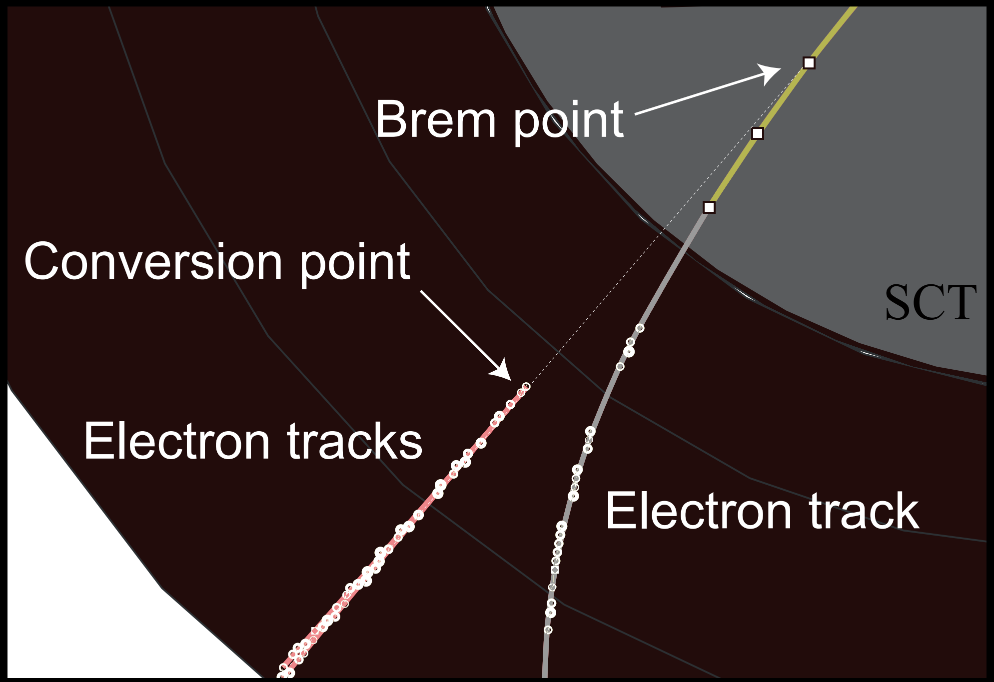
- up to 40% better light rejection
  - ➡ much improved control of charm rejection
  - ➡ best b-tagger in ATLAS

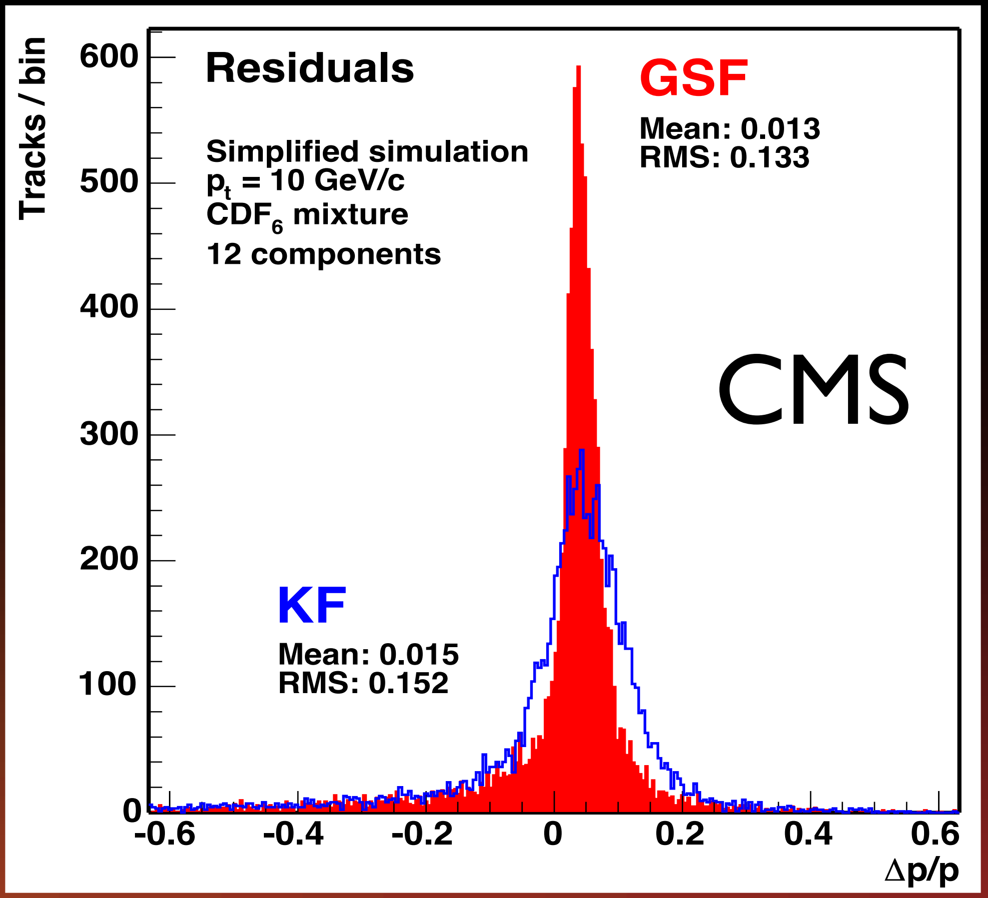




Brem. Fitting for Electrons

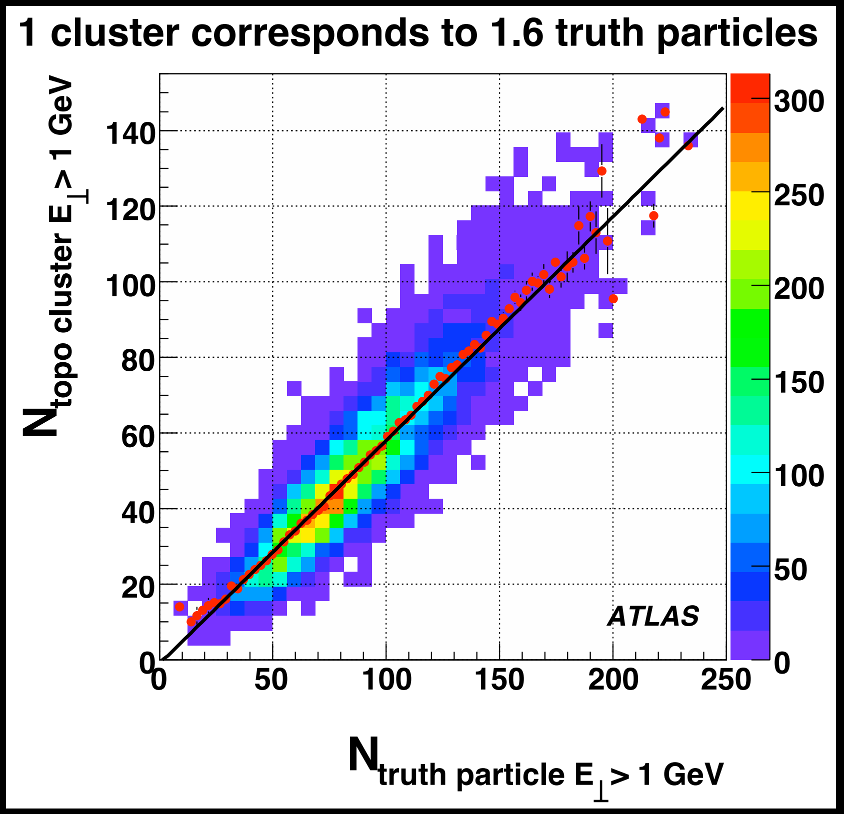
- material in Inner Detectors
  - ➡ e-bremstrahlung and γ-conversions
- compensate using sophisticated tracking tools:
  - ➡ brem. point in global-χ^2 track fit
  - ➡ Kalman filter with dynamic noise adjustment
- Gaussian Sum filter (GSF)
  - ➡ approximate Bethe-Heitler distribution as Gaussian mixture
  - ➡ state vector after material correction becomes sum of Gaussian components
  - ➡ GSF resembles set of parallel Kalman filters for N components
  - ➡ default brem.fitter in CMS and ATLAS

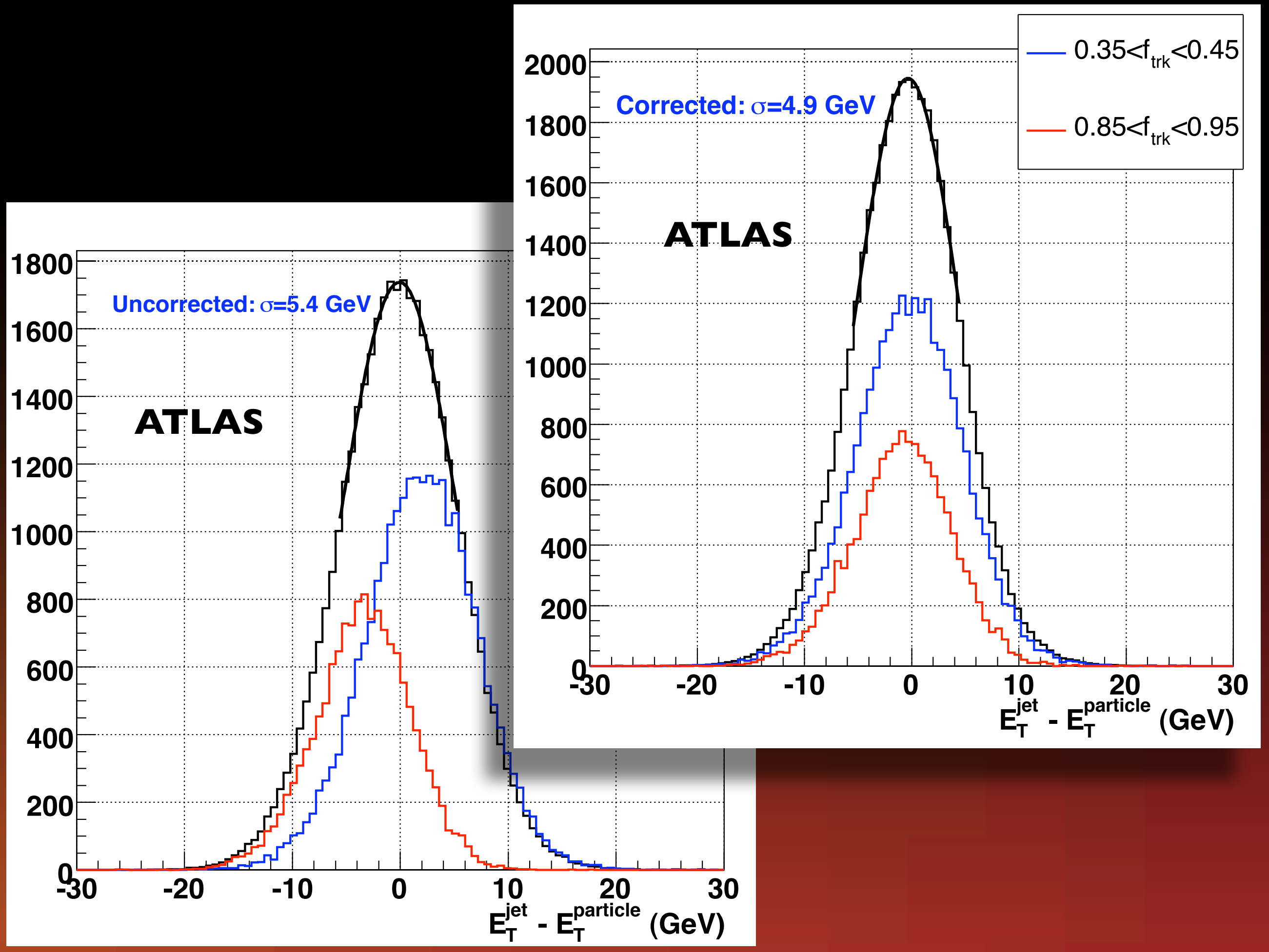




Jets: Topological Clustering

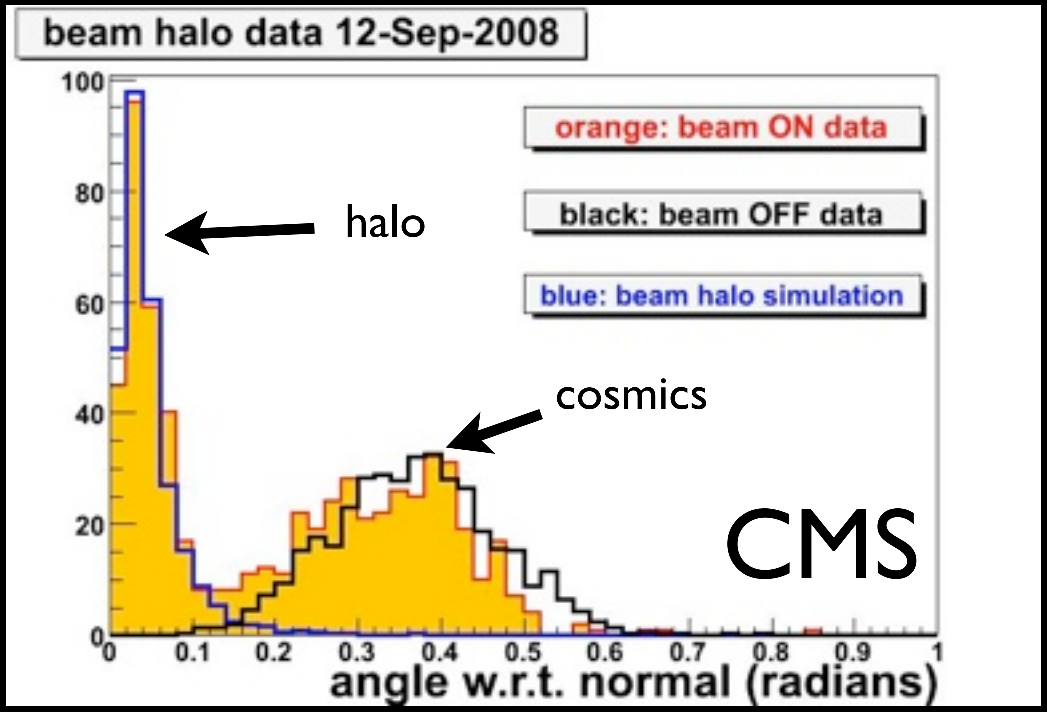
- 3D topological clustering
  - ➡ fully explores lateral and longitudinal segmentation of ATLAS calorimeters
  - ➡ local hadron calibration
    - classify clusters as e.m. or hadronic
    - cell weights for non-compensation
    - out of cluster corrections (thresholds)
    - dead material corrections
    - final jet level correction restores linearity at 2% level
  - ➡ jet shape and jet mass significantly improved
- track based jet correction
  - ➡ fraction of jet energy seen by tracks used to further correct energy
- alternative to particle flow
  - ➡ actively developed in CMS

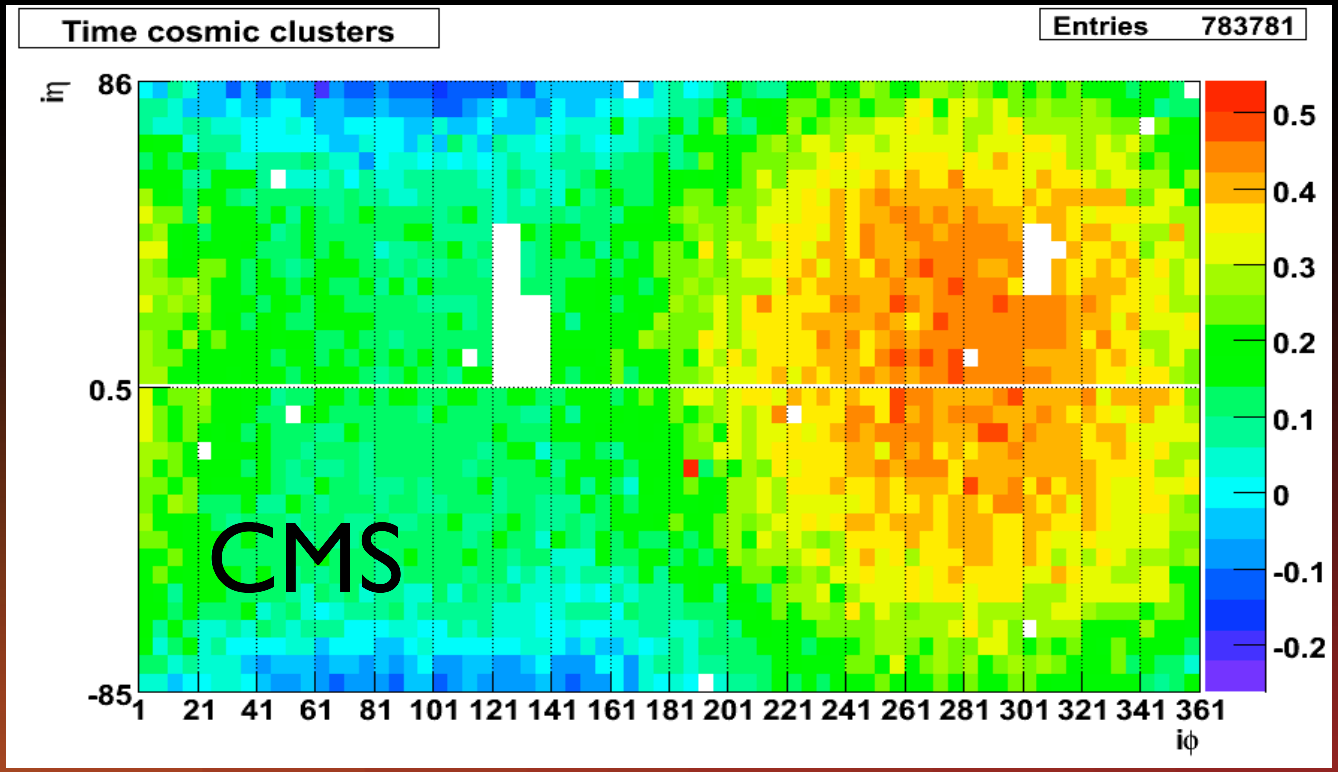




Commissioning and Data Preparation

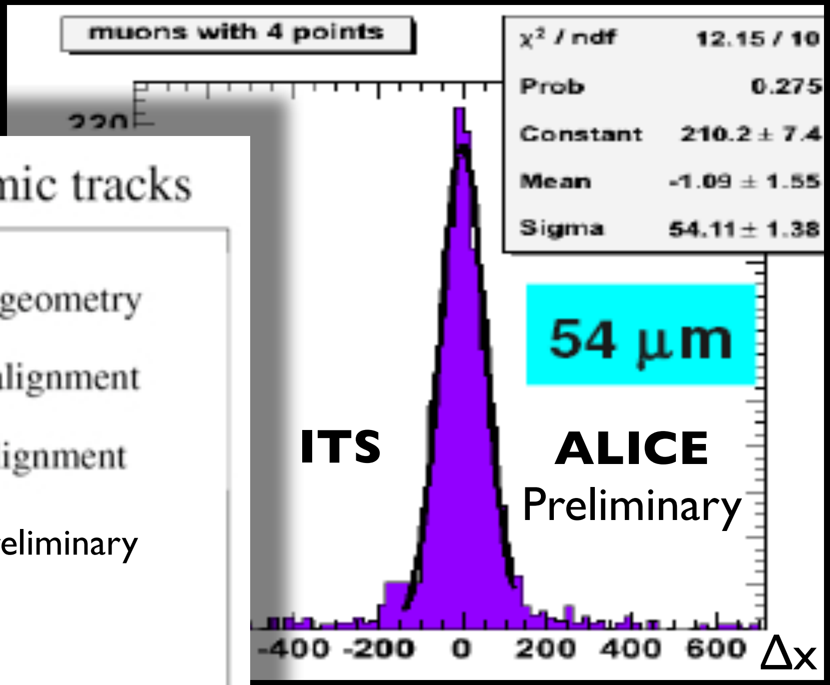
- detector calibration
  - ➡ started with test beam data
  - ➡ experiments did calibration tests in 2008 to prepare for data taking
  - ➡ first beam and halo events
  - ➡ large samples of cosmic events
- intense program of software developments
  - ➡ instrument all reconstruction to use conditions information
  - ➡ procedures to extract constants from data and from online information (detector status, etc...)
  - ➡ results been feed back also to simulation
- reprocessing exercises
  - ➡ validate results and study performance

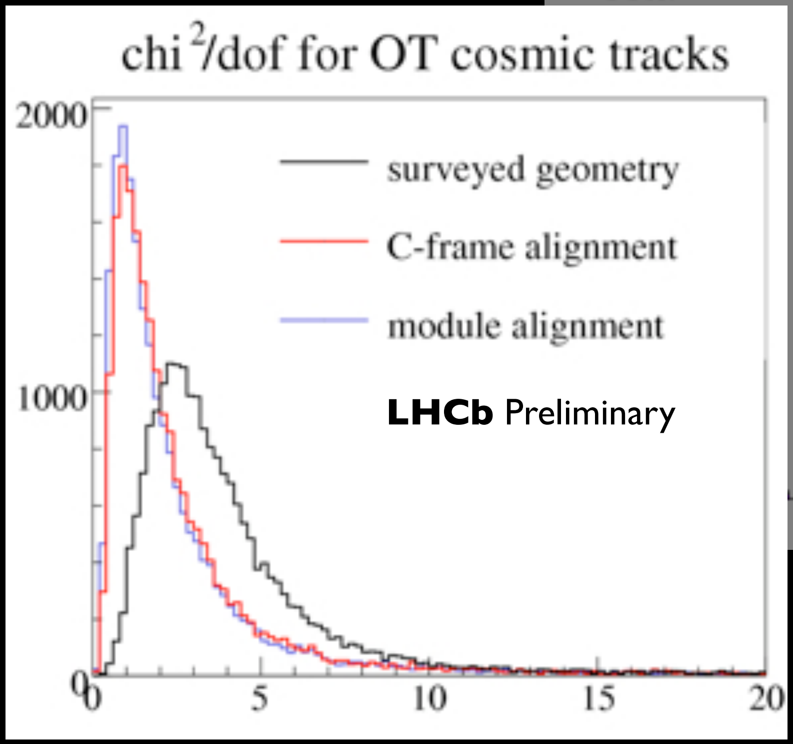


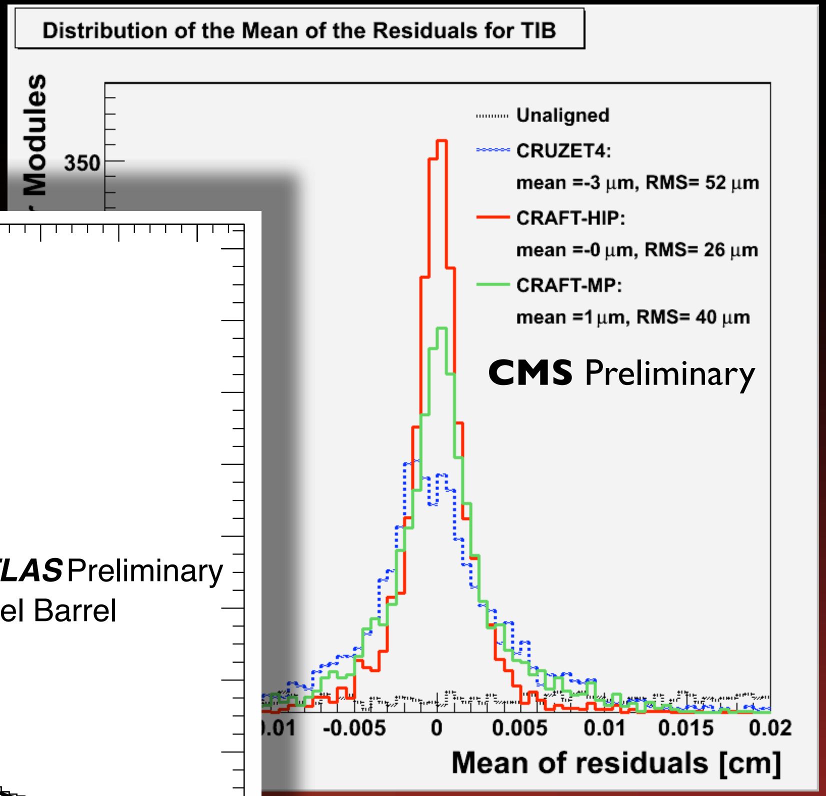


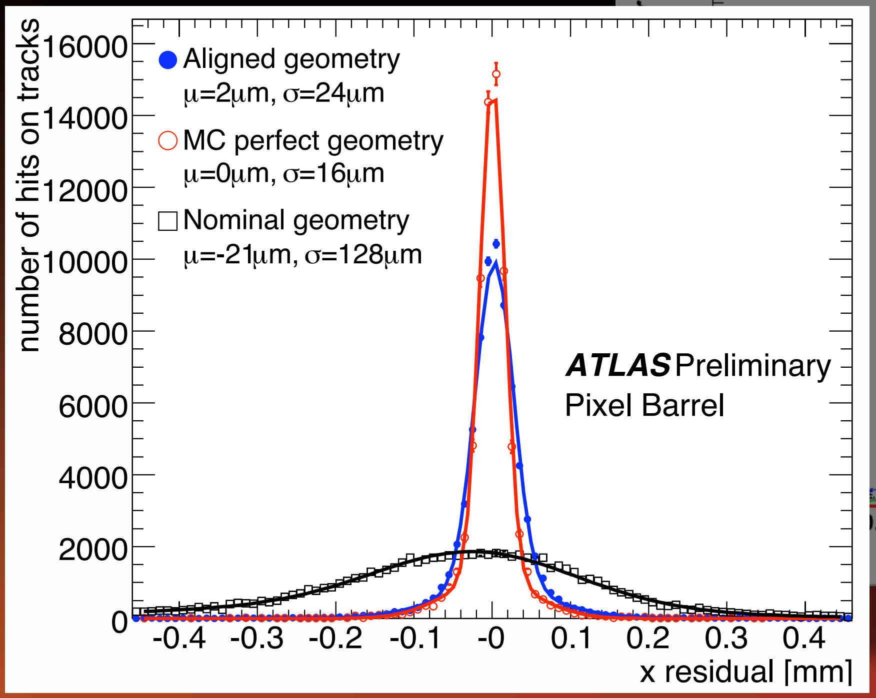
Detector Alignment

- large tracking systems
  - ➡ 100K(36K) D.O.F. for CMS(ATLAS)
  - ➡ hardware alignment systems
- different approaches
  - ➡ resolve global-χ^2 using spare matrix techniques (e.g. Millipede II)
  - ➡ Kalman Filter and local approaches
- so called “weak modes”
  - ➡ deformations that leave χ^2 invariant
  - ➡ tracks collisions and cosmics, ...
- series of LHC alignment workshops
  - ➡ 3rd planned for June 15-16
- initial alignment results
  - ➡ based cosmics or beam induced particles (LHCb velo)



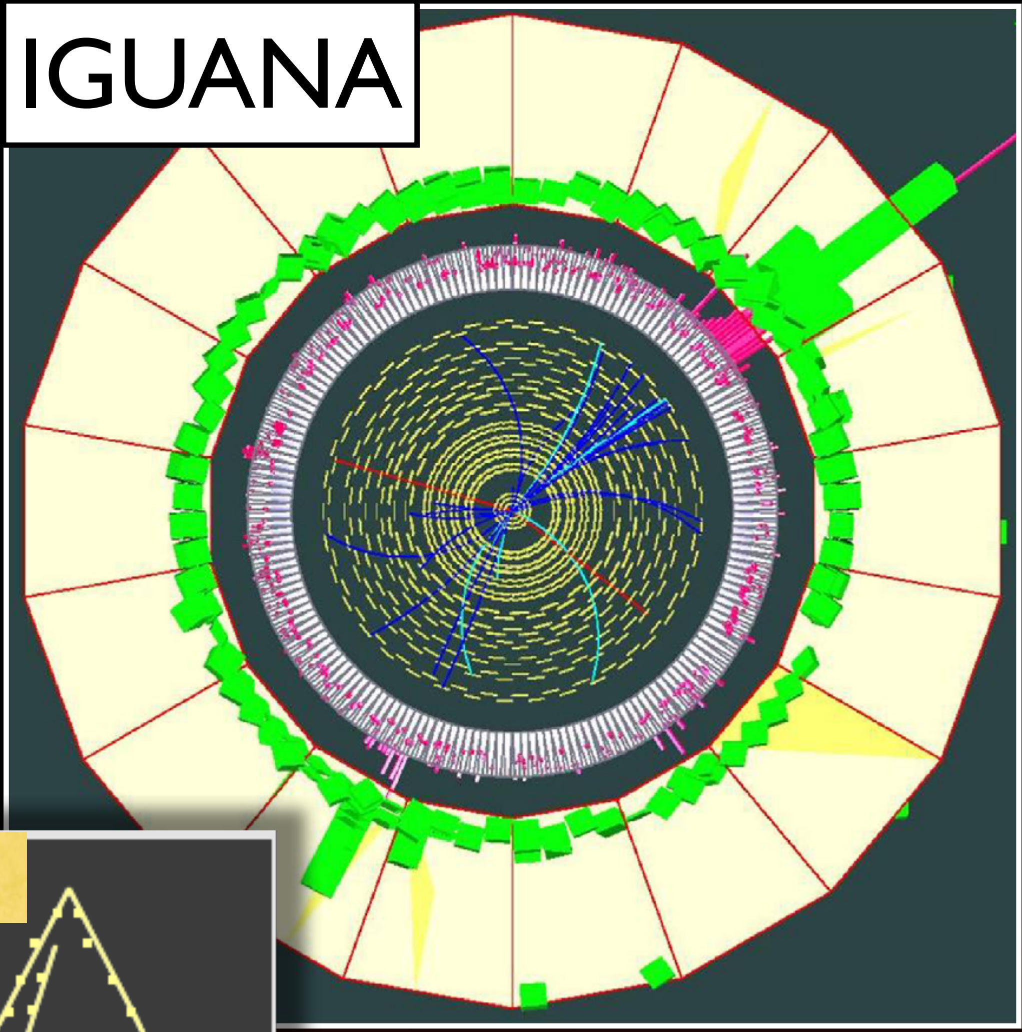


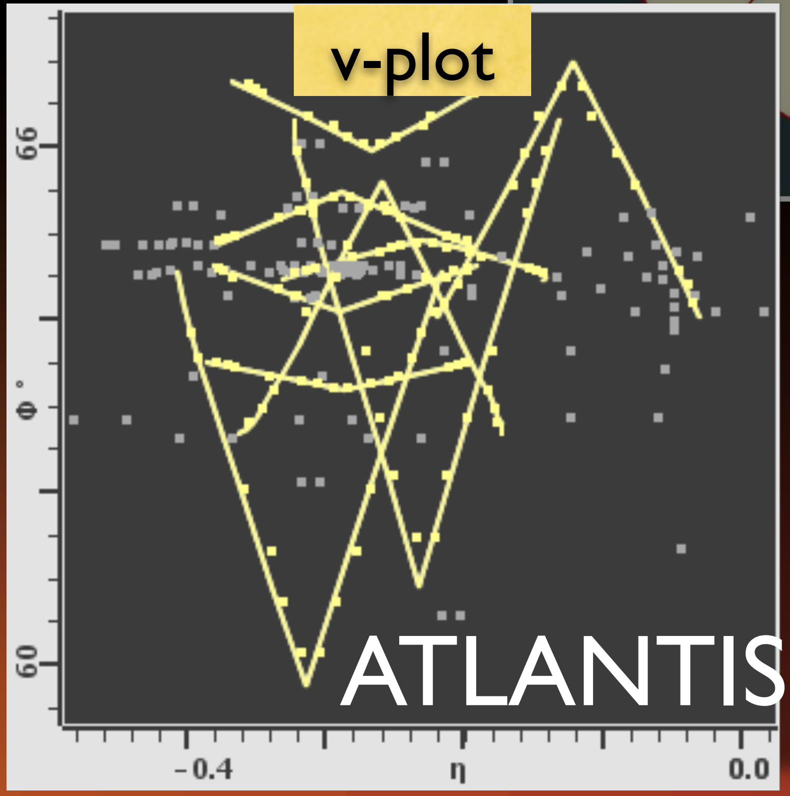




Event Displays and Commissioning

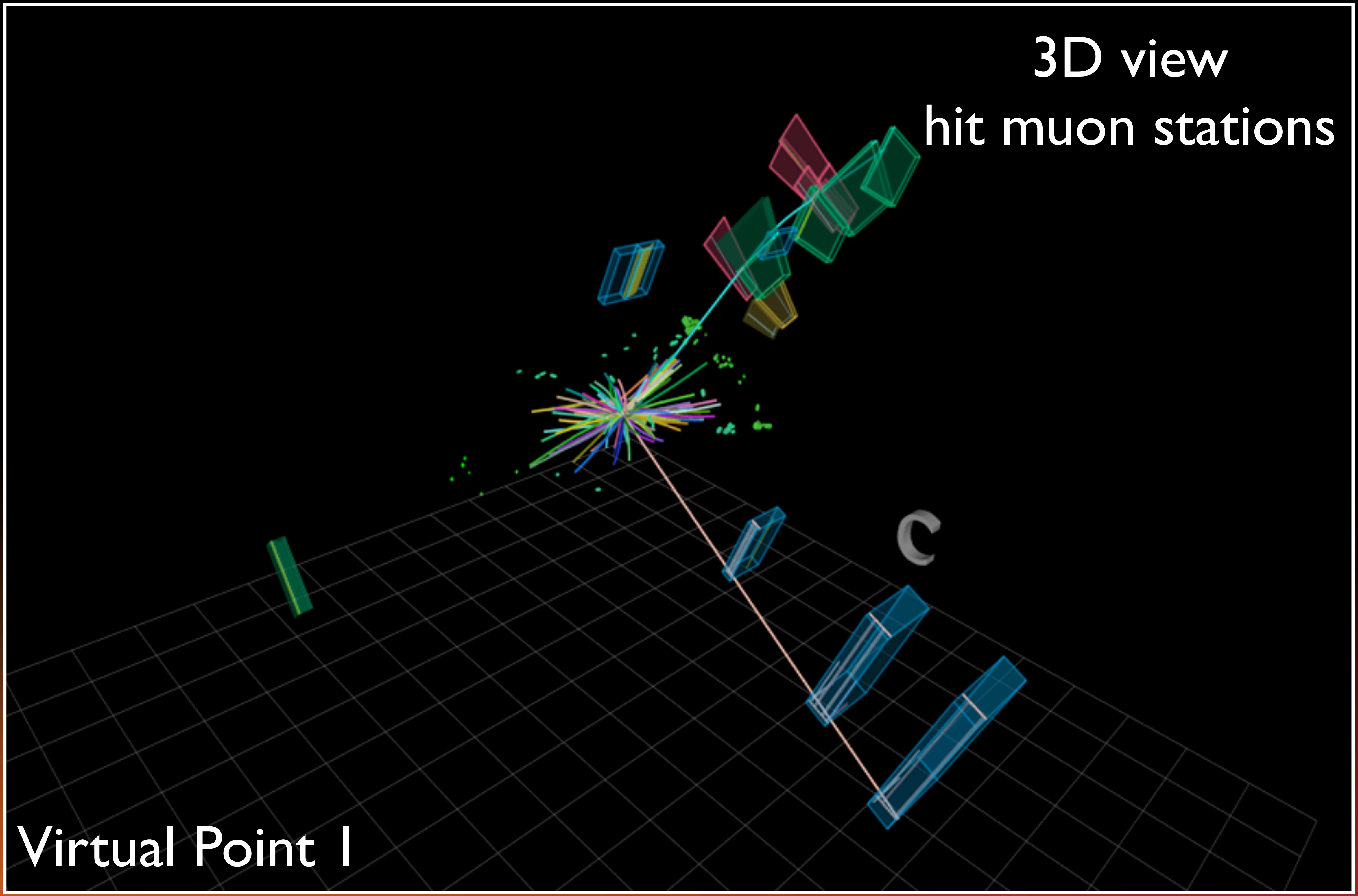
- commissioning the detector benefits from a good display
  - ➡ online event display integral part of data quality monitoring
  - ➡ offline analysis and visual debugging
- functionality vs need for intuitive user interface
  - ➡ must be easy to visualize the important aspects of events
- different techniques
  - ➡ adequate projections
  - ➡ navigation in the event
  - ➡ interactive event analysis



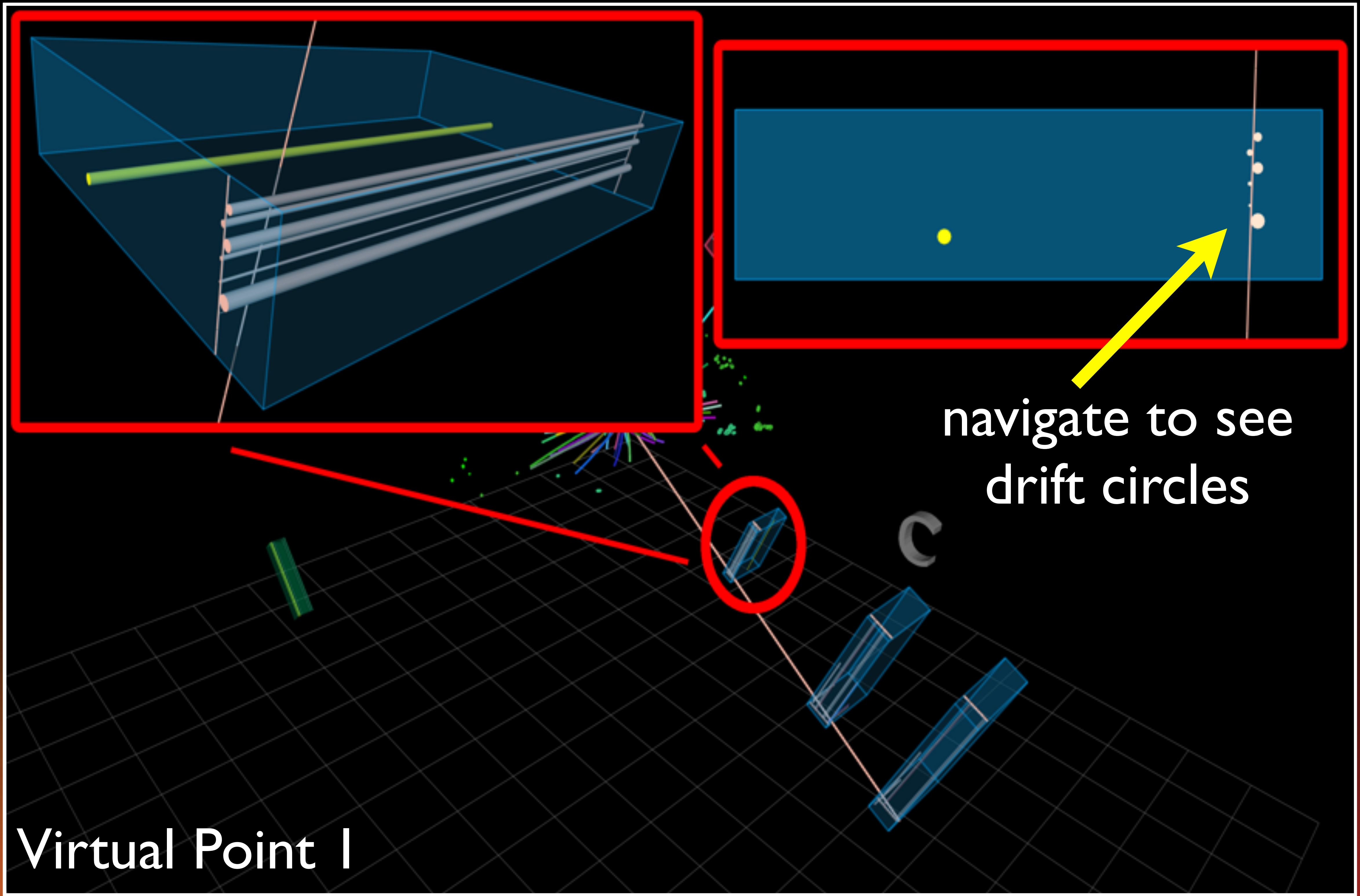


examples for 2D projections

Example for Navigating the Event

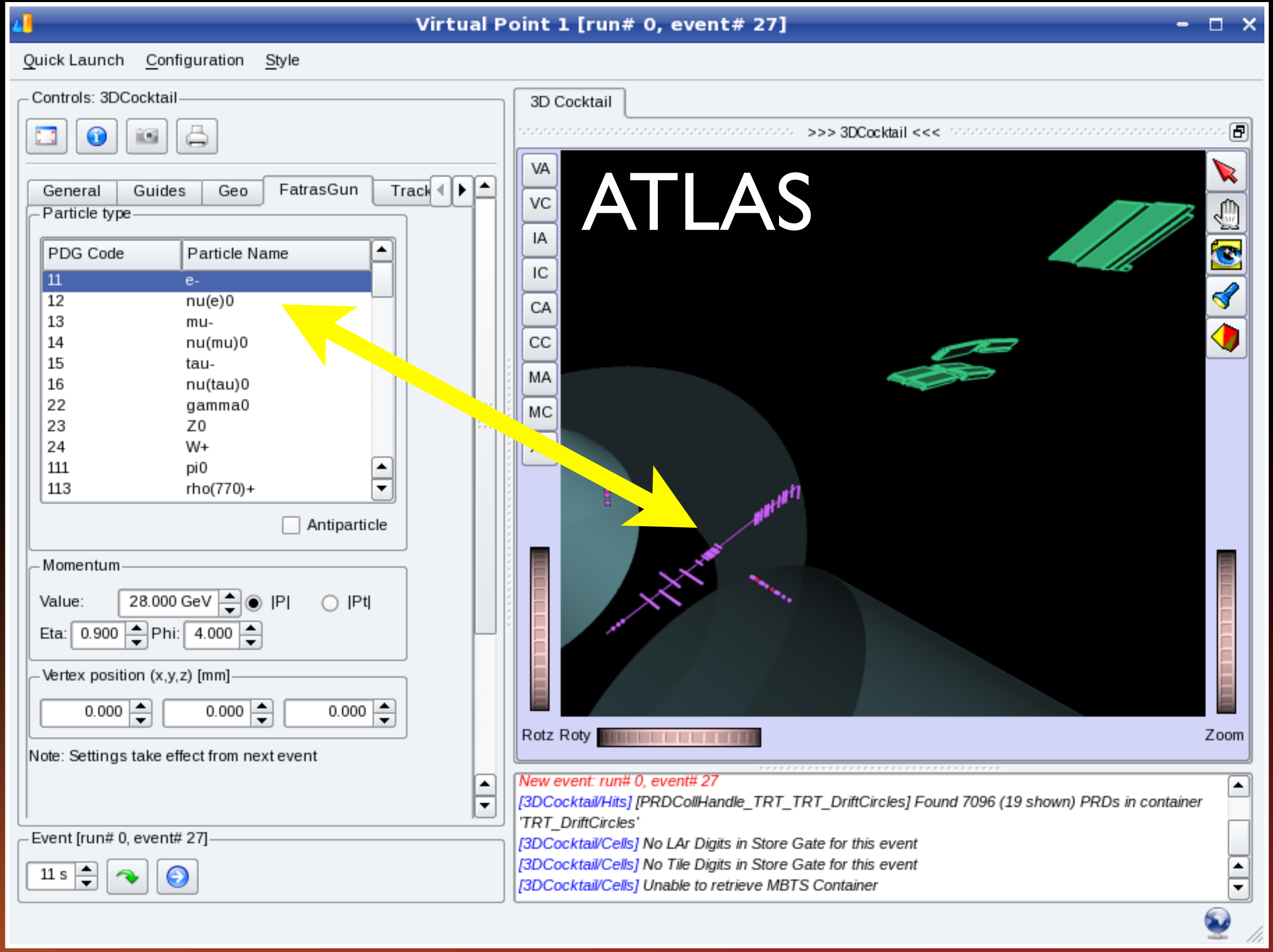


Example for Navigating the Event



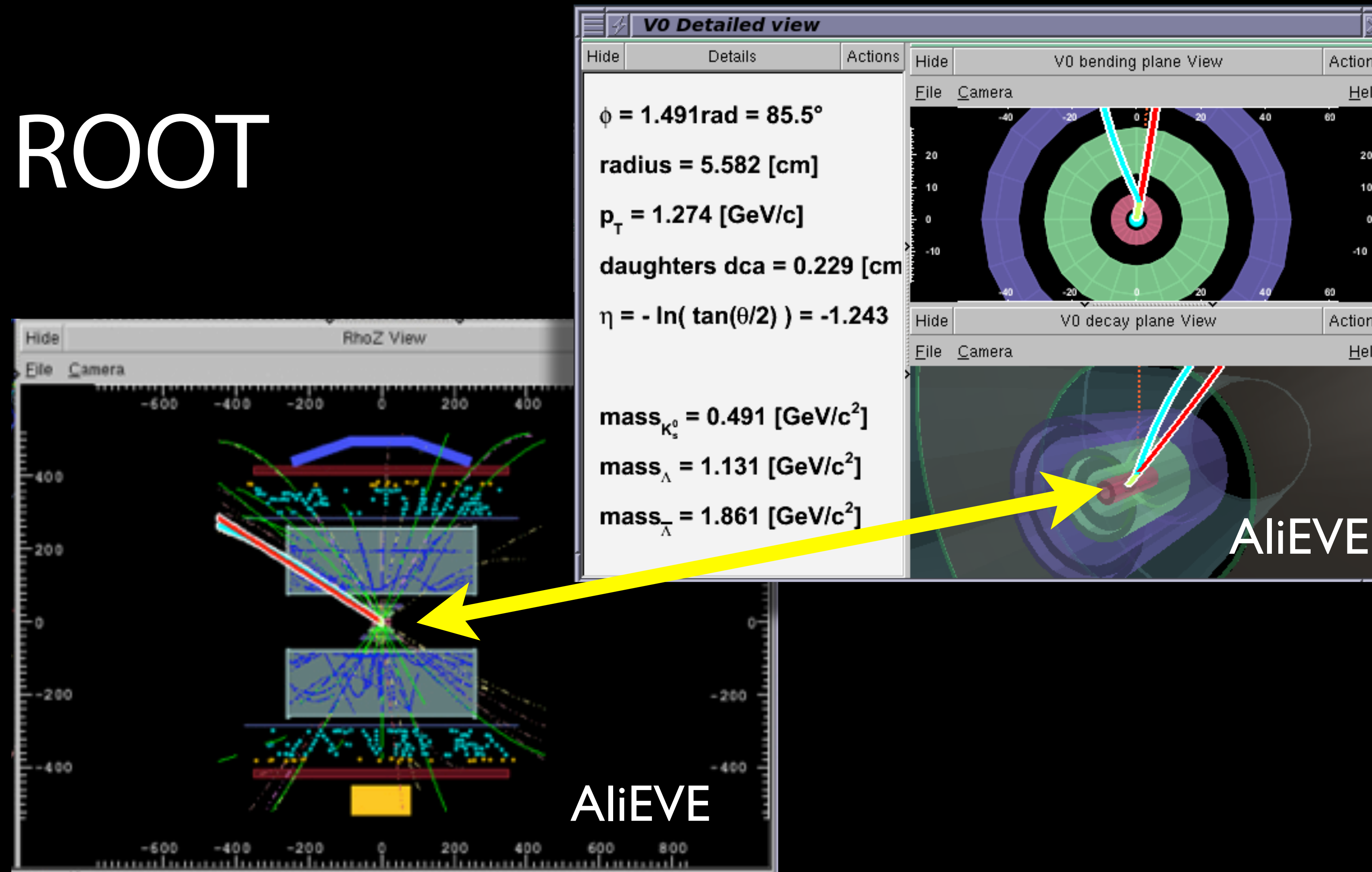
Interactivity and Event Visualization

- Interactivity
  - ➡ requires full integration of graphics with software framework
  - ➡ sometimes conflicting with portability (runs on my laptop ?)
  - ➡ many use-cases
- example: Virtual Point I and FATRAS
  - ➡ single particle gun
  - ➡ fast simulation
  - ➡ reconstruction
  - ➡ visualization
  - ➡ inside ATHENA framework
  - ➡ control via GUI

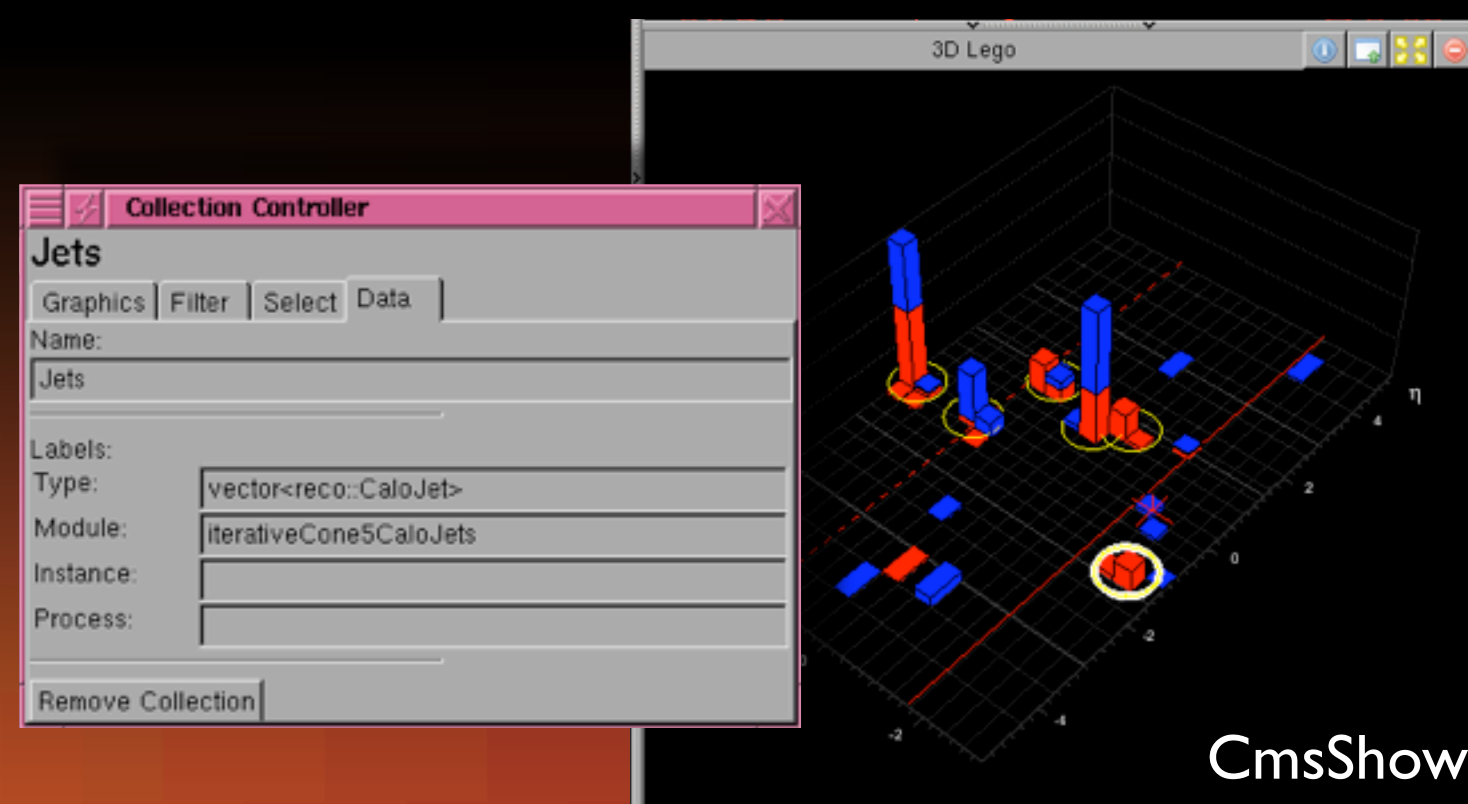


Interactivity in ROOT

- AliEVE uses CINT macros
  - ➡ process event data, create visual representations
  - ➡ thin GUI layer to steer macro execution
  - ➡ example: select and display V0 candidates

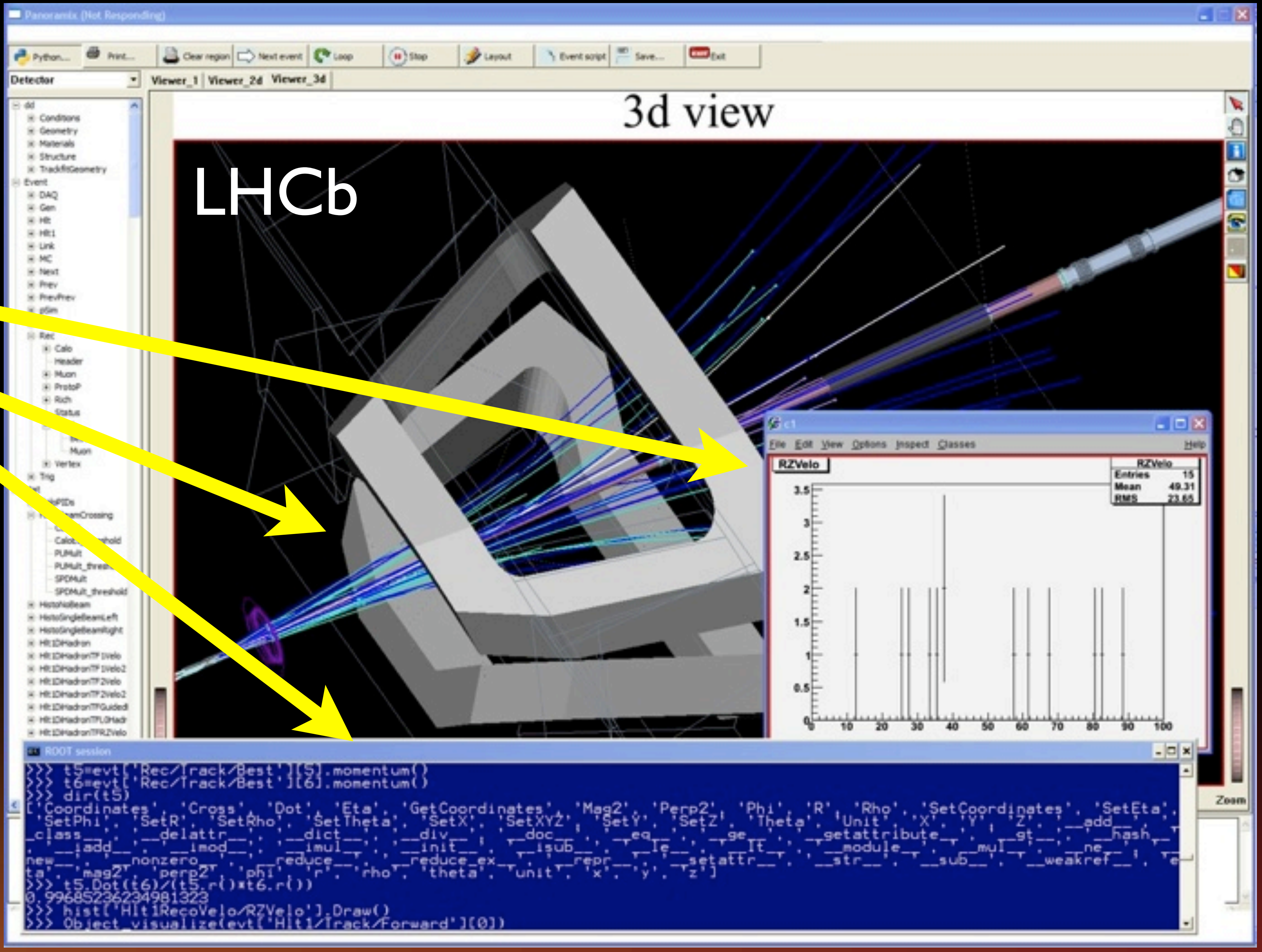


- CmsShow/Fireworks
  - ➡ physics oriented event display
  - ➡ ROOT + CMS framework light
  - ➡ EVE based graphics display
  - ➡ User-interface implemented in ROOT GUI
  - ➡ light installation, runs on OS X and other platforms



Interactive Analysis in GAUDI

- GAUDI python
  - ➡ histogramming
  - ➡ event visualization with PANORAMIX
  - ➡ interactive session
  - ➡ execute algorithm
  - ➡ inspect event



Summary

- experiments use full and simplified geometries
  - ➡ match physics requirements of accurate G4 description
  - ➡ and needs for fast reconstruction and fast simulation
- reconstruction software is getting mature
  - ➡ more sophisticated reconstruction tools to explore all details of the events
  - ➡ common code base for offline and HLT reconstruction is a success
- experiments focus on commissioning
  - ➡ procedures to calibrate and alignment the detectors
  - ➡ increased use of conditions data in reconstruction and simulation
- event displays play their role online and offline
  - ➡ indispensable for the commissioning of the detectors and their software
  - ➡ navigation to relevant information in complex events and interactivity

Acknowledgements

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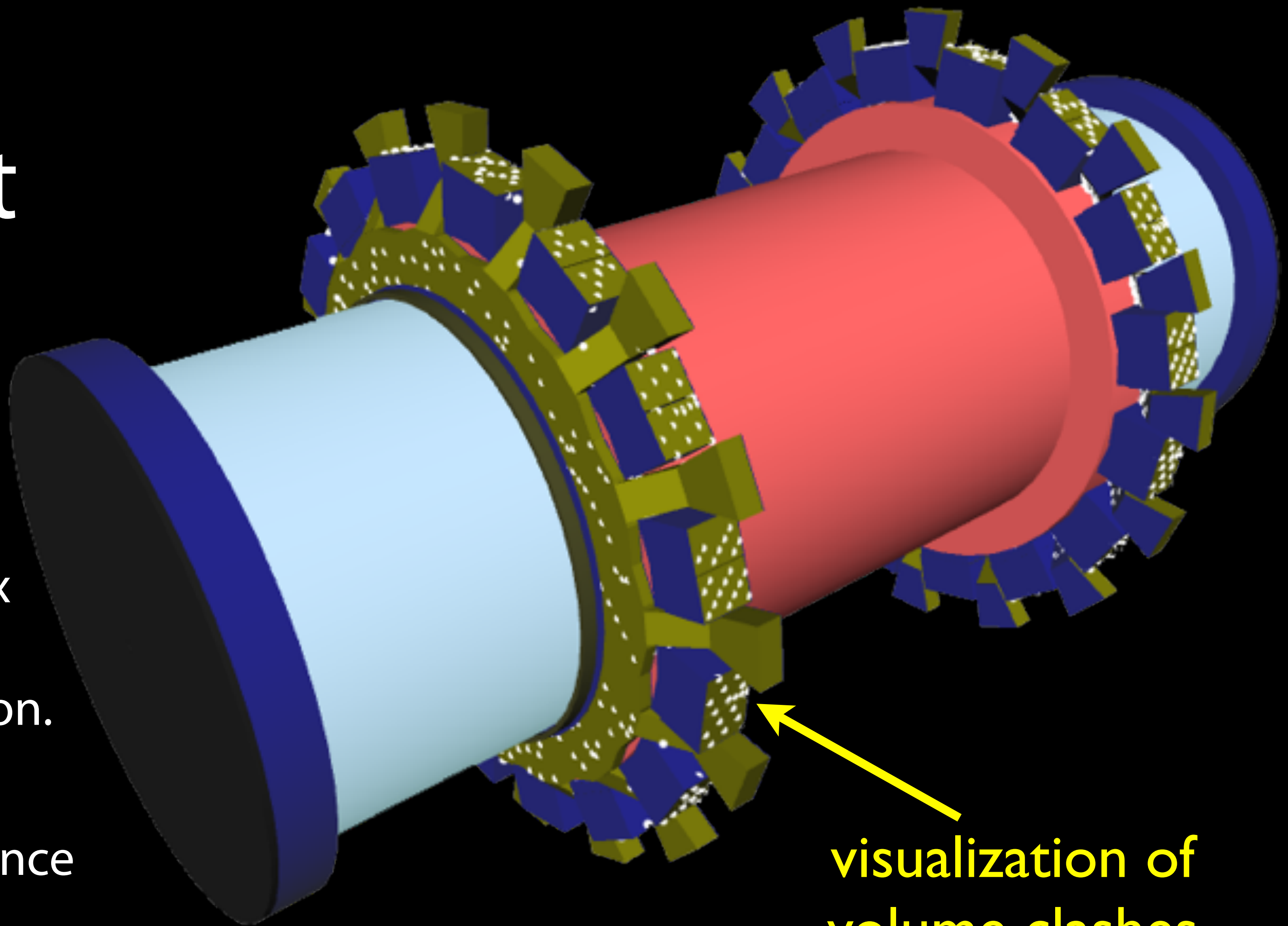
BackUP

GeoModel Toolkit

- library of geometrical primitives
  - ➡ designed as data layer
  - ➡ describing large and complex detector systems
  - ➡ minimal memory consumption.
- memory optimization
  - ➡ shared instancing with reference counting
  - ➡ compressed representation of Euclidean transformations
  - ➡ parameterizations through embedded symbolic expressions of transformation fields
- native mechanism of mis-aligning detectors
  - ➡ 'alignable' delta transformations



- GeoModel serves as central storage of the detector description for all clients
  - ➡ GeoModel description is translated to Geant4 format on the fly, using special translator (Geo2G4)