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U.S. DEPARTMENT OF ENERGY
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Track Propagation and Pathlength

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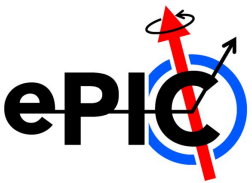
Tracking/PID Workfest Session
ePIC January Collaboration Meeting @ANL
Jan 11, 2024

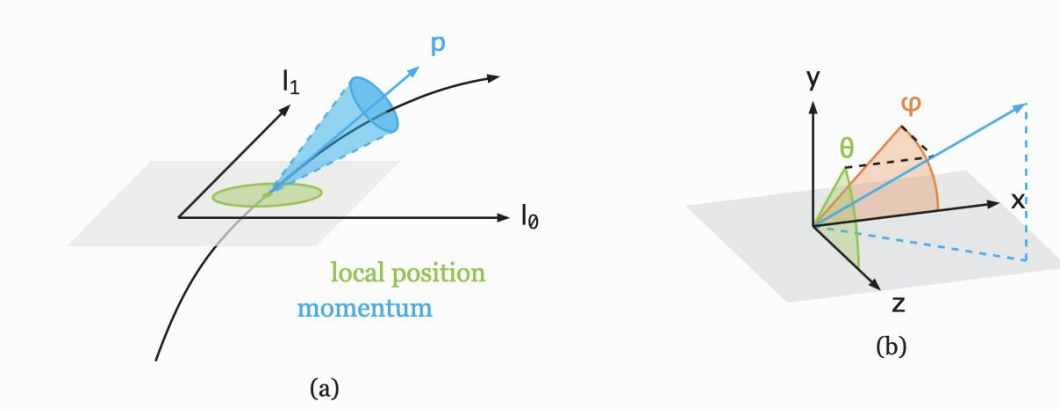


ACTS Track Parameter

https://acts.readthedocs.io/en/latest/tracking.html

Track parameter:

$$\vec{x} = (l_0, l_1, \phi, \theta, q/p, t)^T$$



Covariance Matrix:

$$C = \begin{bmatrix} \sigma^2(l_0) & \mathrm{cov}(l_0, l_1) & \mathrm{cov}(l_0, \phi) & \mathrm{cov}(l_0, \theta) & \mathrm{cov}(l_0, q/p) \\ . & \sigma^2(l_1) & \mathrm{cov}(l_1, \phi) & \mathrm{cov}(l_1, \theta) & \mathrm{cov}(l_1, q/p) \\ . & . & \sigma^2(\phi) & \mathrm{cov}(\phi, \theta) & \mathrm{cov}(\phi, q/p) \\ . & . & . & \sigma^2(\theta) & \mathrm{cov}(\theta, q/p) \\ . & . & . & . & \sigma^2(q/p) \end{bmatrix}$$

Track Propagator

Stepper:

- update the track parameter according to the equation of motion through numerical integration
- Default: 4th order Runge-Kutta with adaptive step size. Magnetic field and material effects included
- Pathlength = accumulated step size

Navigator:

Sort out the order of volumes, layers, and surfaces, keeps track of the current position in the geometry and adjusts the step size to reach the target surface

Propagating Through Material

Initial to final step: evolve covariance in time

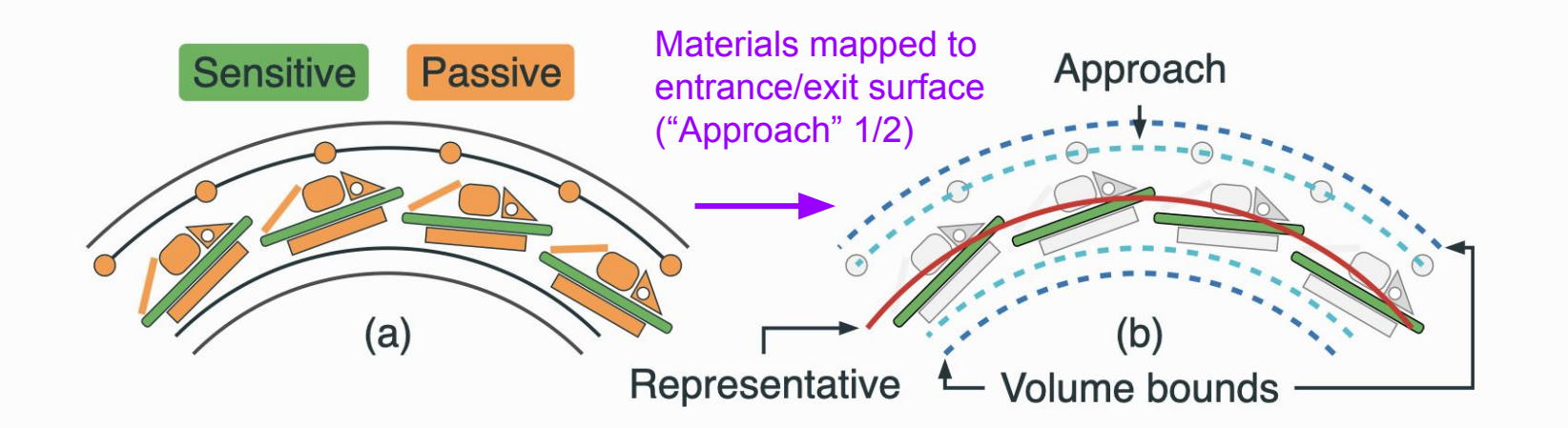
$$C^f = J \cdot C^i \cdot J^T,$$

$$J = \begin{bmatrix} \frac{\partial l_0^f}{\partial l_0^i} & \cdots & \frac{\partial l_0^f}{\partial (q/p)^i} \\ \vdots & \ddots & \vdots \\ \frac{\partial (q/p)^f}{\partial l_0^i} & \cdots & \frac{\partial (q/p)^f}{\partial (q/p)^i} \end{bmatrix},$$

Material effects:

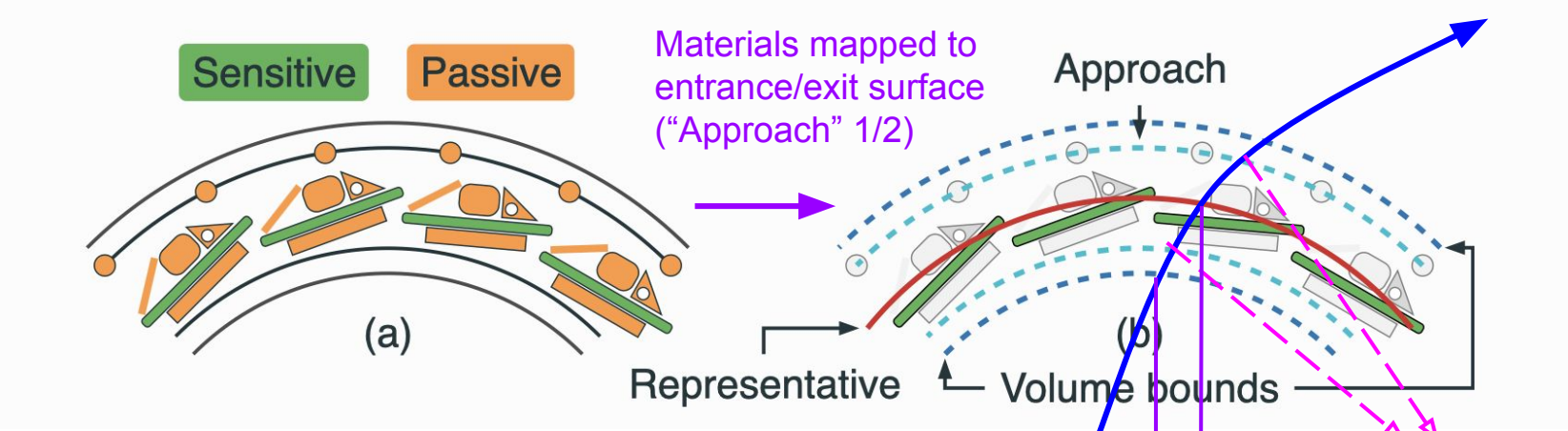
- Deflection and offset → averaged to 0, increased uncertainties
- Energy loss → reduced trajectory energy
- Hadronic process → disintegration etc.

Propagating Through Material



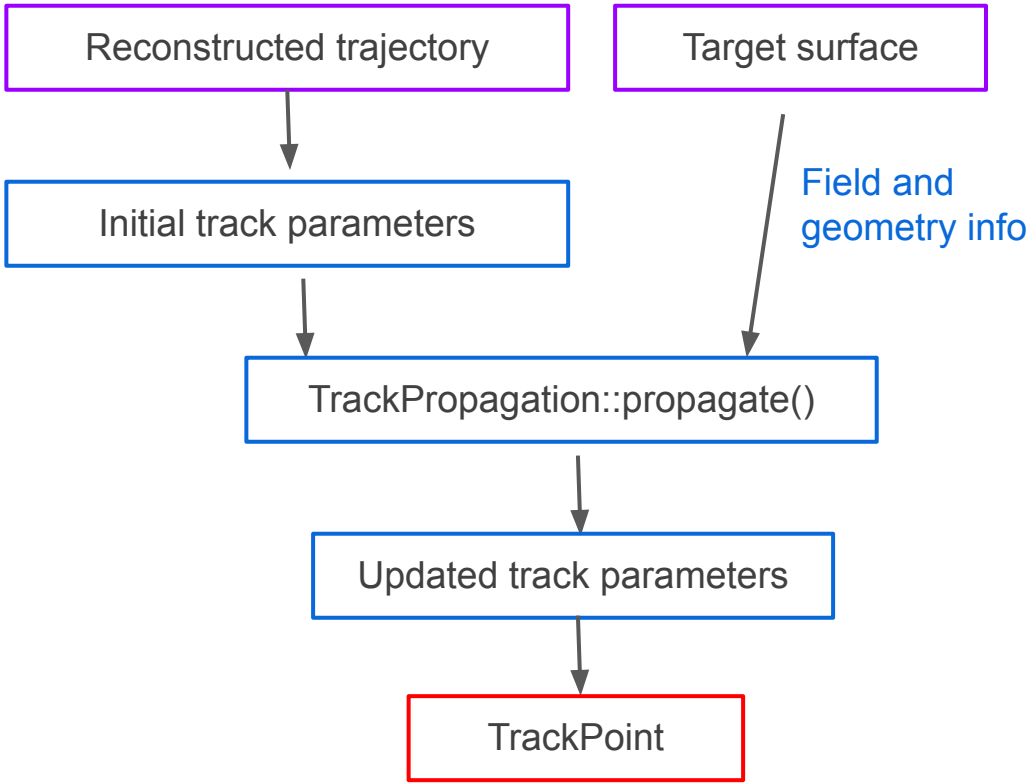
Propagating Through Material

track



Track Propagation in EICrecon

Code: EICrecon/src/algorithms/tracking/**TrackPropagation.cc**



Example: CalorimeterTrackProjections

Thanks Barak Schmookler and Tyler Kutz

edm4eic data structure

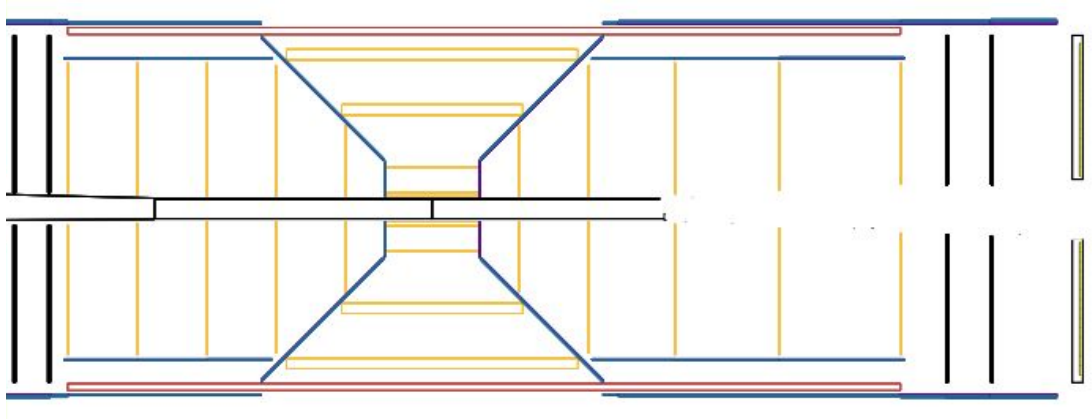
```
## A point along a track
edm4eic::TrackPoint:
  Members:
    - uint64_t          surface
    - uint32_t          system
    - edm4hep::Vector3f position
    - edm4eic::Cov3f    positionError
    - edm4hep::Vector3f momentum
    - edm4eic::Cov3f    momentumError
    - float             time
    - float             timeError
    - float             theta
    - float             phi
    - edm4eic::Cov2f    directionError
    - float             pathlength
    - float             pathlengthError
```

Entry in EICrecon output

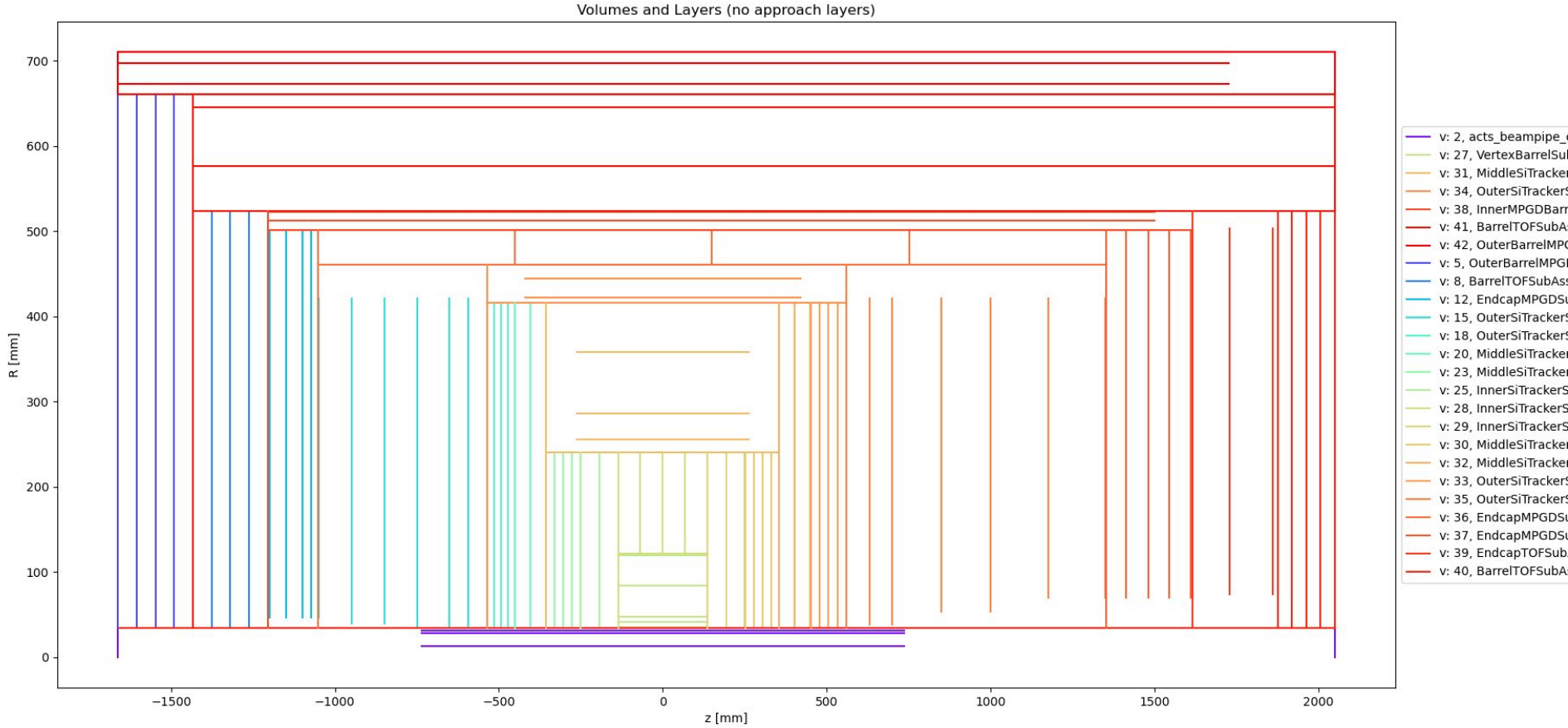
```
entry  subentry  surface  system  position.x  position.y   position.z
    0         0        1     101  434.296143  683.730103 -3126.125732

positionError.xx  positionError.yy  positionError.zz  positionError.xy
             0.0               0.0               0.0               0.0

positionError.xz  positionError.yz  momentum.x  momentum.y  momentum.z
             0.0               0.0    2.344102    3.632064  -16.861221

momentumError.xx  momentumError.yy  momentumError.zz  momentumError.xy
    7.289197e-09      1.419472e-07      1.927672e-07      1.127397e-10

momentumError.xz  momentumError.yz         time     timeError     theta
   -6.448492e-10      6.667218e-08  3241.924316  2.997925e+12  2.890622

     phi  directionError.xx  directionError.yy  directionError.xy  \
0.997668       7.289197e-09       1.419472e-07       1.127397e-10

 pathlength  pathlengthError
3261.229004             0.0
```

Define Track Projection Surface

- For existing surfaces or boundary:
  - Find corresponding geometry ID
- For detector volumes:
  - Manually define a list of passive surfaces in DD4hep for projection. See instruction at https://github.com/acts-project/acts/issues/2403

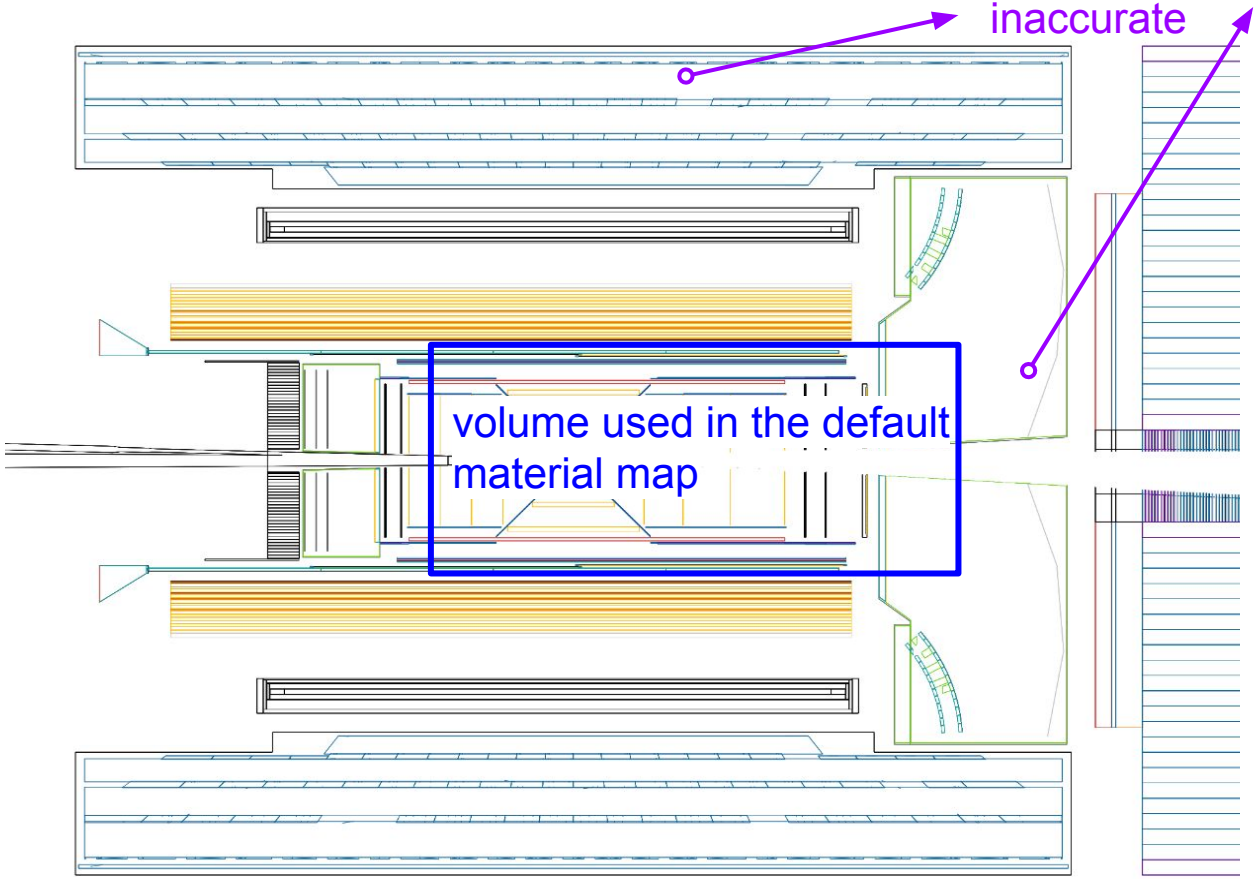


Volumes and Layers in Tracking Envelope



Material Projection Matters

NO material info is currently provided for track propagation etc → track projection is inaccurate



For creating a proper material map, see
https://indico.bnl.gov/event/20842/

Track Projection Steps:

1. Prepare the DD4hep geometry description.
2. Locate the projection surface. For layer detectors, make sure the chosen surface are recognized by ACTS. For volume detectors, create virtual passive surfaces.
3. For accurate propagation, prepare the material map for the entire detector envelop up to your target surface
4. In EICrecon, take the trajectory from track recon and feed into TrackPropagation to obtain a TrackPoint object at your target surface