The ATLAS New Track Reconstruction

Concept, Design, Implementation and Performance

A. Salzburger, University of Innsbruck & CERN
on behalf of the ATLAS Collaboration

universität innsbruck

ATC
ATLAS COMPUTING

Outline

Track Reconstruction in ATLAS

- *from ten years ago to now*
- the component model of NEWT

NEWT ID reconstruction

- inside-out sequence
- outside-in sequence
- third stage pattern

Performance

- efficiency on MC data
- track parameter resolutions and test beam comparisons

Conclusion

- where we are and where we go

06 older CHEP contribution

x other talks

B backup slides

time/evt for ttbar@NLO
Intel(R) Xeon(R) CPU 5150 @ 2.66GHz

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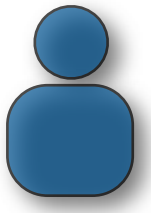
Intro: simple algebra of track reconstruction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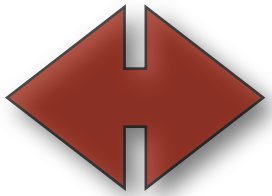
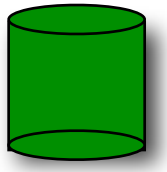
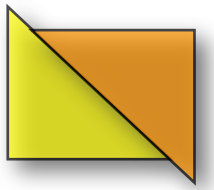
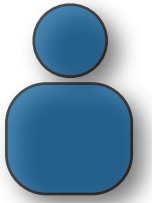

algorithmic


geometry


data model

former ATLAS track reconstruction (until 4 years ago)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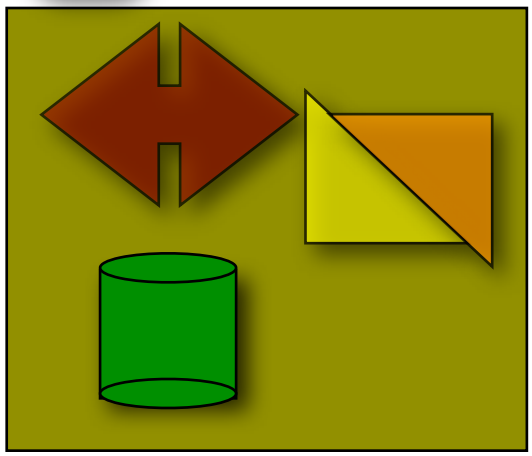

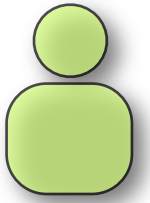
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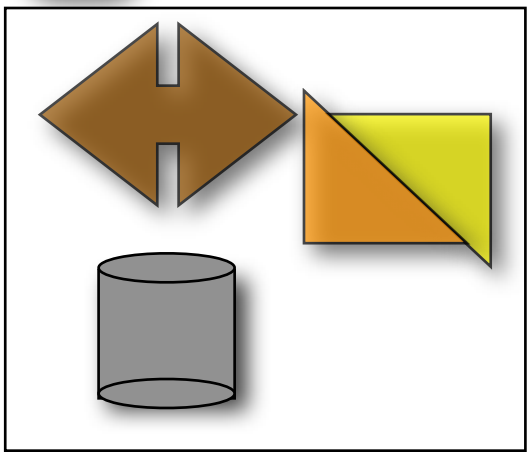

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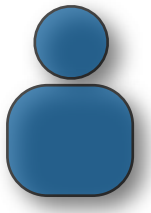

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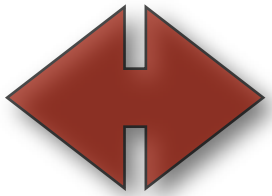

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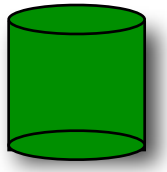

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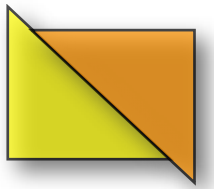

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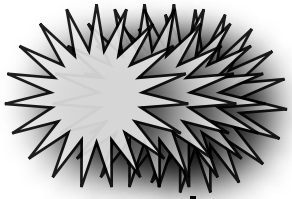

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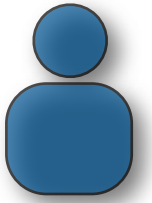

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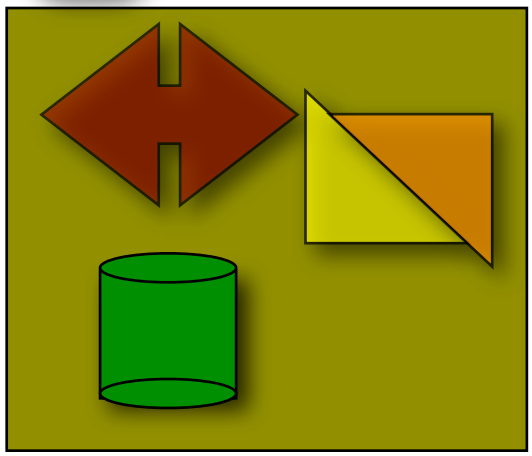

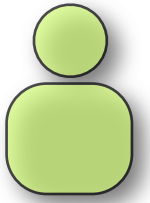

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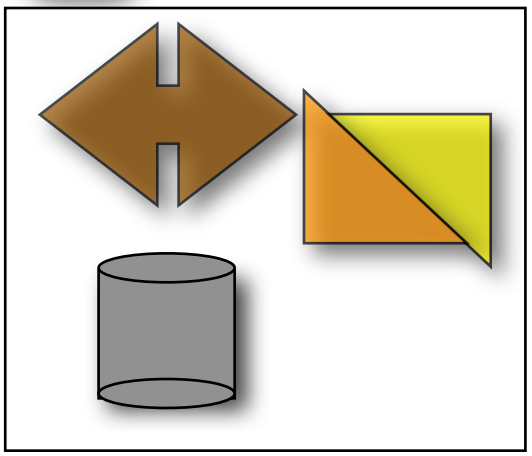

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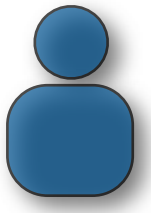

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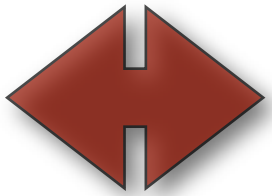

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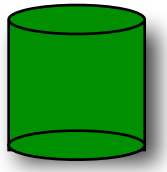

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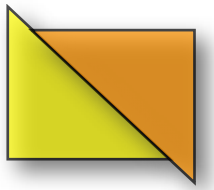

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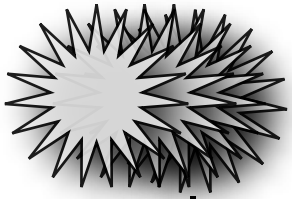

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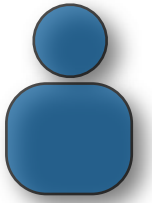

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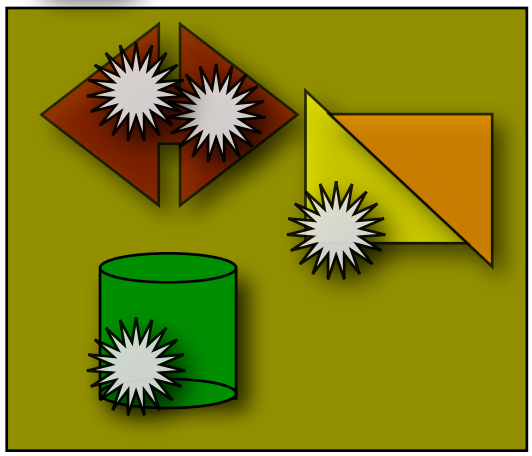

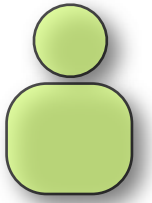

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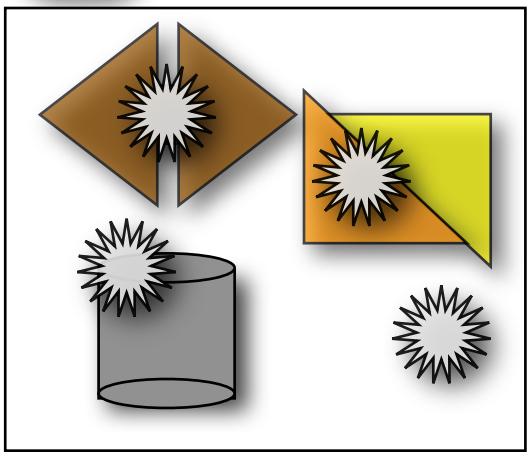

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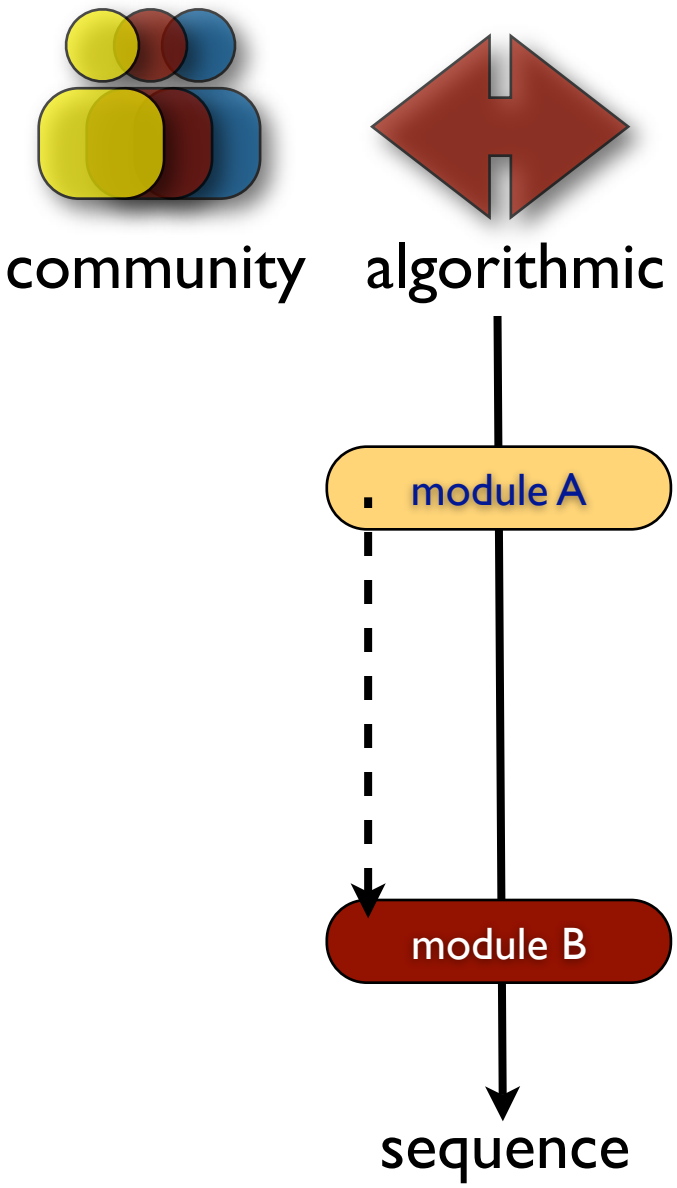

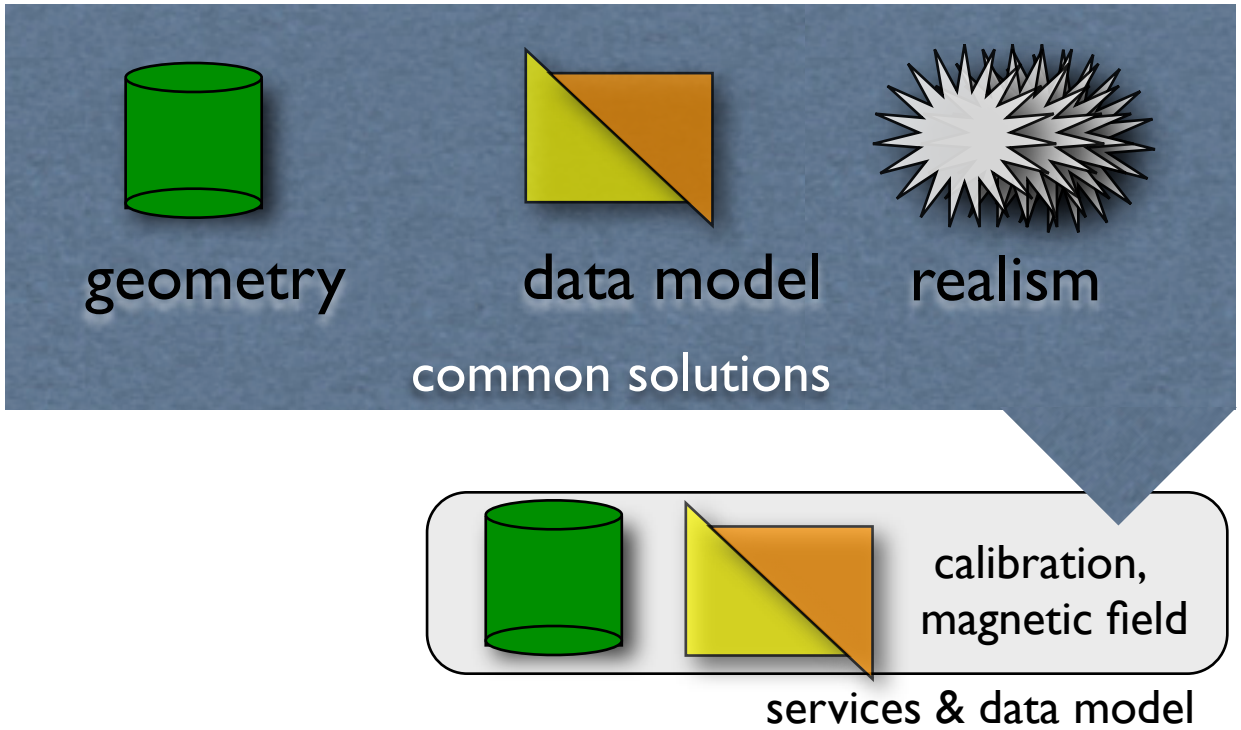

B

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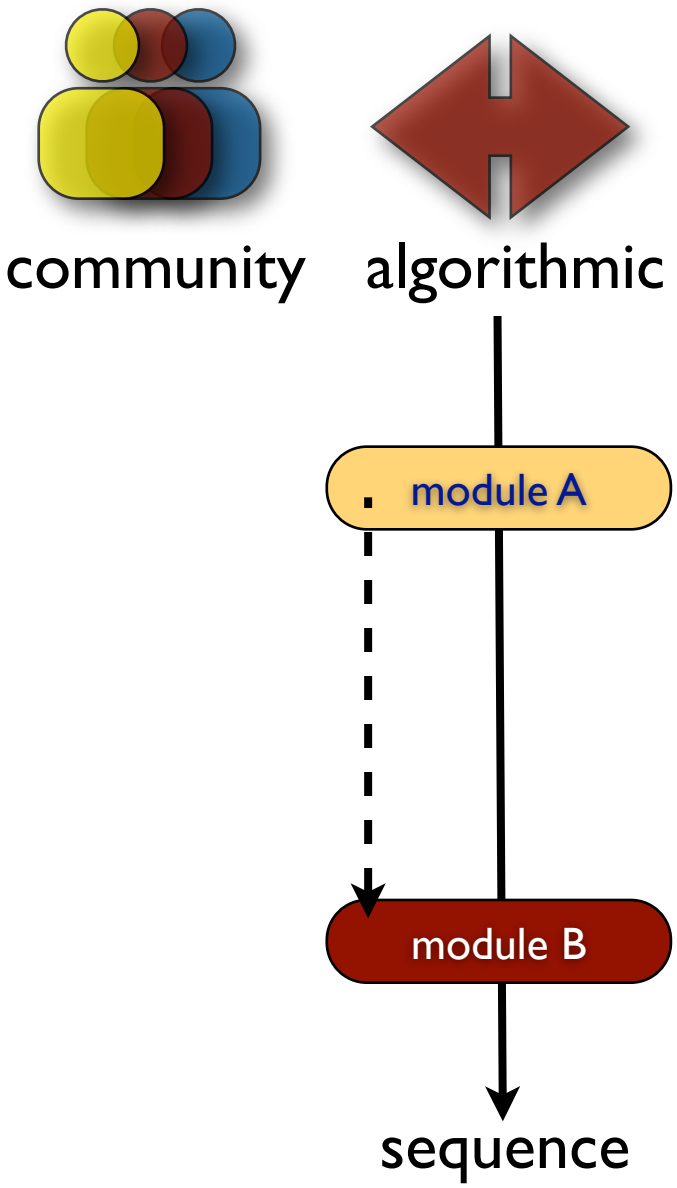

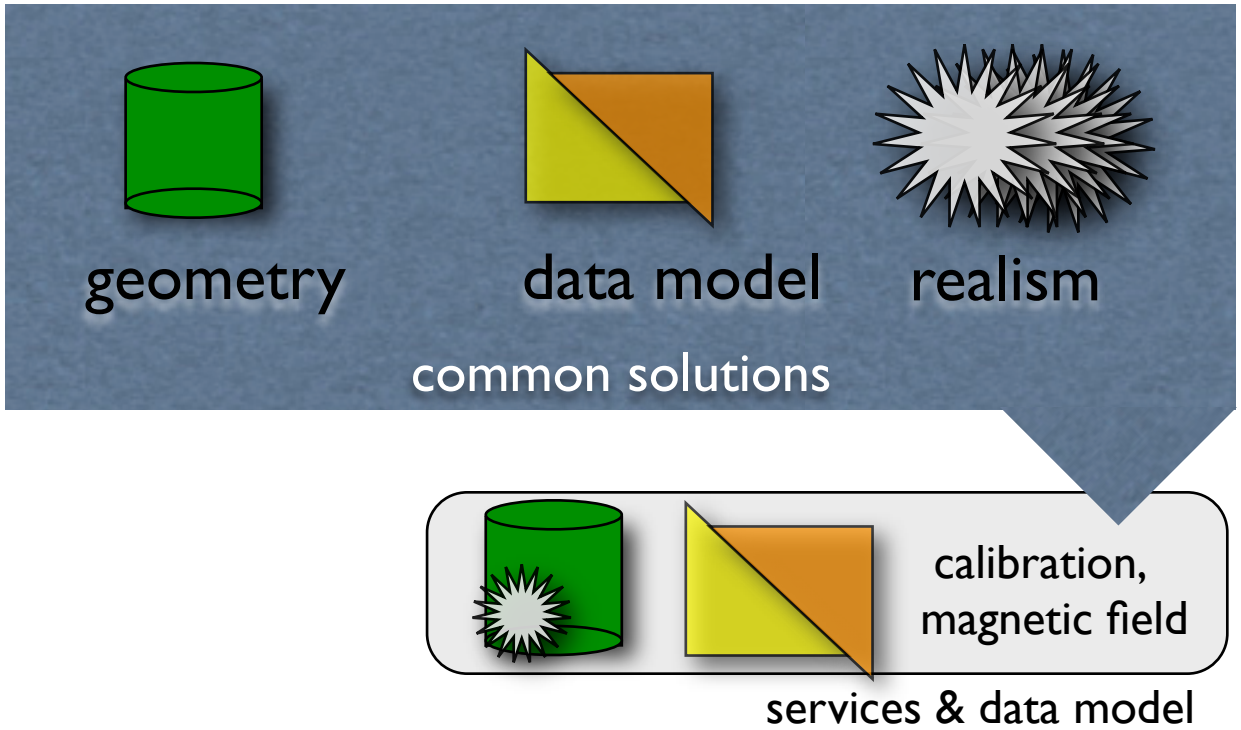

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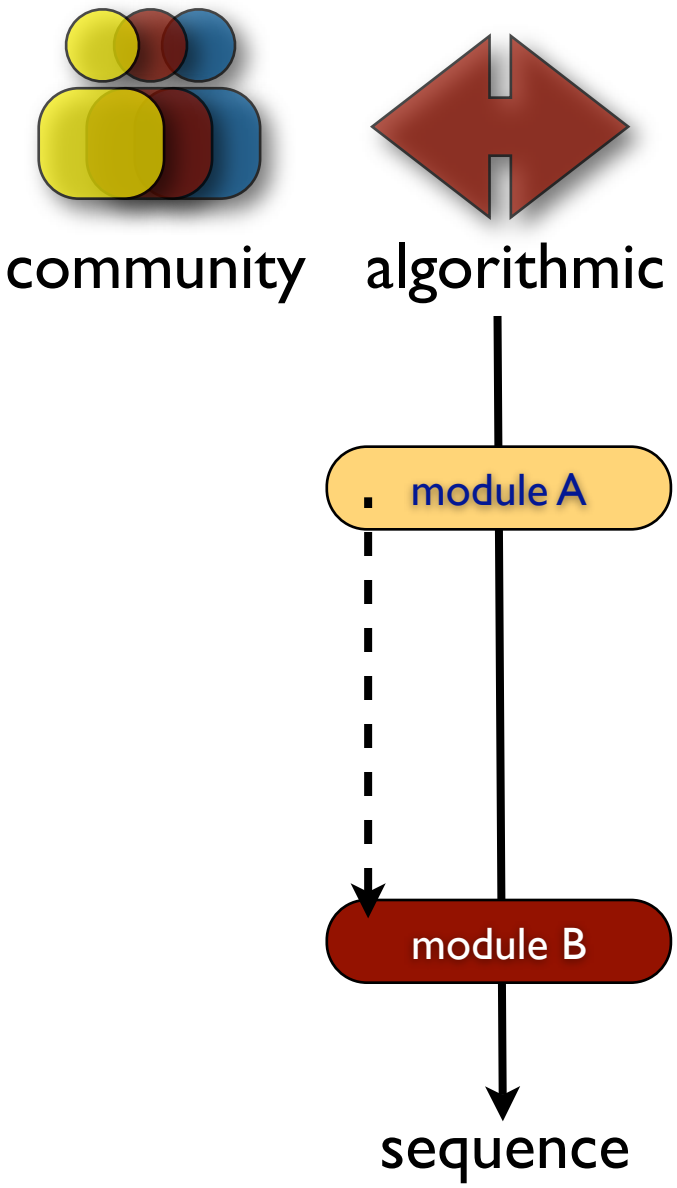

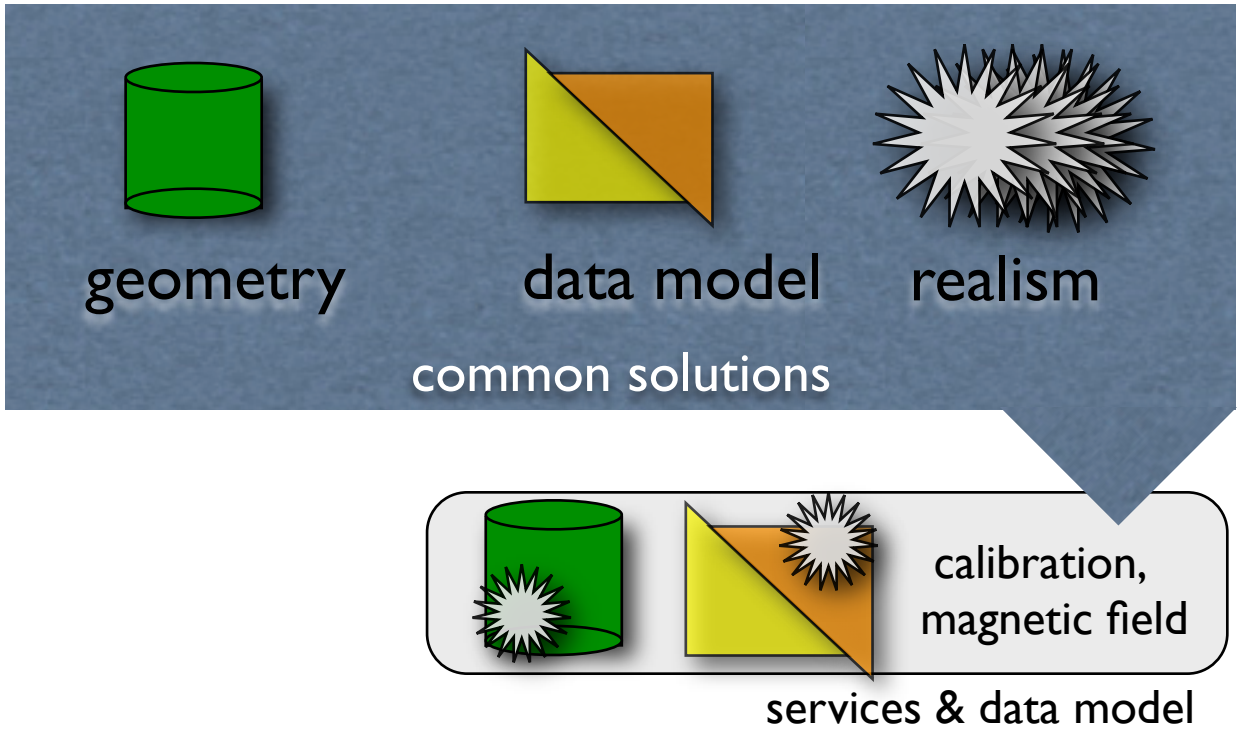

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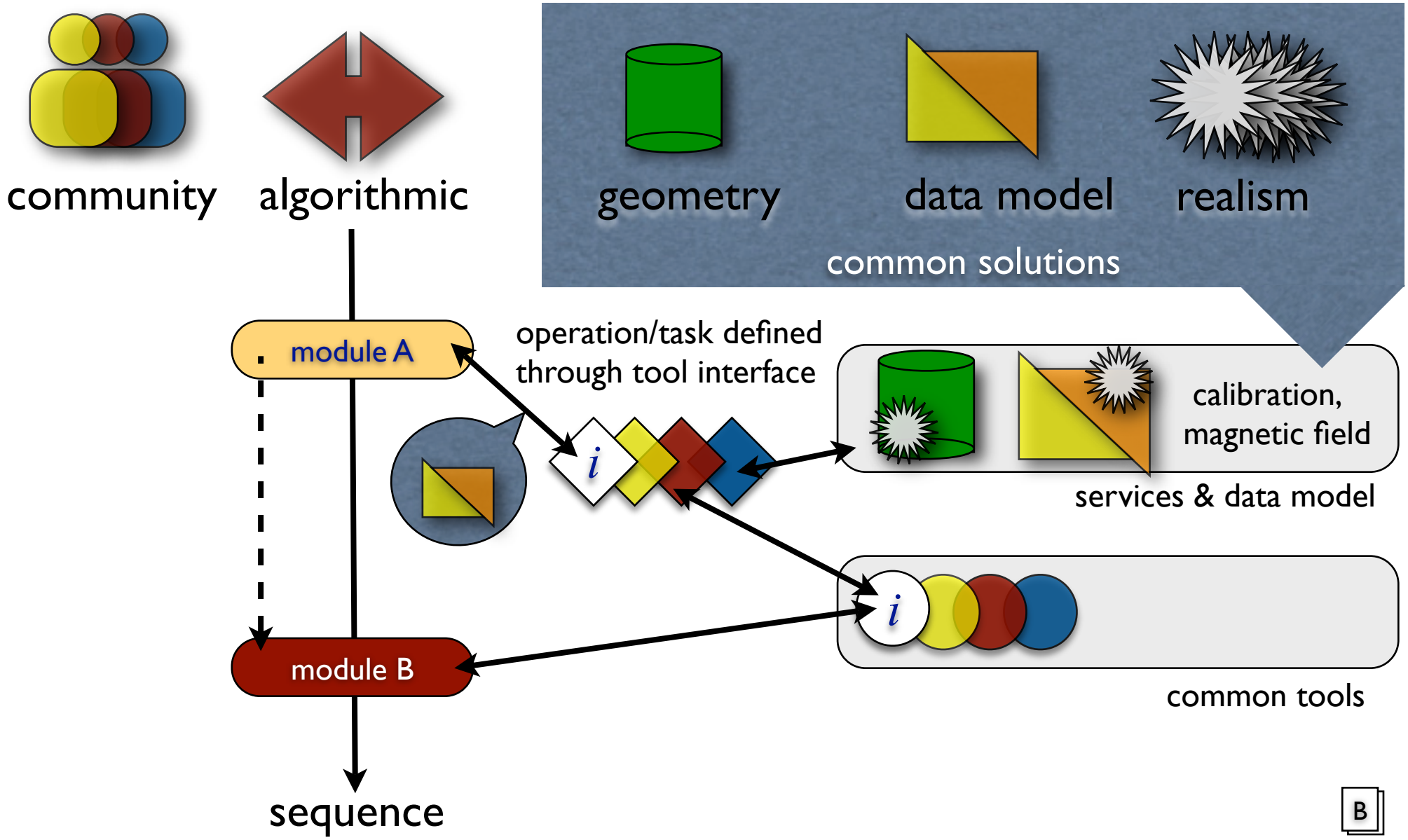

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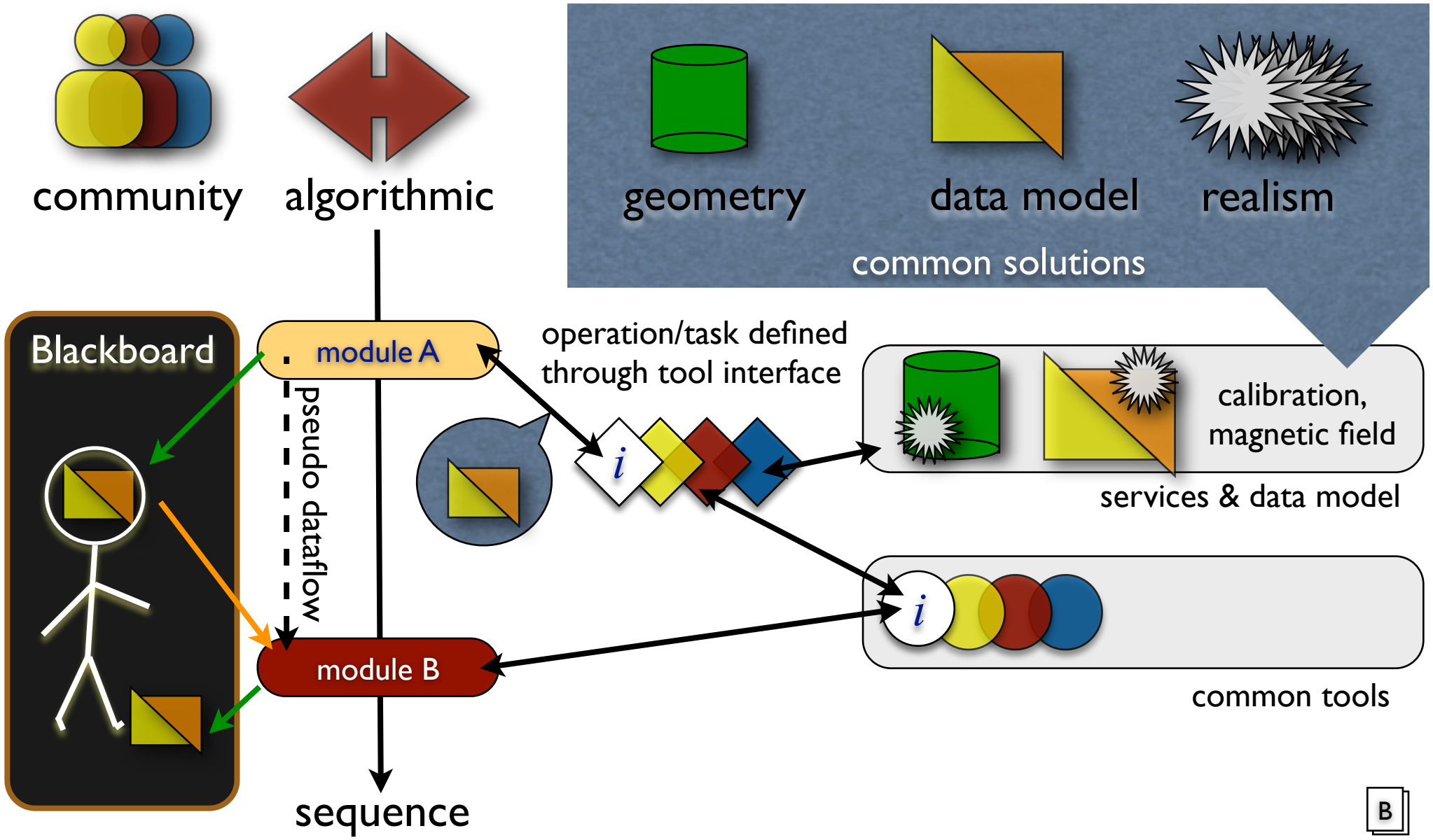
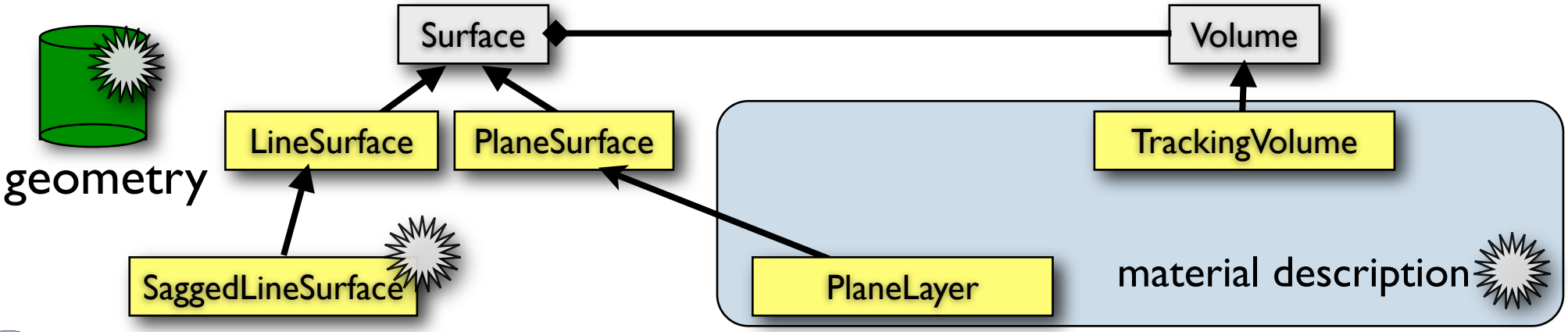


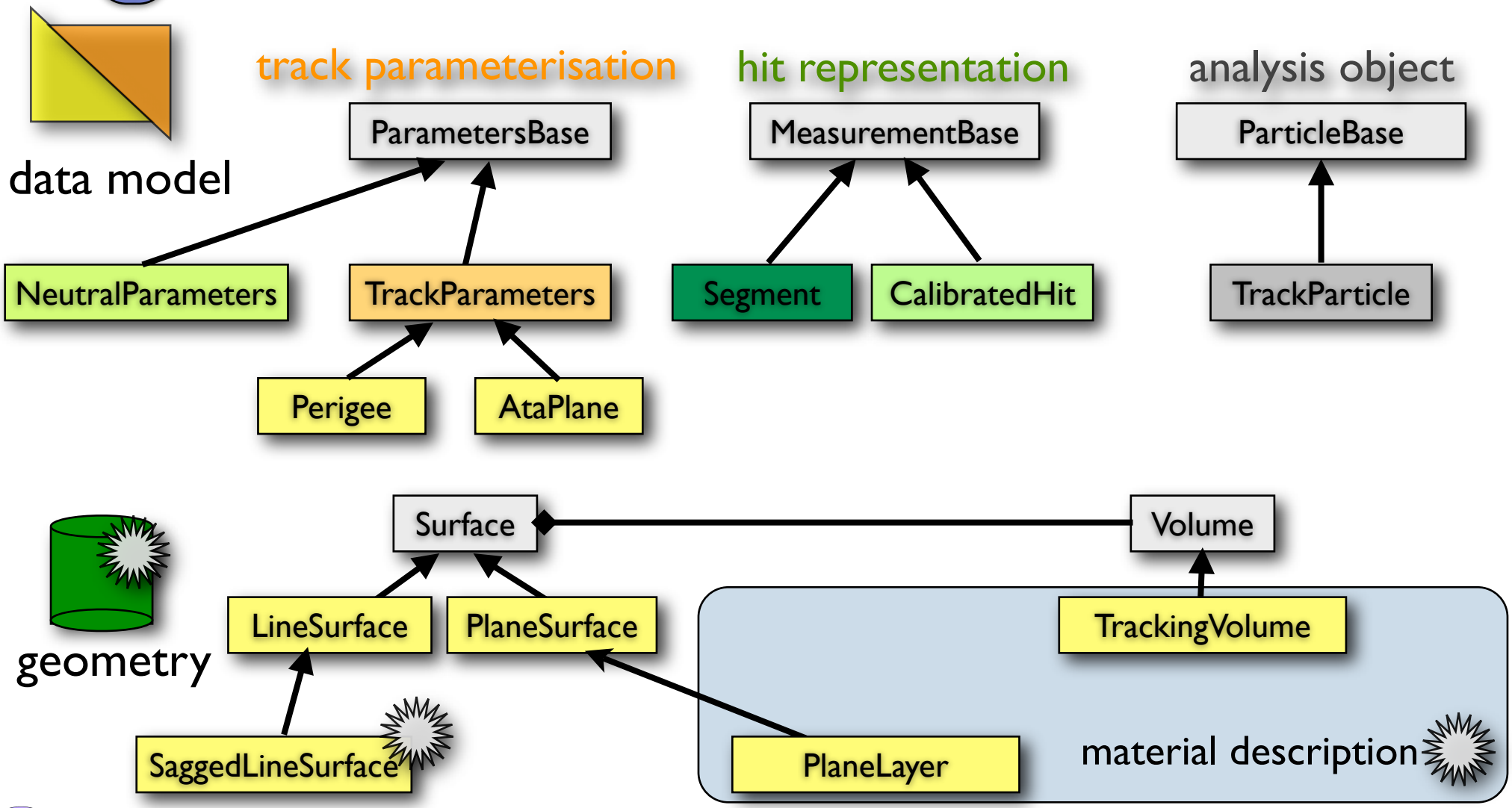
NEWT: geometry and event data model



NEWT: geometry and event data model

E. Moyse

06 04



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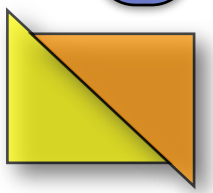


data model

many common tools work on base class level

track parameterisation

hit representation

analysis object

ParametersBase

MeasurementBase

ParticleBase

NeutralParameters

TrackParameters

Segment

CalibratedHit

TrackParticle

Perigee

AtaPlane

geometry

Surface

Volume

LineSurface

PlaneSurface

TrackingVolume

SaggedLineSurface

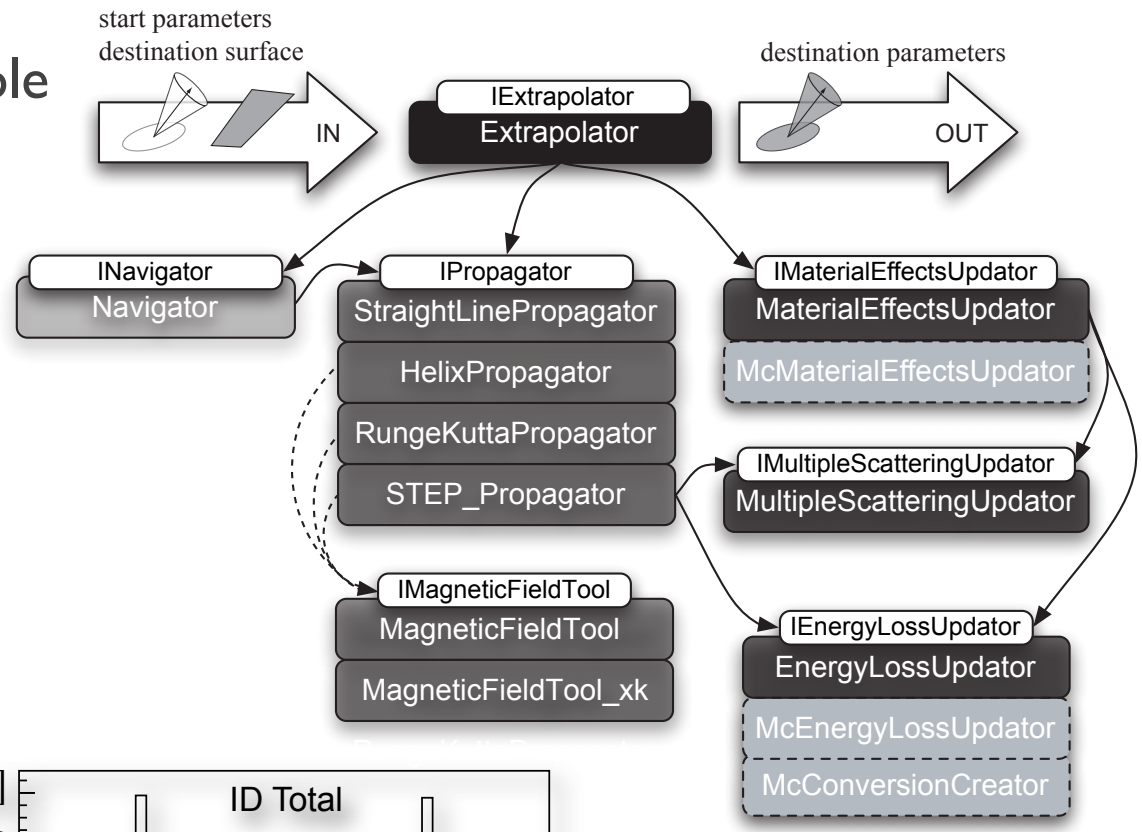
PlaneLayer

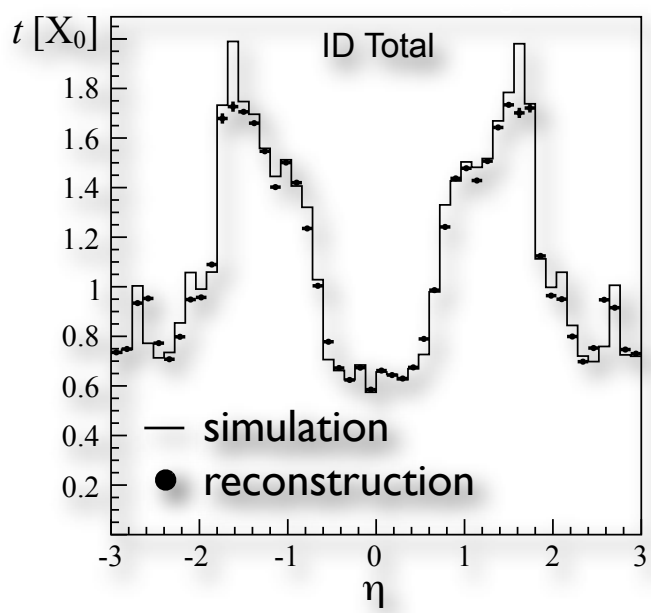
material description

NEWT: Extrapolation & TrackingGeometry

- Extrapolation engine is good example for commonly used tool
  - mathematical propagation
  - navigation
  - material effects integration

- based on a smart reconstruction geometry (TrackingGeometry)
  - all nodes extend/contain surfaces and can be used with Extrapolator
  - fully attached volume setup
  - complete navigation model B
  - enhances:
    precise material mapping
    (automatic)
    holes search
    fast track simulation



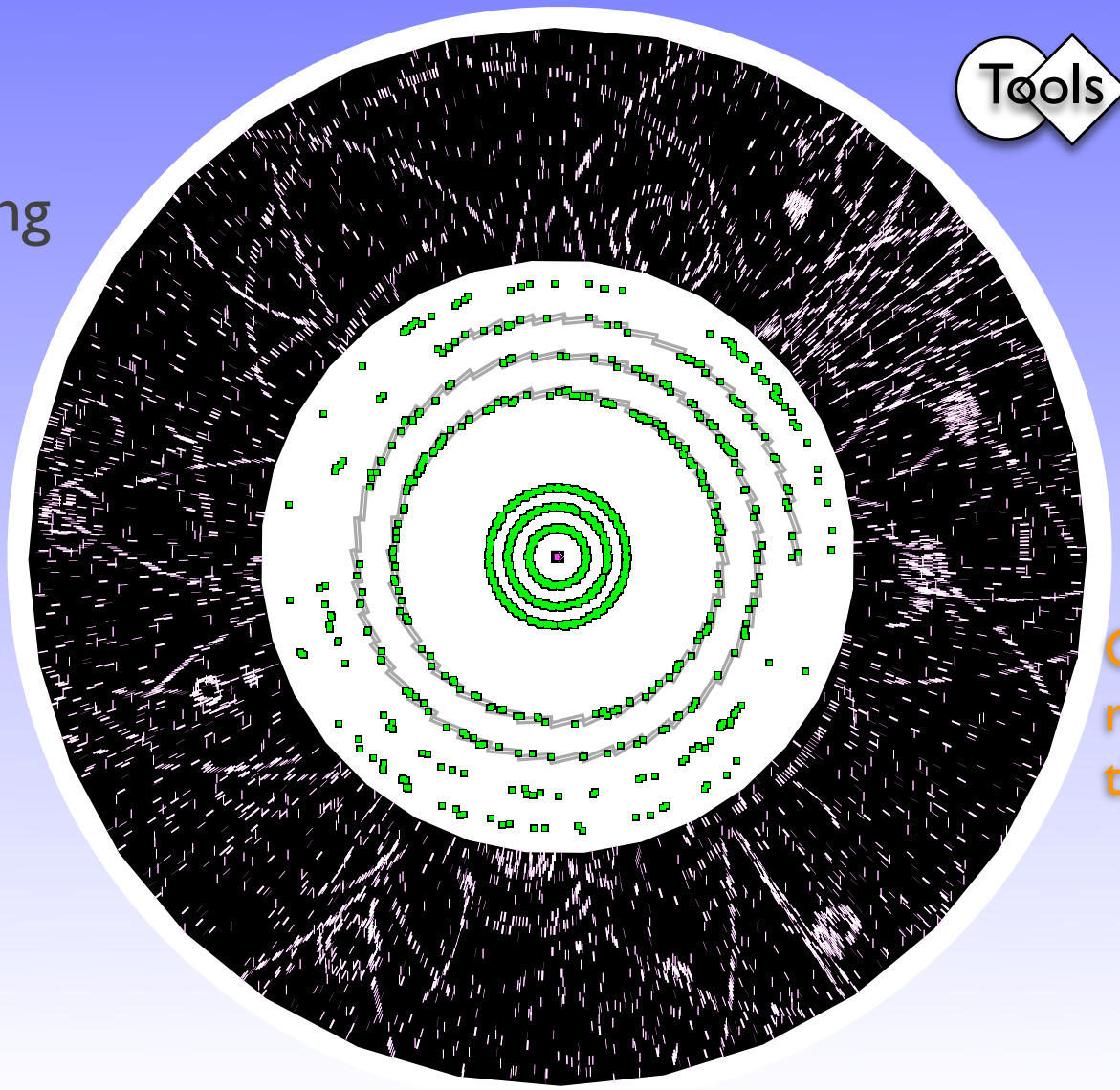


A. Salzburger 06 04

Overview: ID reconstruction (nutshell view)

Modules

- pattern finding
- track fitting
- vertexing
- conversion & V0 finding
- particle identification



Tools

- extrapolation
- material description
- magnetic field
- Hit calibration
- ambiguity Solving
- alignment
- back tracking
- brem recovery

Good performance relies on all of these components !

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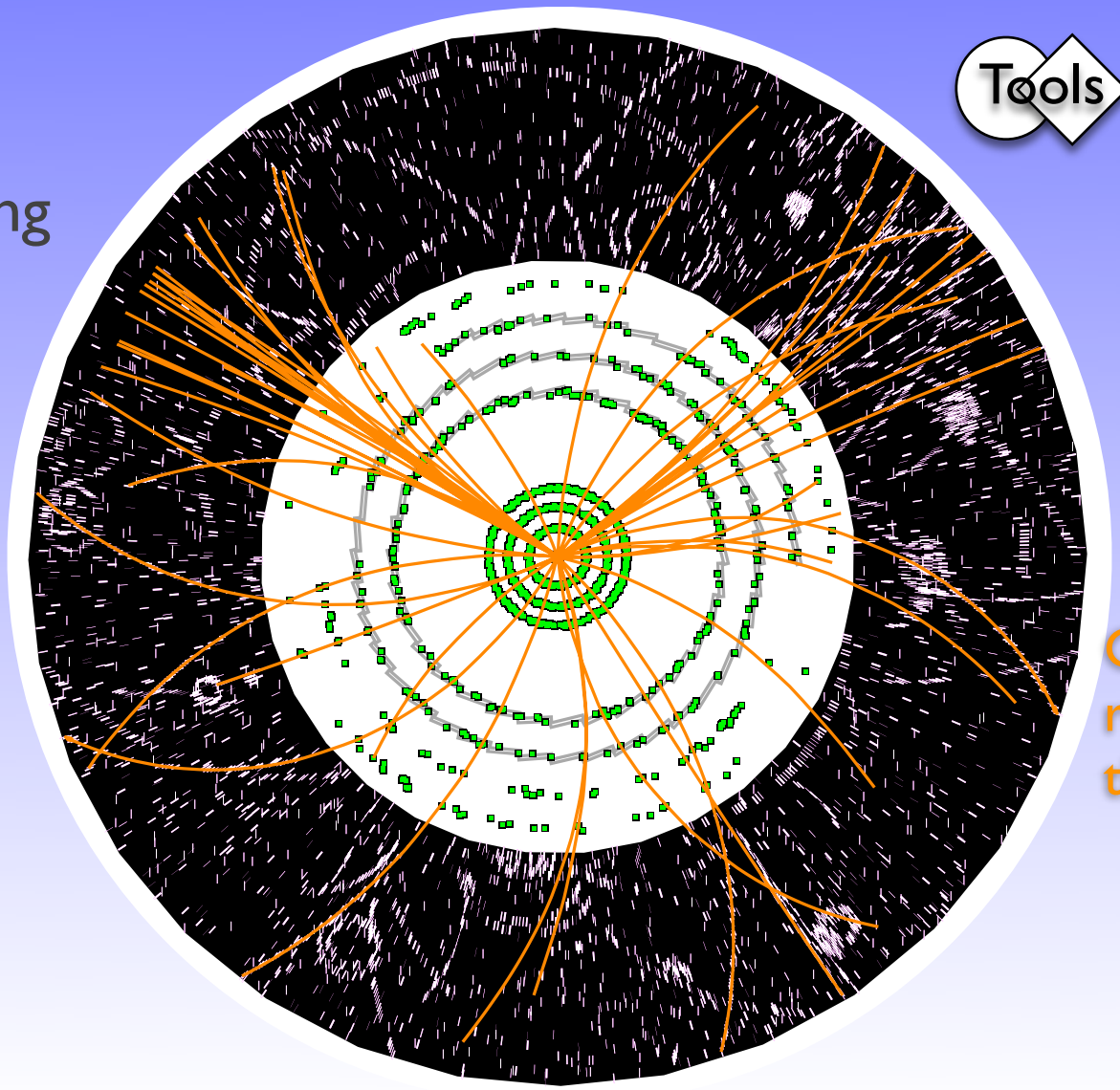

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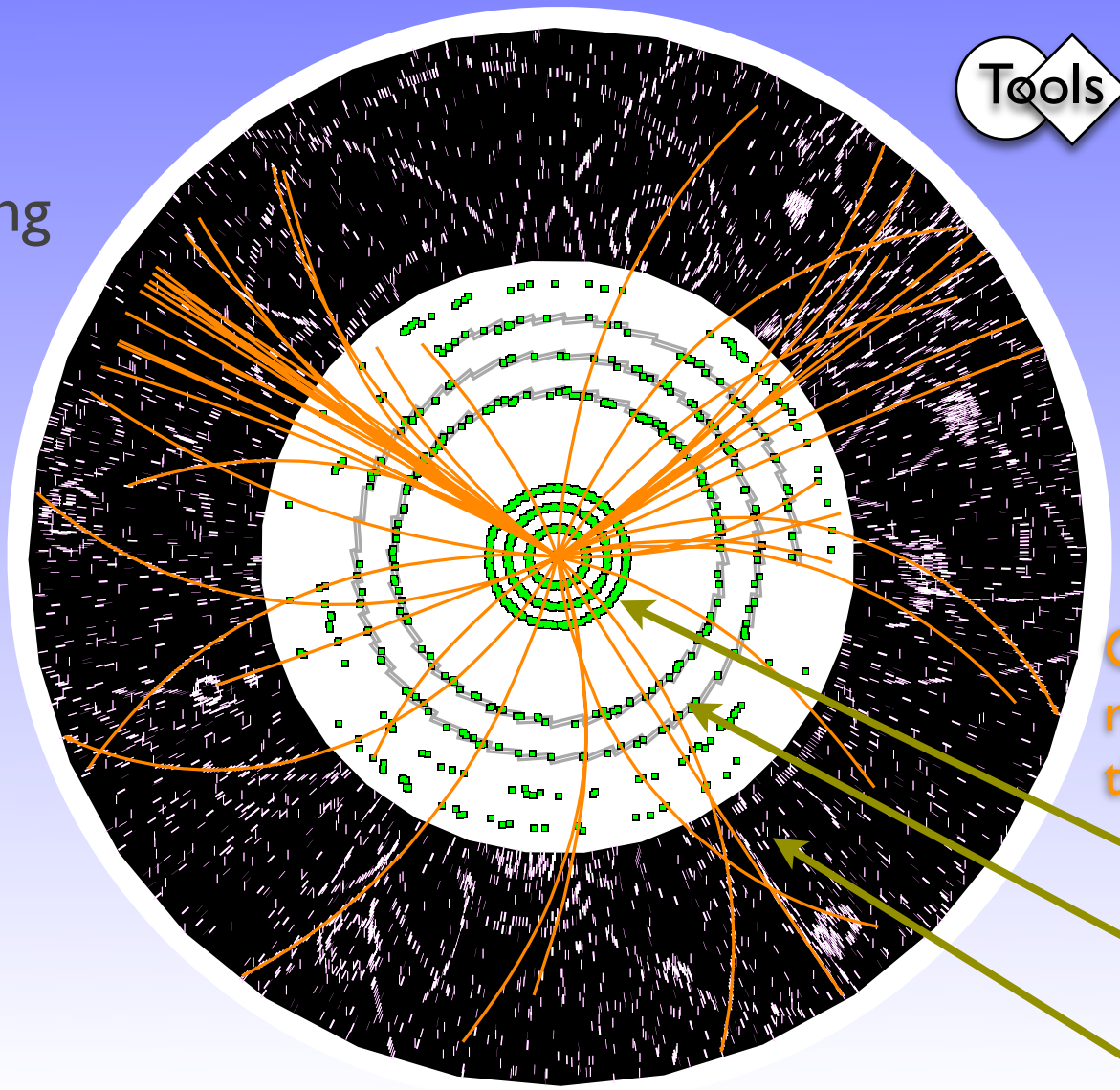

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3 layers Si pixel

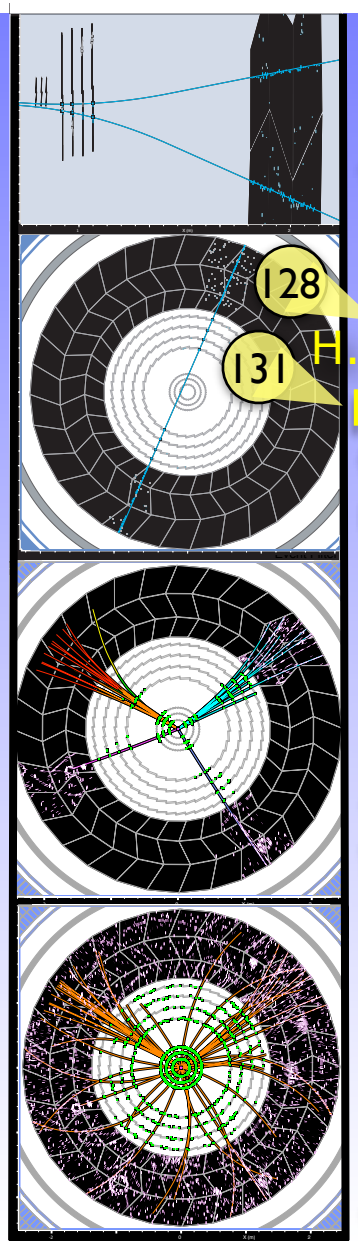
4 layers Si strip (sandwich modules)

transition radiation tracker (~36 hits)

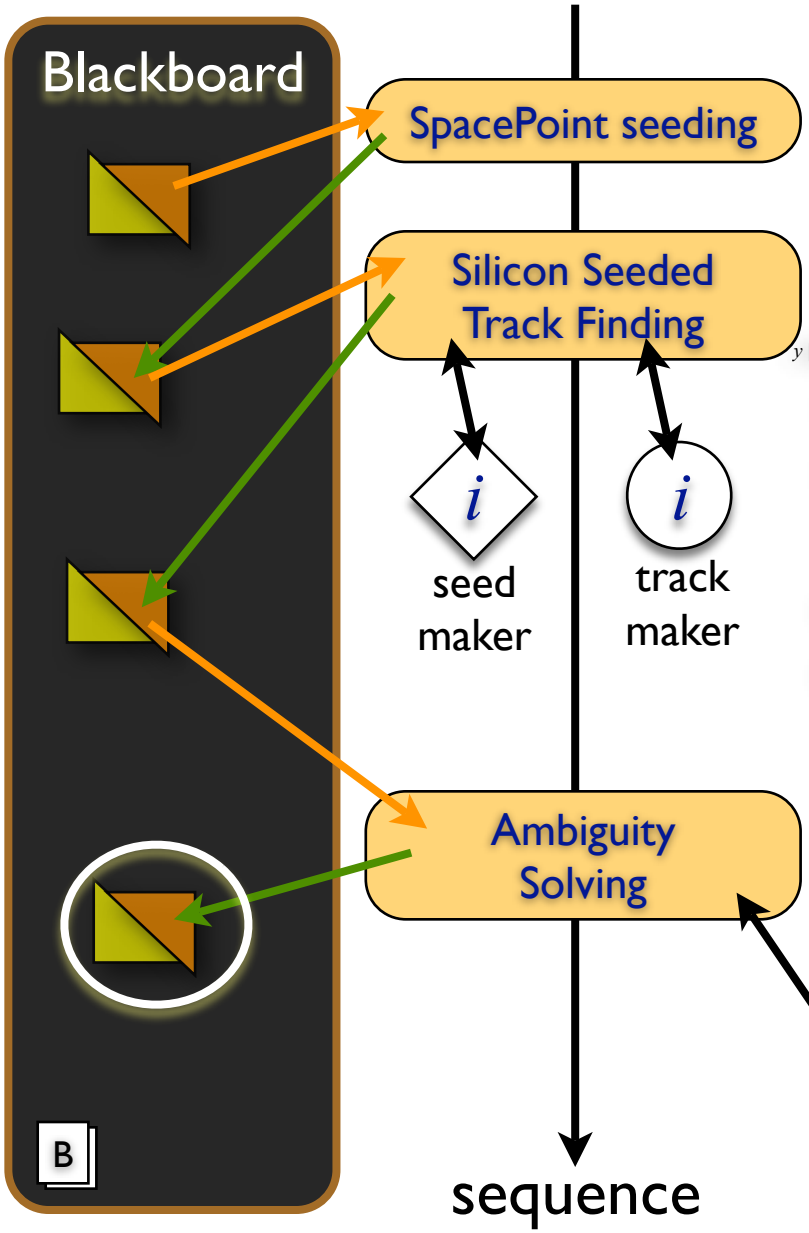
77 K. Prokofiev

Modularity gain

- NEWT runs in a similar configuration for several setups using same underlying tools
- Number of algorithmic components increased dramatically
  - e.g. from 2 track fitters to 6 different fitters (dedicated electron fitters, high hit occupancy, fast trigger fit, etc.) 144 T. Cornelissen/M. Elsing
- Commonly used validation framework
  - allows inter-module comparison on different levels
- Faster development cycles, since single tasks can be assigned to individual authors
  - necessary to integrate feedback from detector tests and commissioning runs
- Expansion of reconstruction tools to user analysis
  - extrapolation, vertex and kinematic fitting, etc.

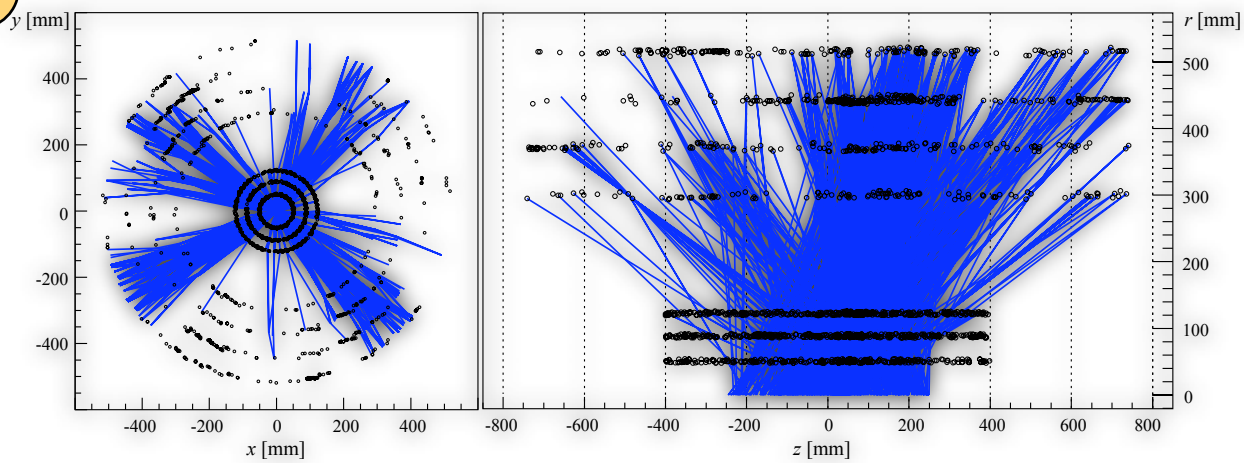


ID track reconstruction - inside out (I)



transforms local hit information on detection devices (2-dim) to 3-dim objects (with surface constraint)

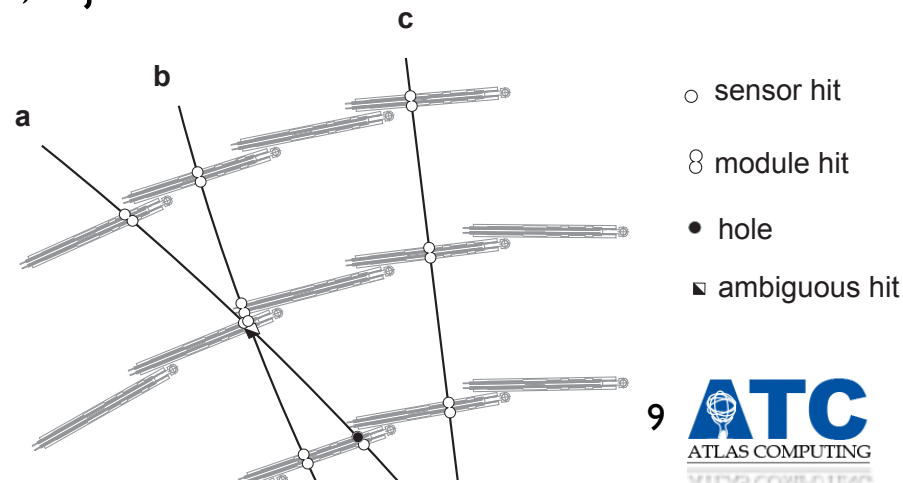
finds space point seeds (flexible 3,4,5 ... space points) to build first track candidates



scores tracks in respect to another, resolves or flags hit ambiguities, rejects bad track candidates

e.g. scoring for SCT

scoring tool



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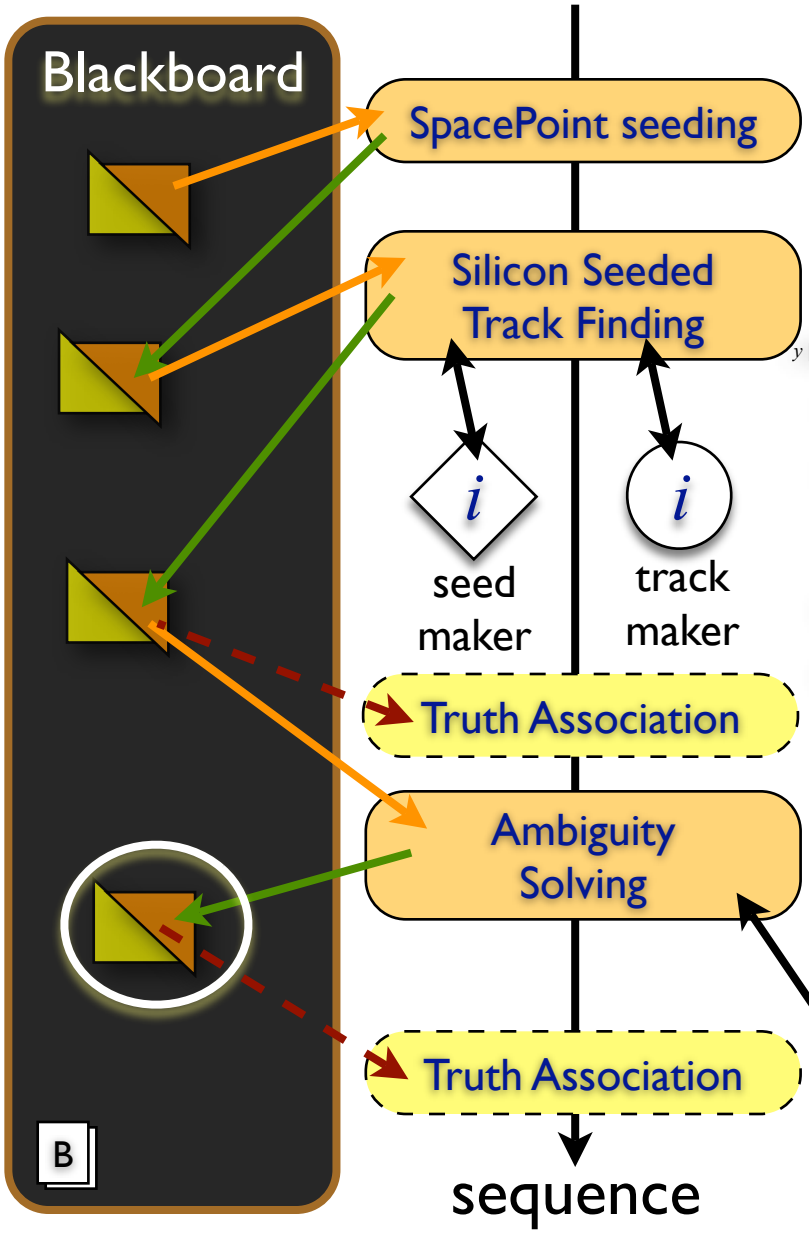

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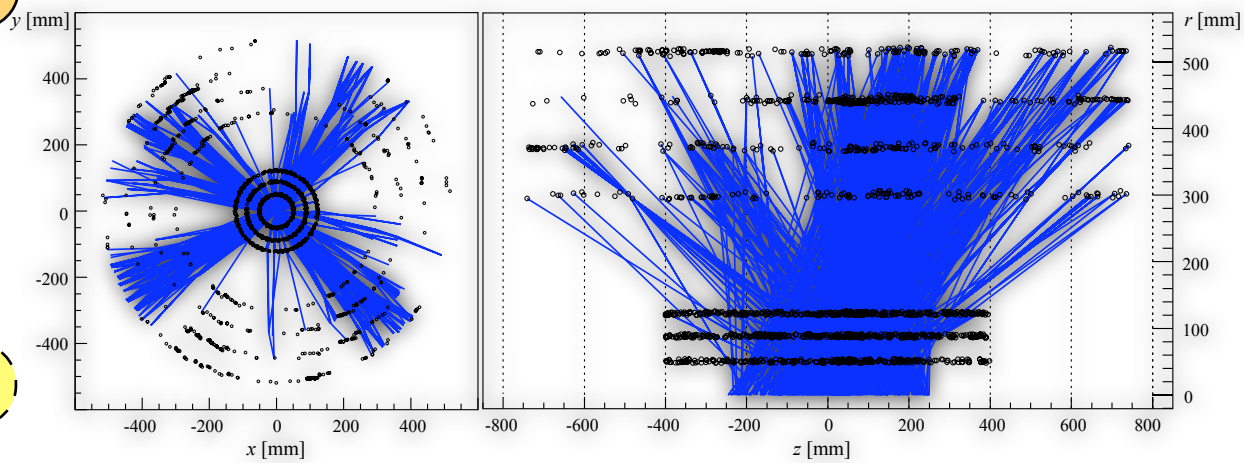

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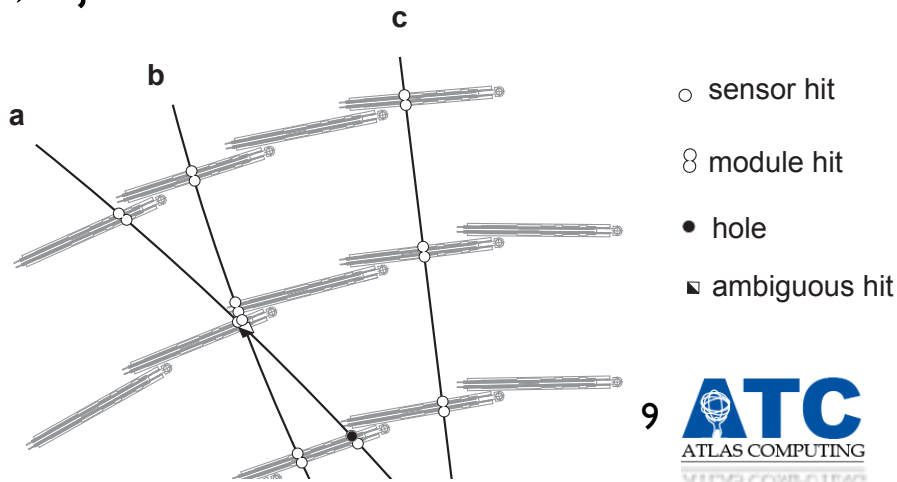

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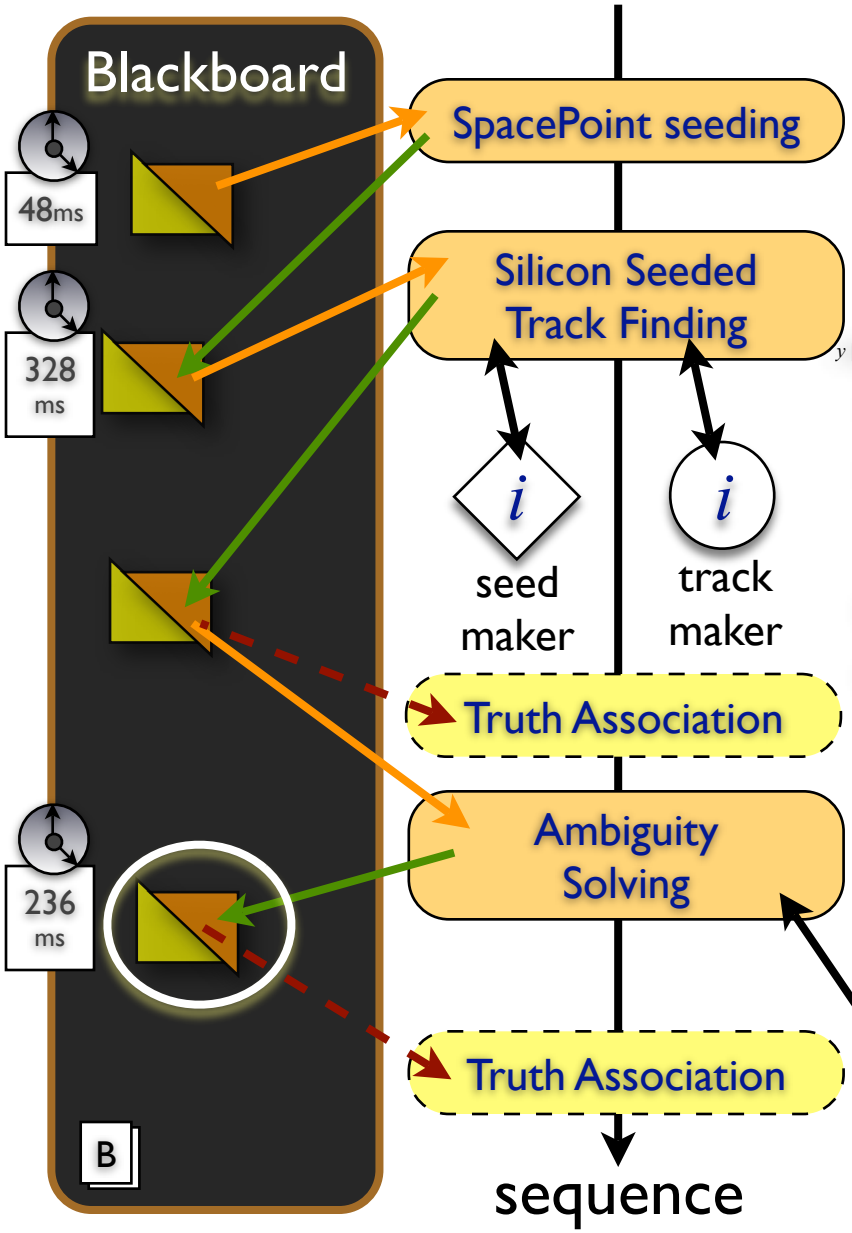

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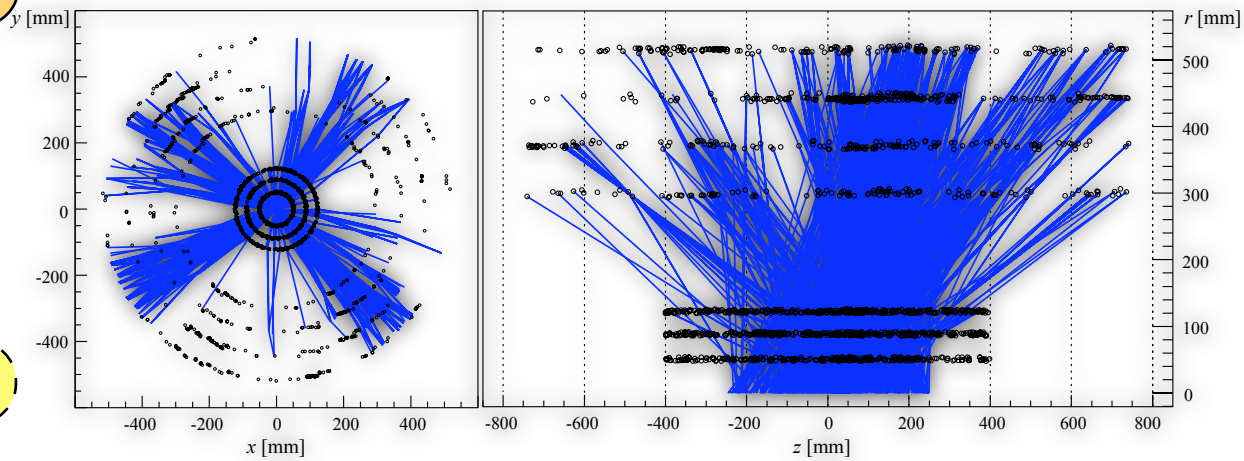

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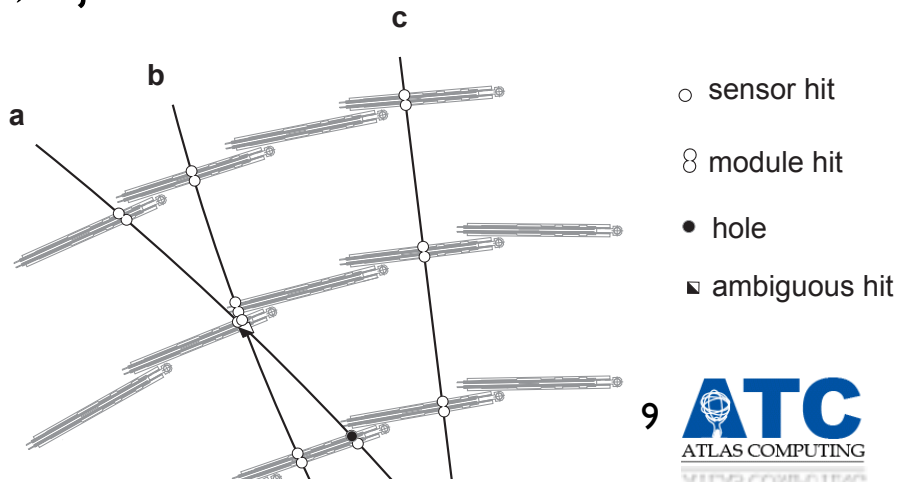
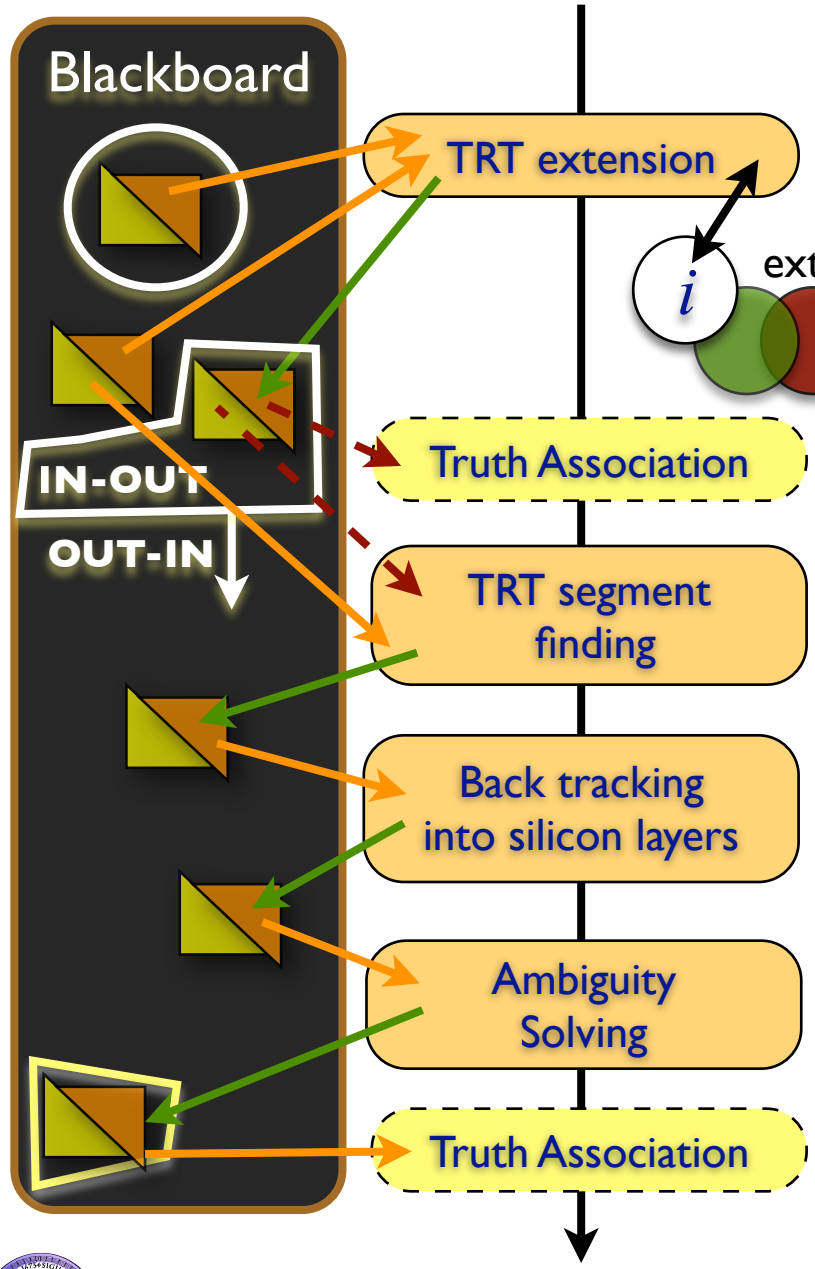
e.g. scoring for SCT

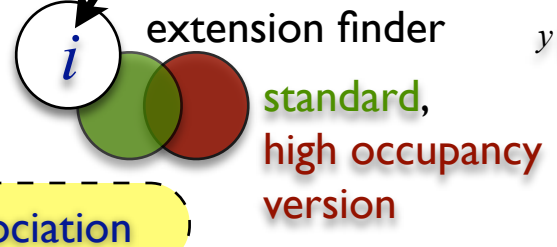
scoring tool



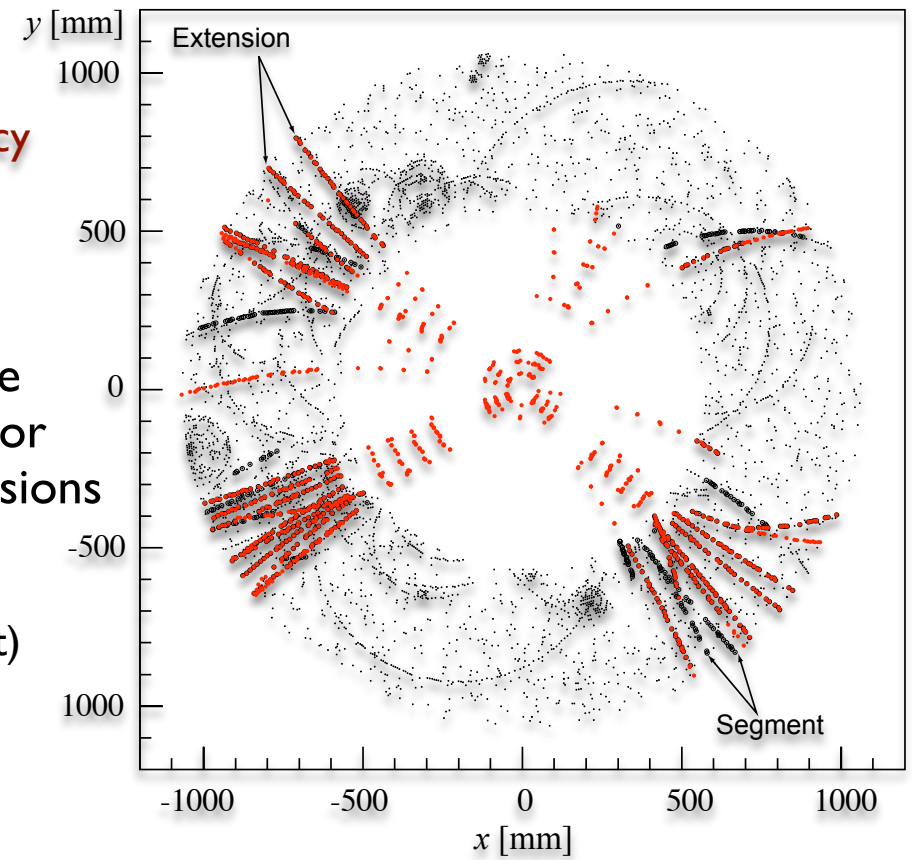
ID track reconstruction - inside out (II) + outside in



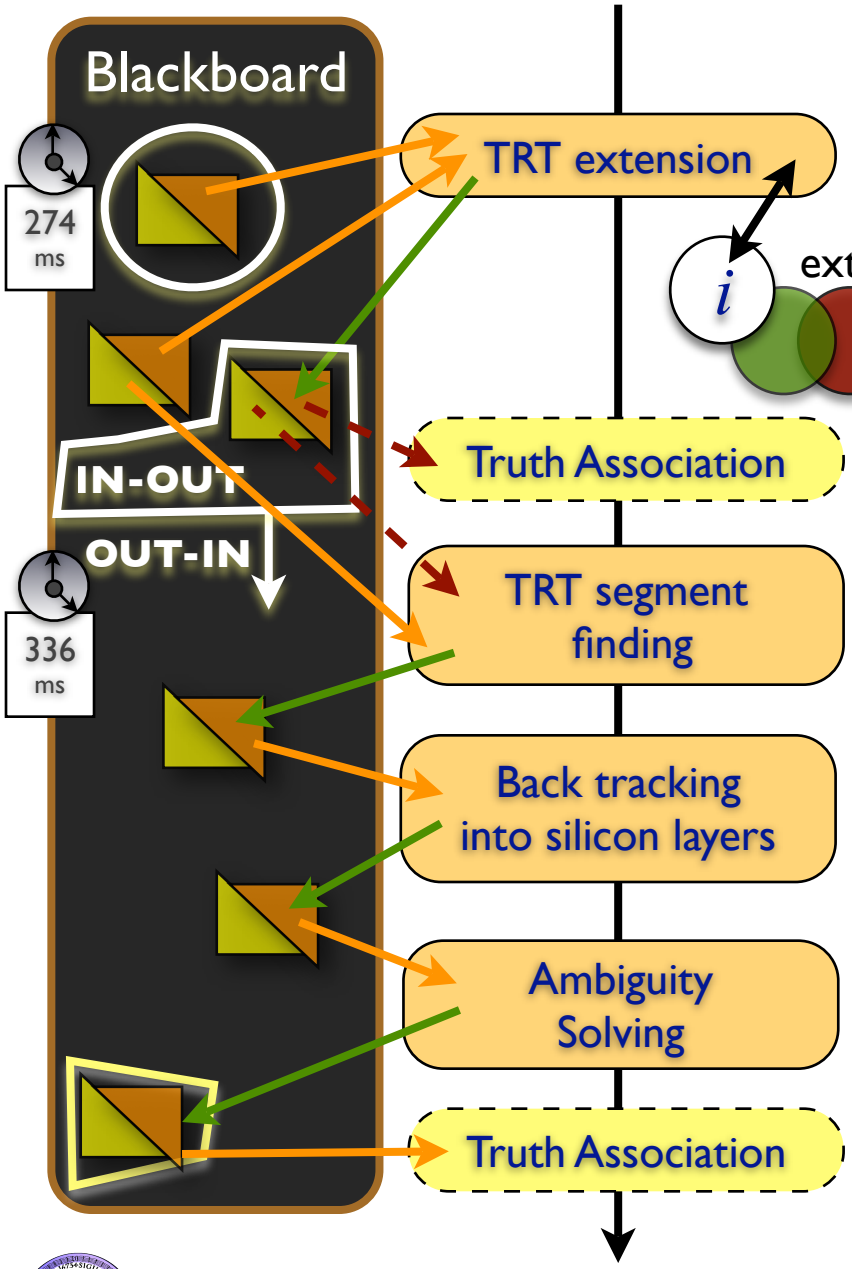
the resolved *silicon* tracks are extended into the transition radiation tracker (TRT)



searches for tracks from late decay vertices or photon conversions (may not have enough Si hits for seeding inside-out)



ID track reconstruction - inside out (II) + outside in



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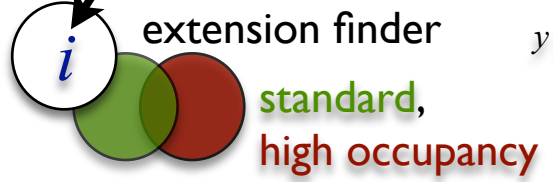
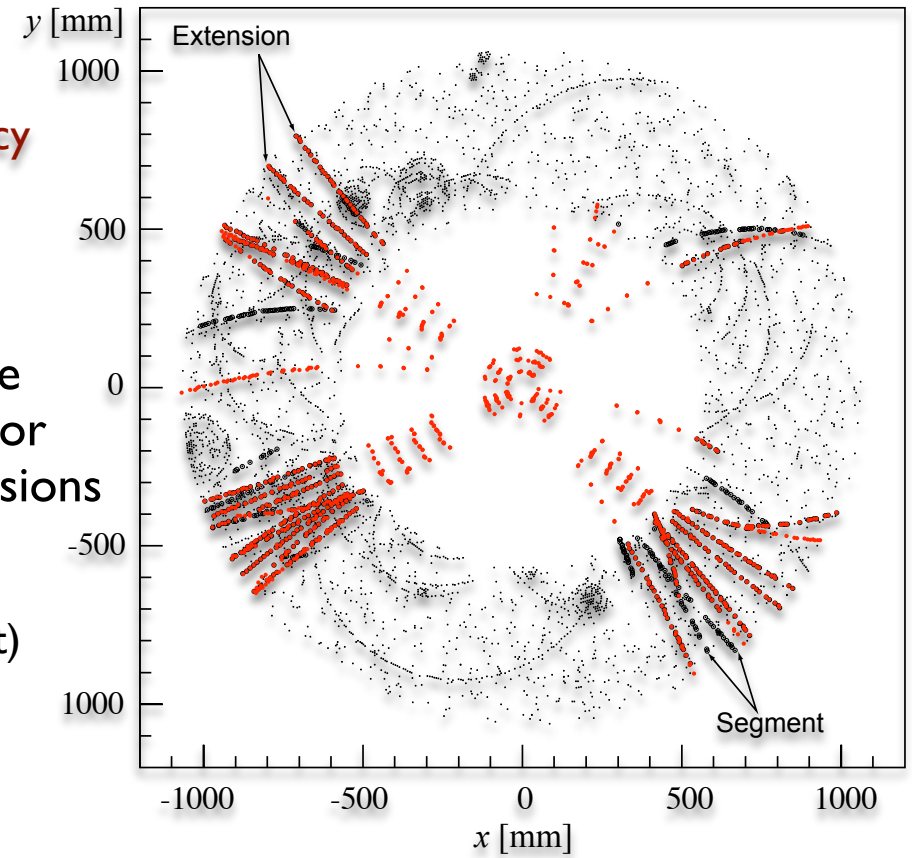


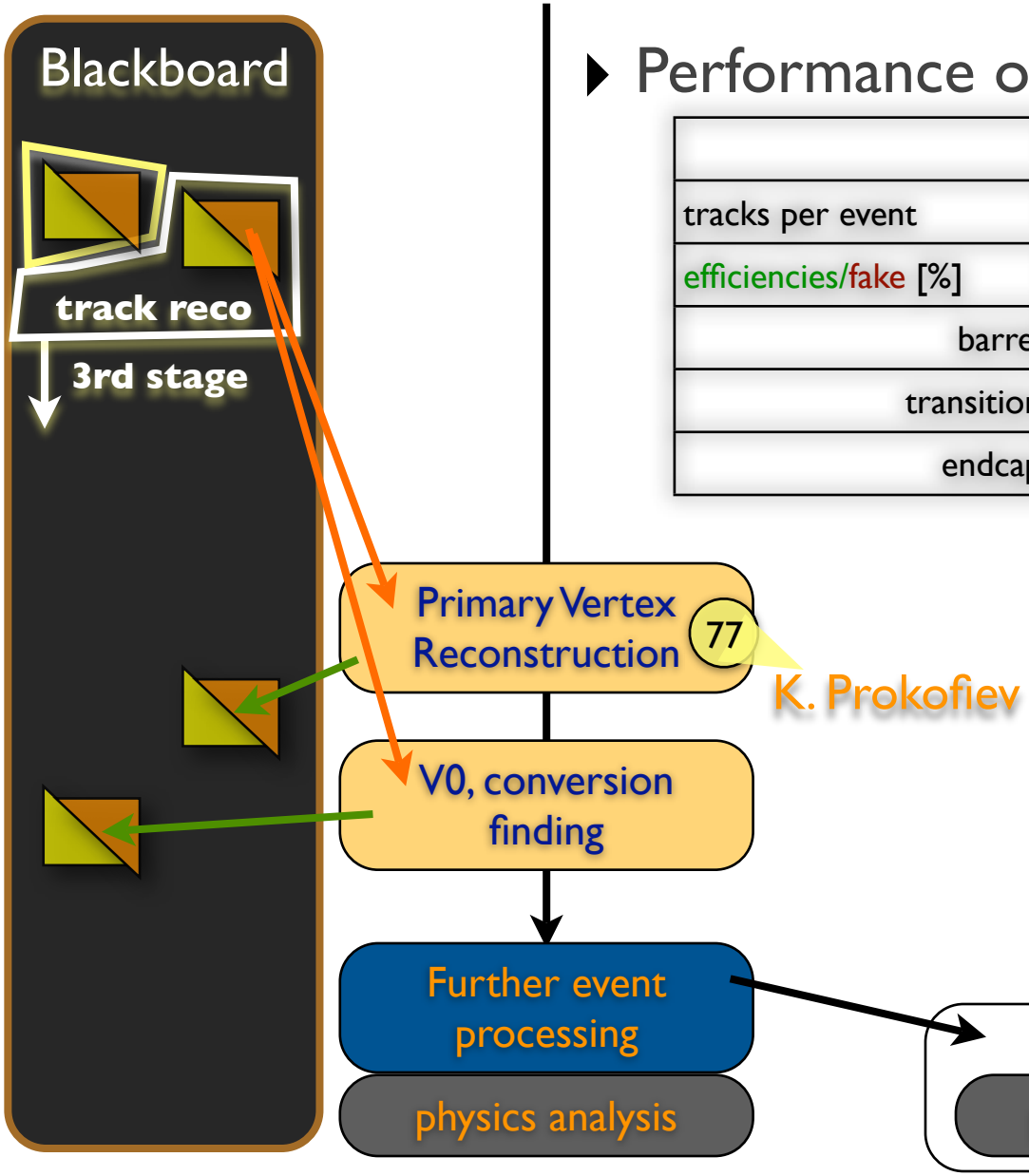
extension finder

standard, high occupancy version

searches for tracks from late decay vertices or photon conversions (may not have enough Si hits for seeding inside-out)



Efficiency - Further processing



- Performance on MC simulated data

	Z->μμ	ttbar@NLO
tracks per event	12.50	~44
efficiencies/fake [%]		
barrel	99/0.4	98/-
transition	99/0.6	97/0.14
endcap	96/1.2	96/0.34

"efficiency": reconstructed track matching stable particle with production vertex inside pixel acceptance, no decay vertex

!

"fake": reconstructed track, no link to truth association

outside the framework

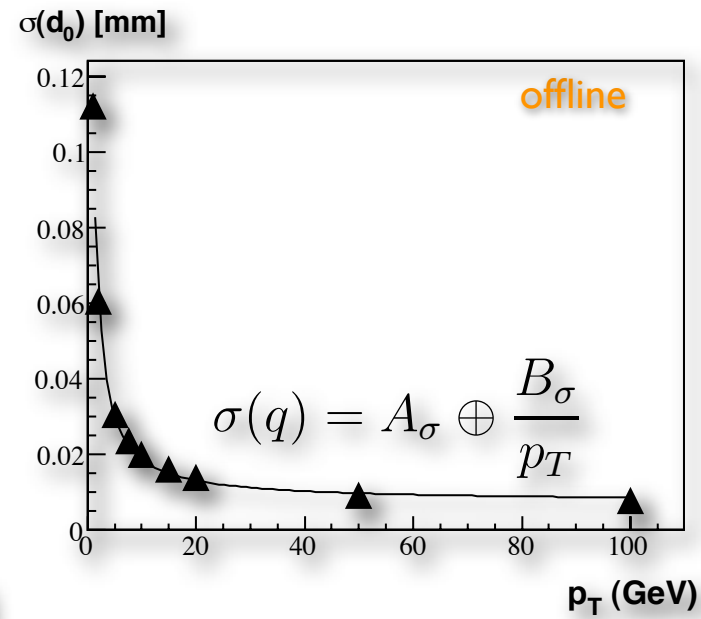
physics analysis

Performance - single μ compared to Technical Design Report (TDR)

- base-line validation
  - efficiencies, resolutions vs. transverse momentum
  - pull distribution for cluster and material validation
- 2-layer-model fits $\sigma(q) = A_\sigma \oplus \frac{B_\sigma}{p_T}$ to track parameters

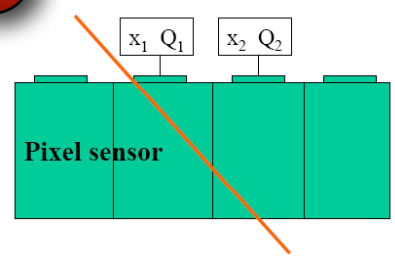
d_0	A (μ)	B (μ GeV)
TDR	10.9	72
13.0.10	7.9	157

$1/p_T$	A (TeV^{-1})	B
TDR	0.365	12.3
13.0.10	0.275	11.9

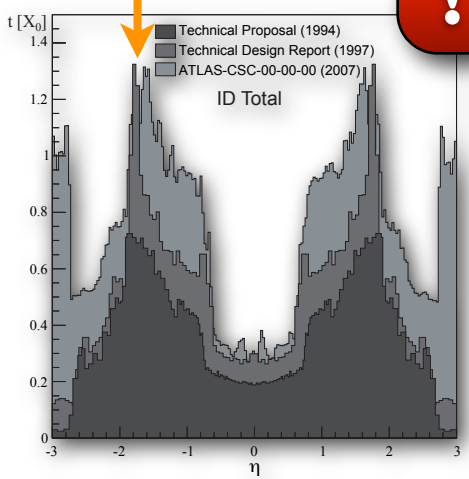


analog pixel clustering, perfect alignment, no module distortions

!

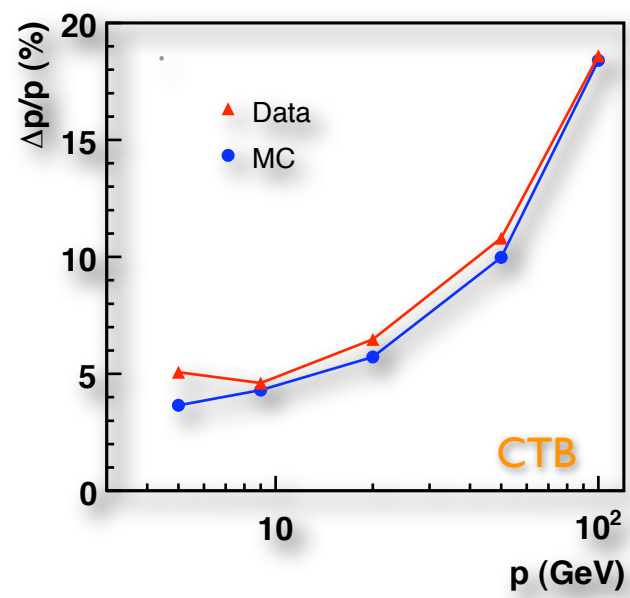


analog cluster position via TOT measurement



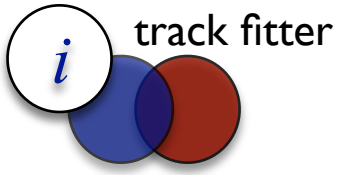
increase of ID material

!

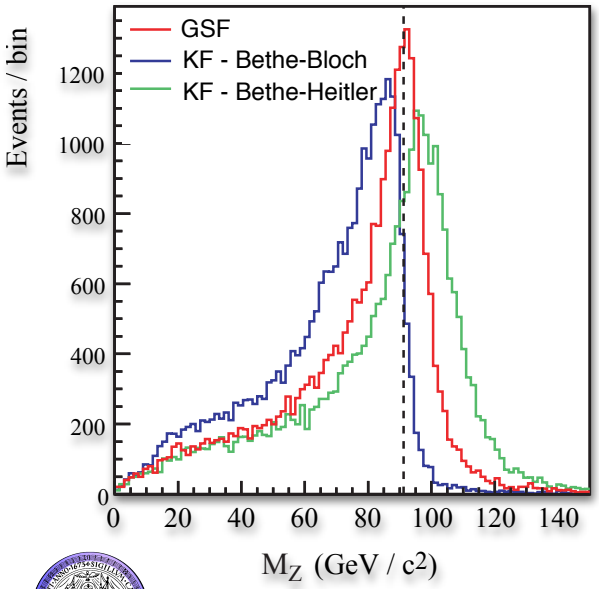


Performance (II)

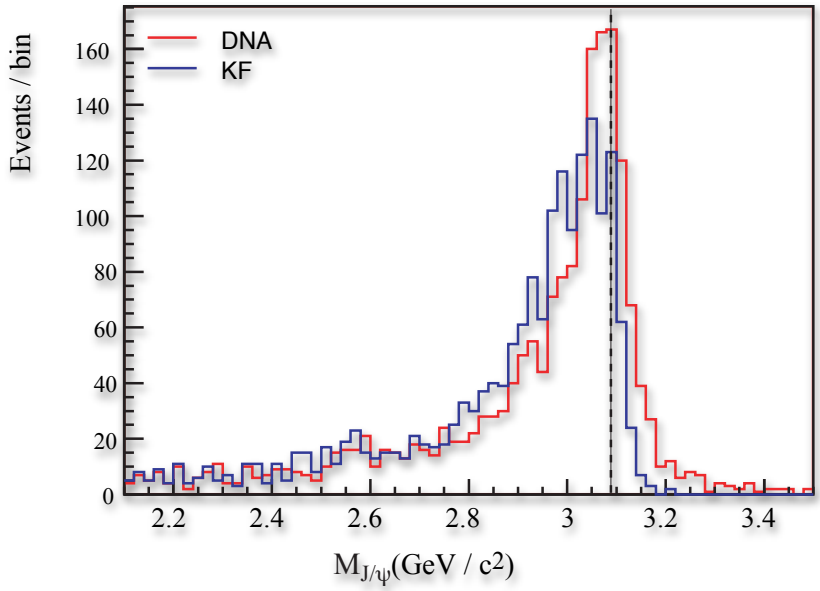
- Good example for power of component model is electron track fitting
  - bremsstrahlung undermines the purely Gaussian noise model
  - biases track fit
- Dedicated fitting techniques can be used, e.g.
  - Gaussian Sum Filter (GSF) 98 Fruehwirth/Strandlie
  - Dynamic Noise Adjustment Schema (DNA)
  - by simply extending the track fitter interface, these options can be chosen at job configuration level



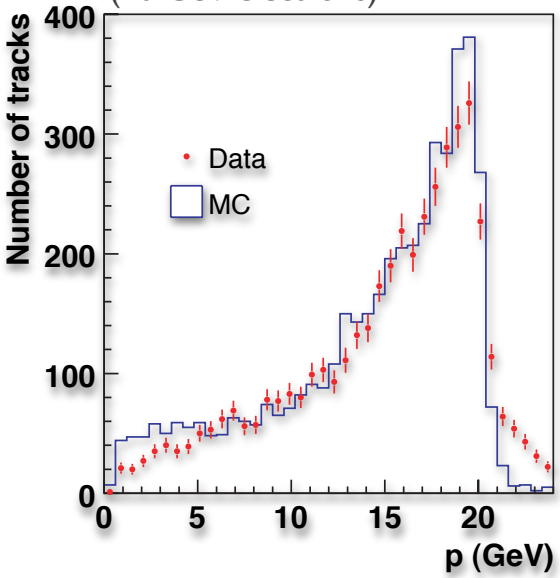
$Z \rightarrow e^+e^-$



J/Psi→ e^+e^-



GlobalChi2Fitter
(20 GeV electrons)



Conclusion

NEW Track reconstruction

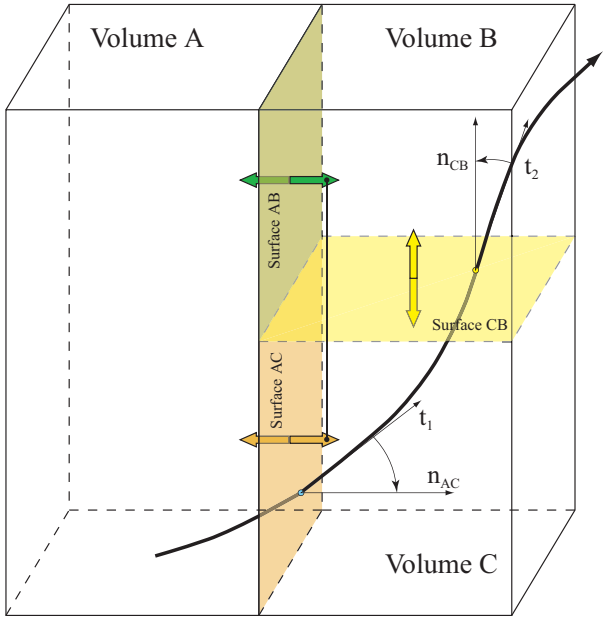
- in good shape, close to completeness
- EDM is almost frozen, redesign to multi-component model finished
- a lot of the former existing code/algorithms ported to NEWT
- well performing in simulated data exercises
- design has proven to work well in test beam and commissioning setups

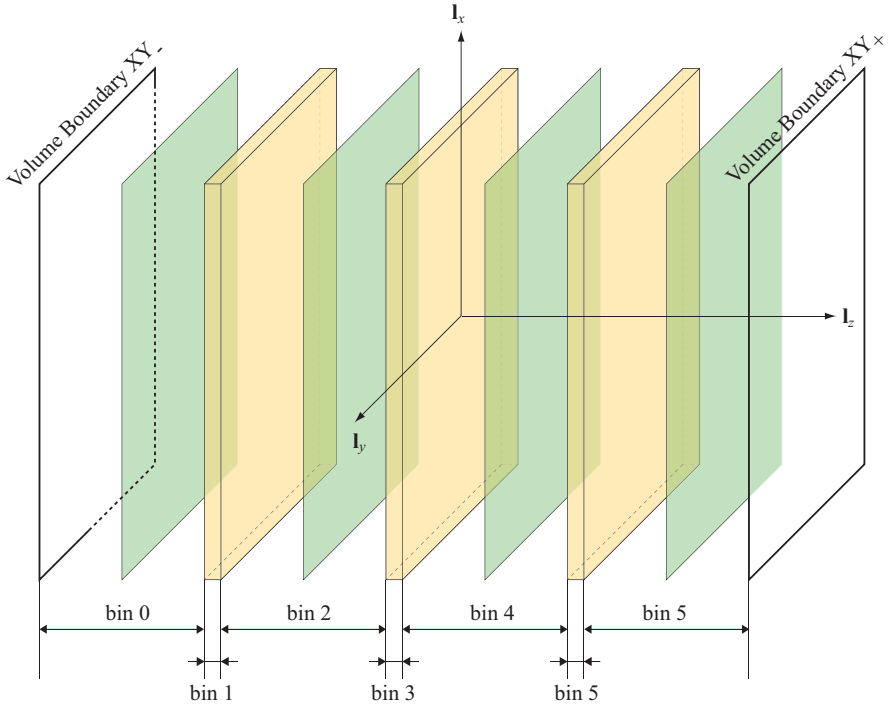
Towards data taking

- level of realism has recently been increased dramatically (geometrical/material distortions, conditions data, channel information)
- software undergoes constant validation
- experiences from test beam and commissioning setups have been integrated (facilitated by the component software model)

Backup

B1: Extrapolation - Navigation model





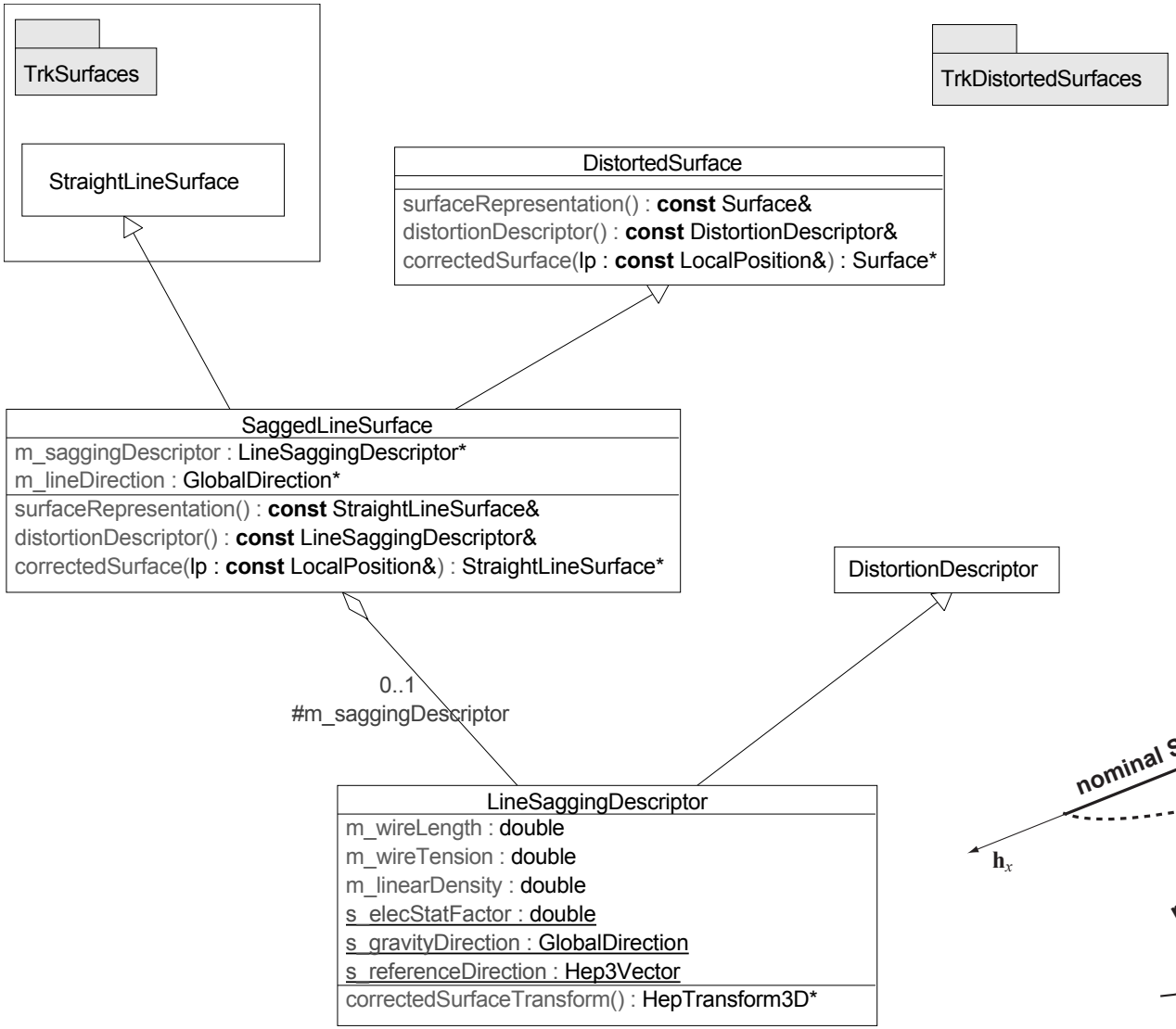
Navigation between volumes

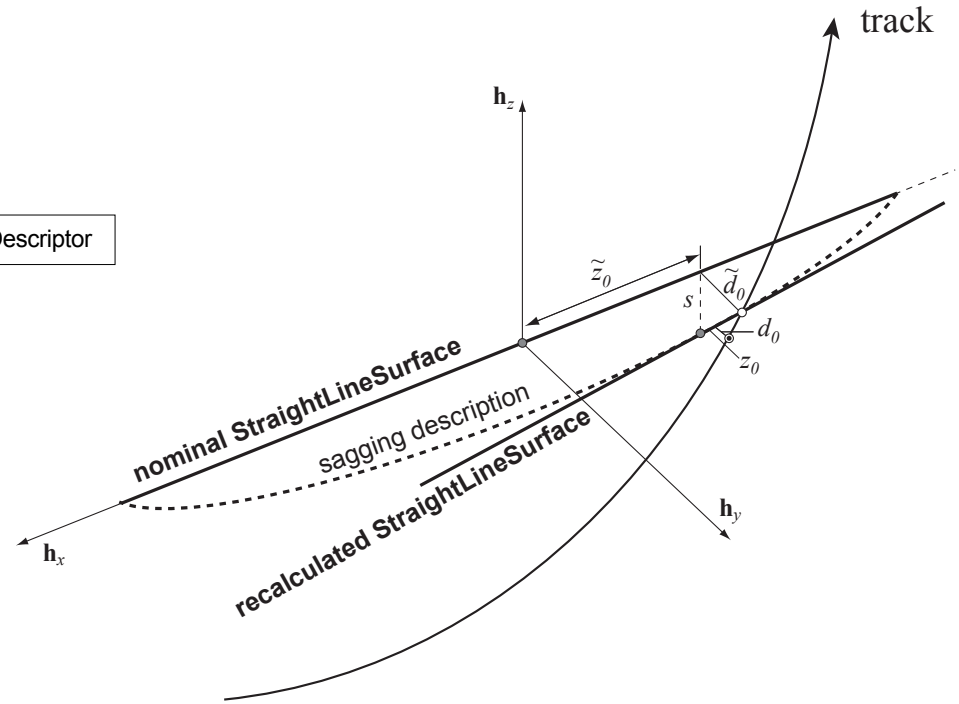
- following the trajectory with Extrapolator
- volume class is container for surfaces
- boundary schema attaches volumes to surfaces

Navigation inside volumes

- layers are ordered in binned arrays
- interlinking between layer objects

B2: Geometry - Distortions





B2: NewTracking - Inside-out sequence

Inside-out

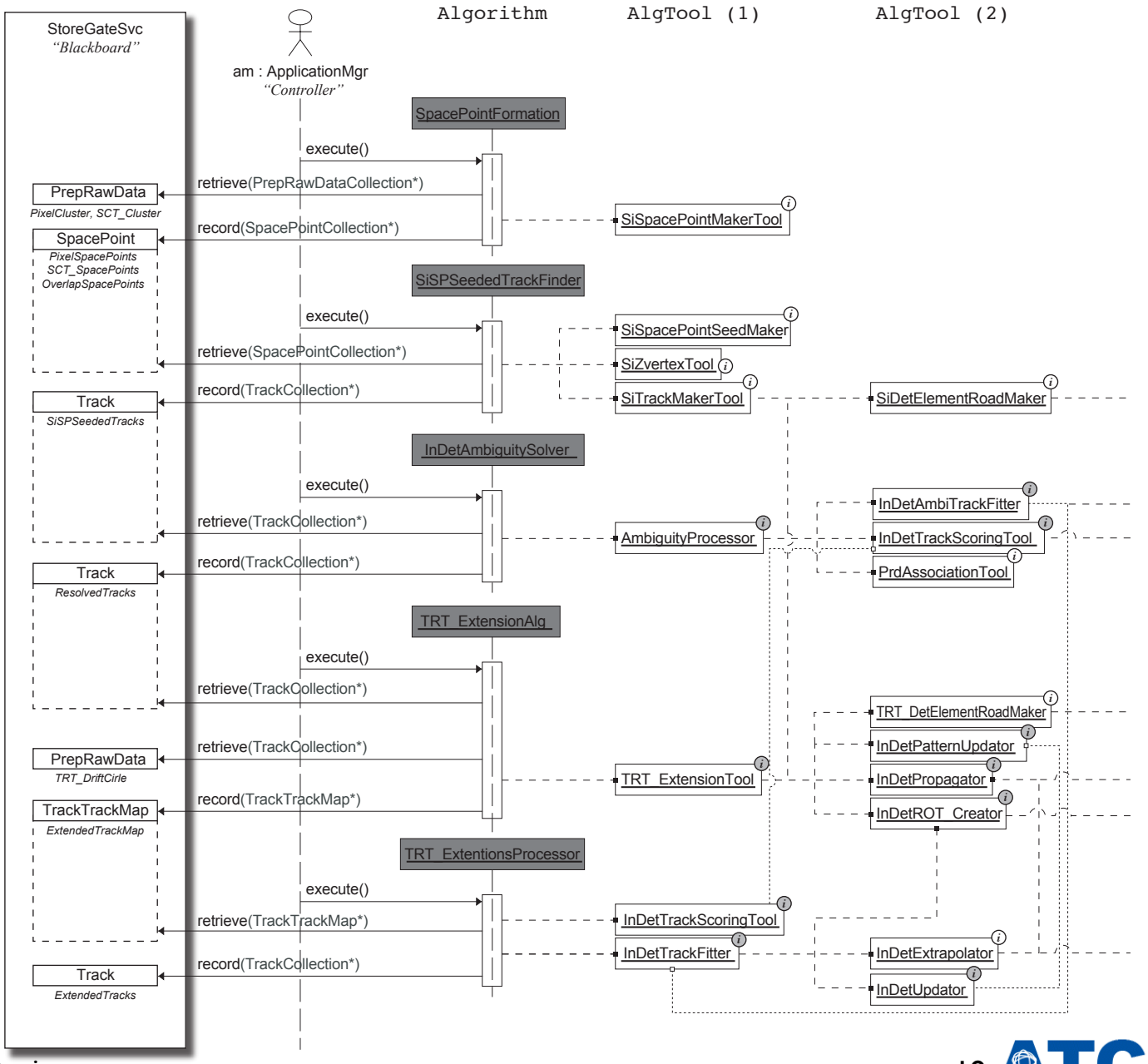
- SpacePoint formation
- SpacePoint seeded tracking
- Ambiguity Solving
- TRT Extension search
- TRT Extension processing

Algorithm/AlgTools

- Algorithms are small
- mainly delegation to AlgTools
- 4 to 5 levels of AlgTools
- Complex configuration matrix

Status

- complete NewTracking chain
- fully implemented and validated
- modifications & refinement, updates ongoing



Description of non UML markers and relations:

- - - - ▪ *uses, delegates*
- ..... ▫ *common tool (optional)*
- ⓘ *interface definition exists*
- ⓘ *inteface definition and multiple implementations exist*