The SttCellTrackFinder and Timebased Track Reconstruction

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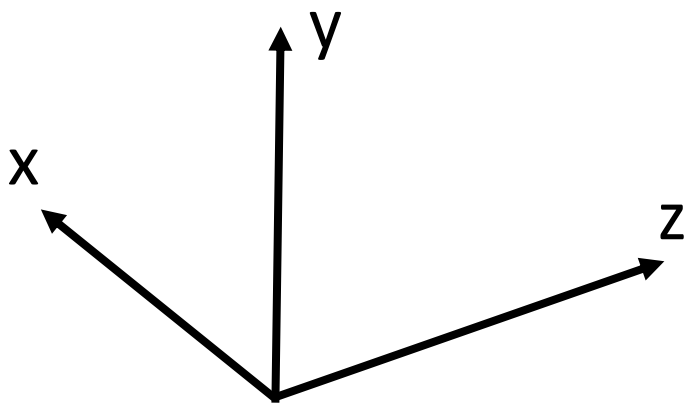
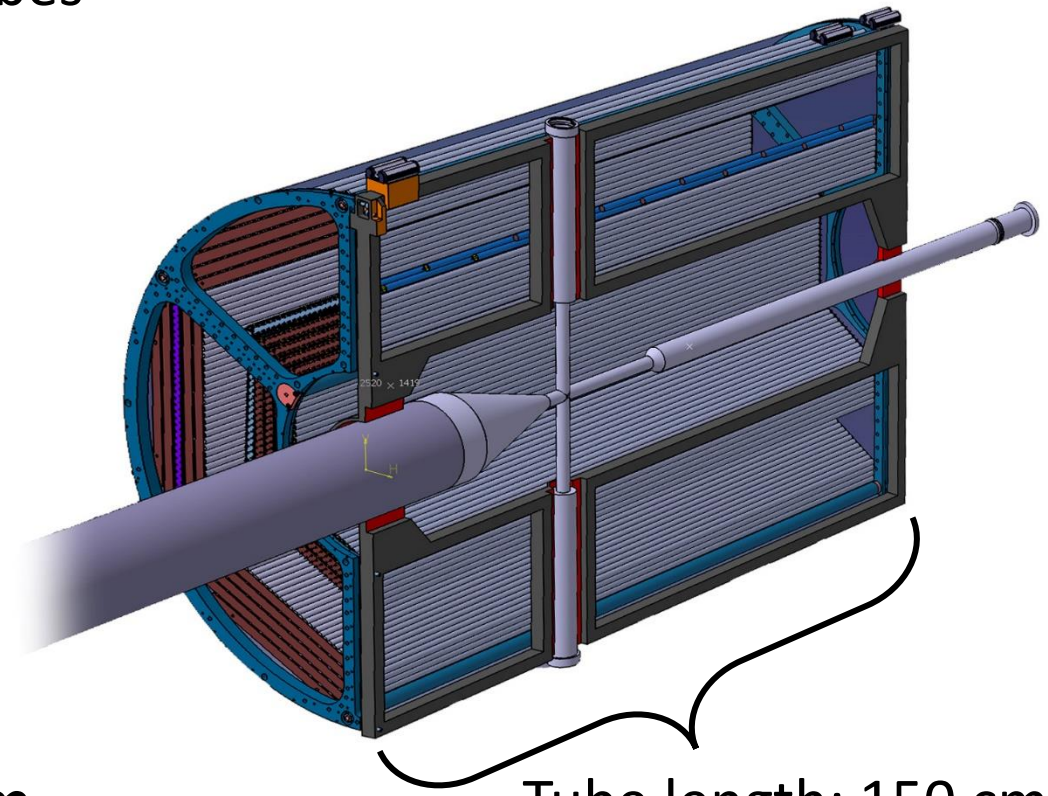
Content

- Straw Tube Tracker (STT)
- Micro Vertex Detector (MVD)
- SttCellTrackFinder
  - Track fitting- Cellular Automaton
  - Track Finding- Riemann Fit
  - Extension to MVD
- Time based time structure
- Open Issues

The Straw Tube Tracker (STT) of PANDA

Single channel readout drift tubes

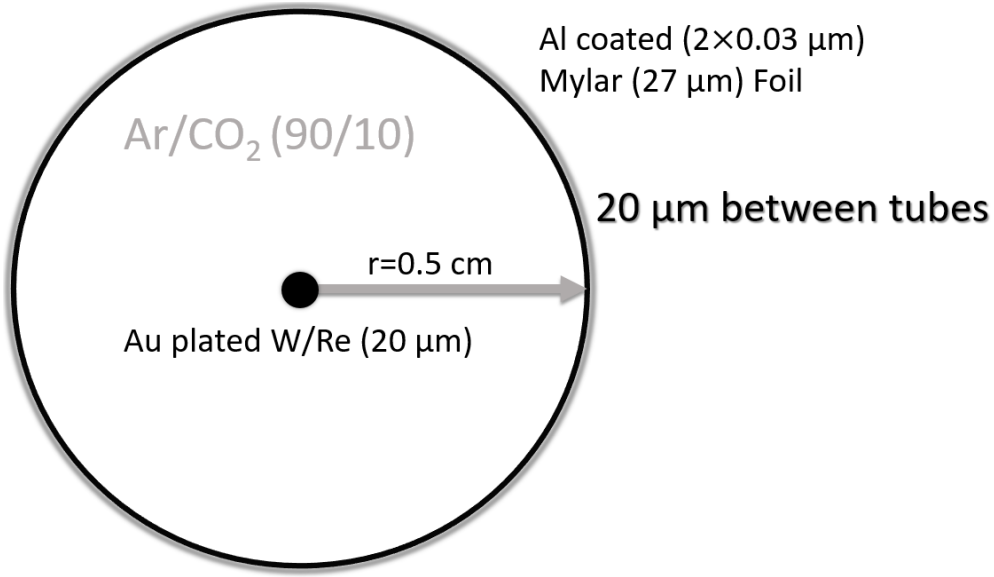


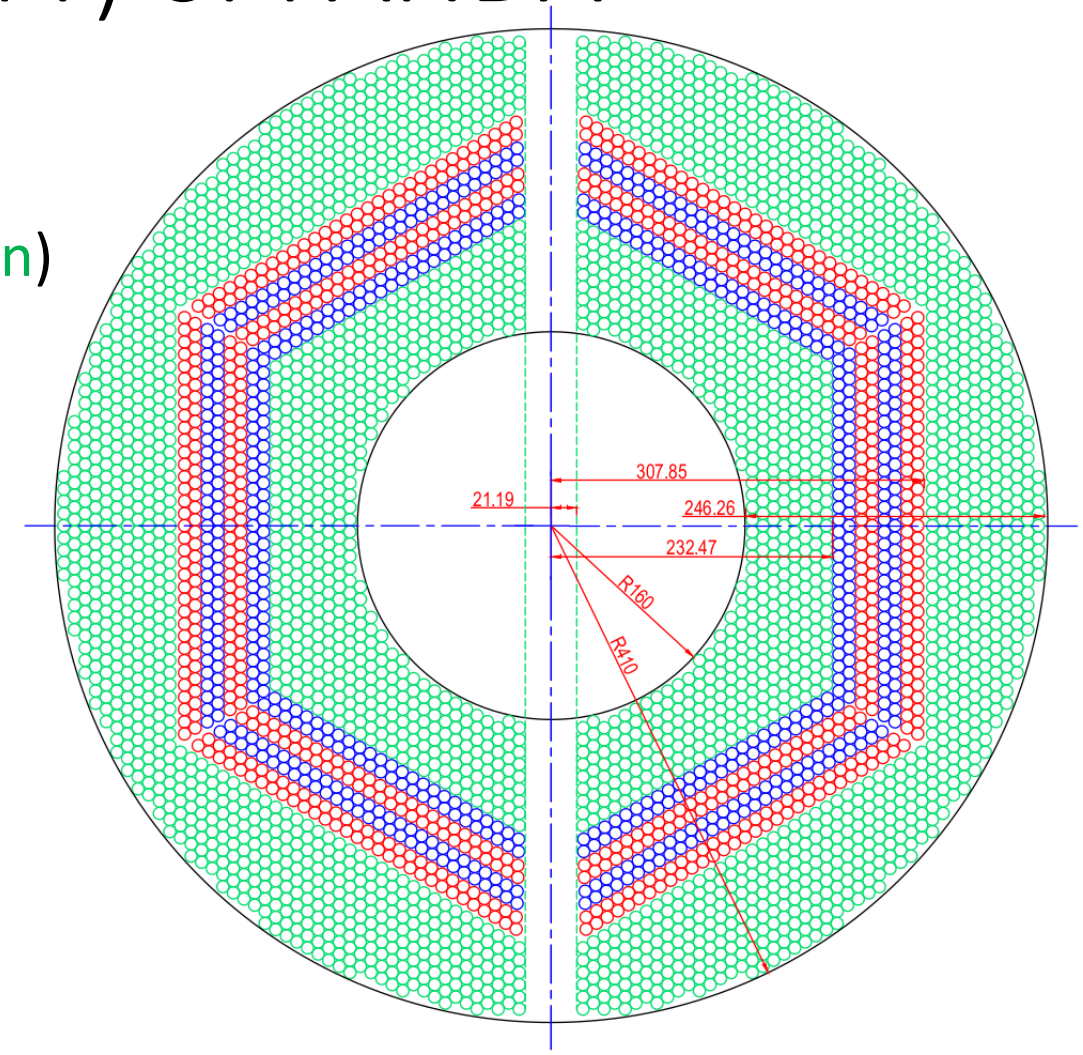


- Internal radius: 15 cm
- External radius: 42 cm

The Straw Tube Tracker (STT) of PANDA

- 4636 [1] tubes planned
- 27 radial layers
- 19 paralell layers consisting of paralell tubes (green)
- 8 central layers consisting of tilted tubes (red and blue) for transverse momentum reconstruction

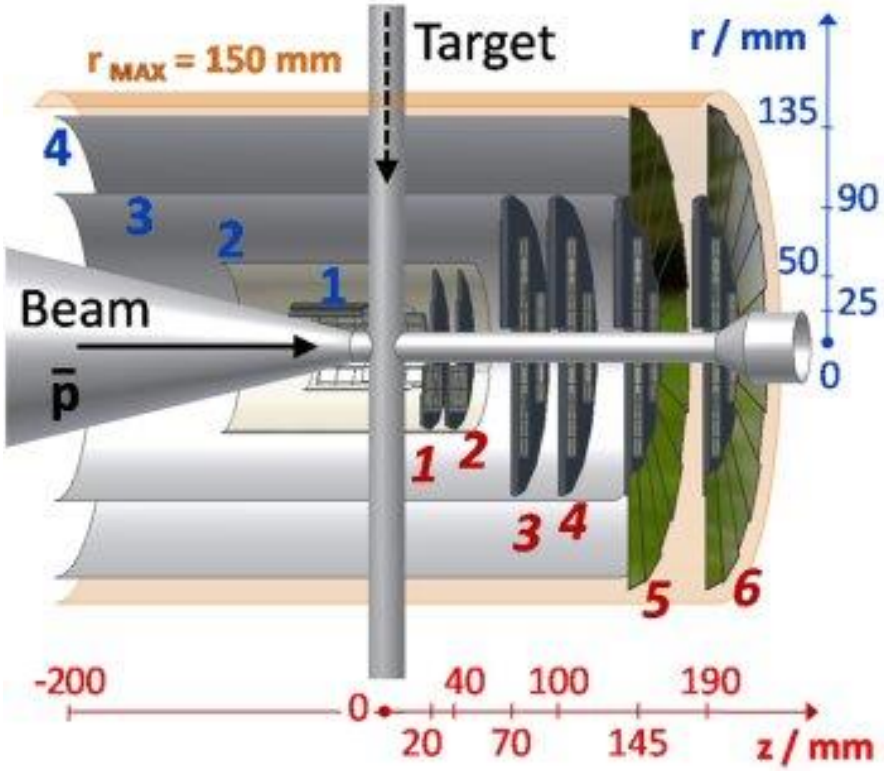




[1] PANDA Collaboration, Technical Design Report for the: PANDA Straw Tube Tracker, *https://arxiv.org/abs/1205.5441v2*, 2012

The Micro Vertex Detector (MVD) of PANDA

- Constrain displaced vertices



Pixel Detectors and
Double Sided Silicon Strip Detectors

- **4 barrel layers**
  - 2 innermost **pixel** layers
  - 2 outermost **strip** layers
- **6 forward disc layers**
  - **Pixel** sensors
  - Outermost parts of 2 most downstream layers will have **strip** sensors

The SttCellTrackFinder, Concept

Developed by Jette Schumann, currently under vevelopment in Uppsala

- Perform track finding with STT hits as starting point
- Extension to additional detectors
- Secondary track finder-> no assumption of origin of track

Track Finding

- Cellular Automaton
  - Group hits

Track Fitting

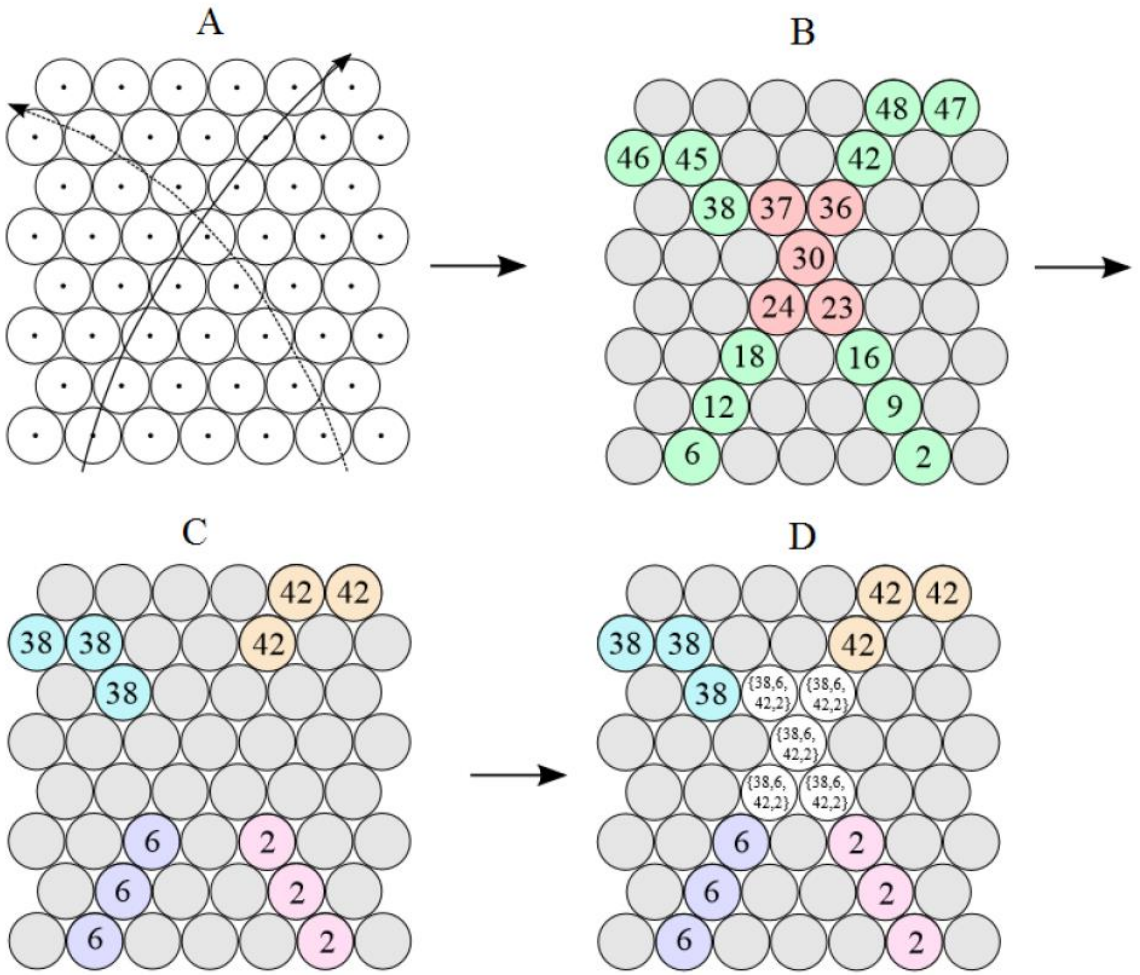
- Riemann Fit
  - Estimate track parameters
  - Error estimations

The Cellular Automaton (CA)

- Discrete neighborhood relations

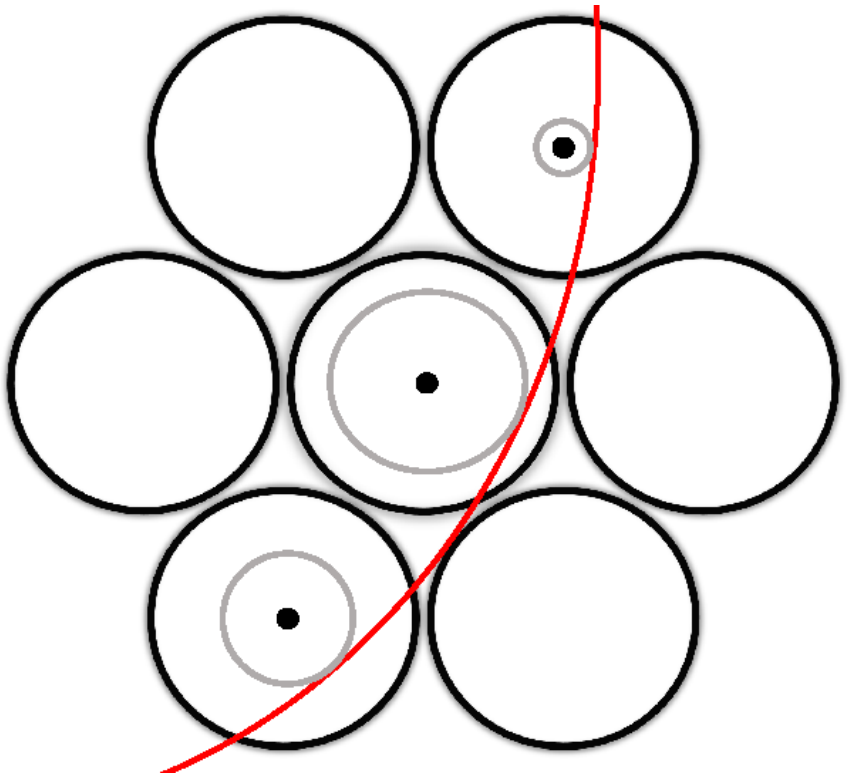
A. Tracks traverse STT
B. Hit tubes are numbered
C. Unambiguous hits are iteratively renumbered until hits in one cluster have same number
D. Ambiguous hits are given all numbers possible

- **At least 3 STT hits required**
- **Time information can be taken into account**



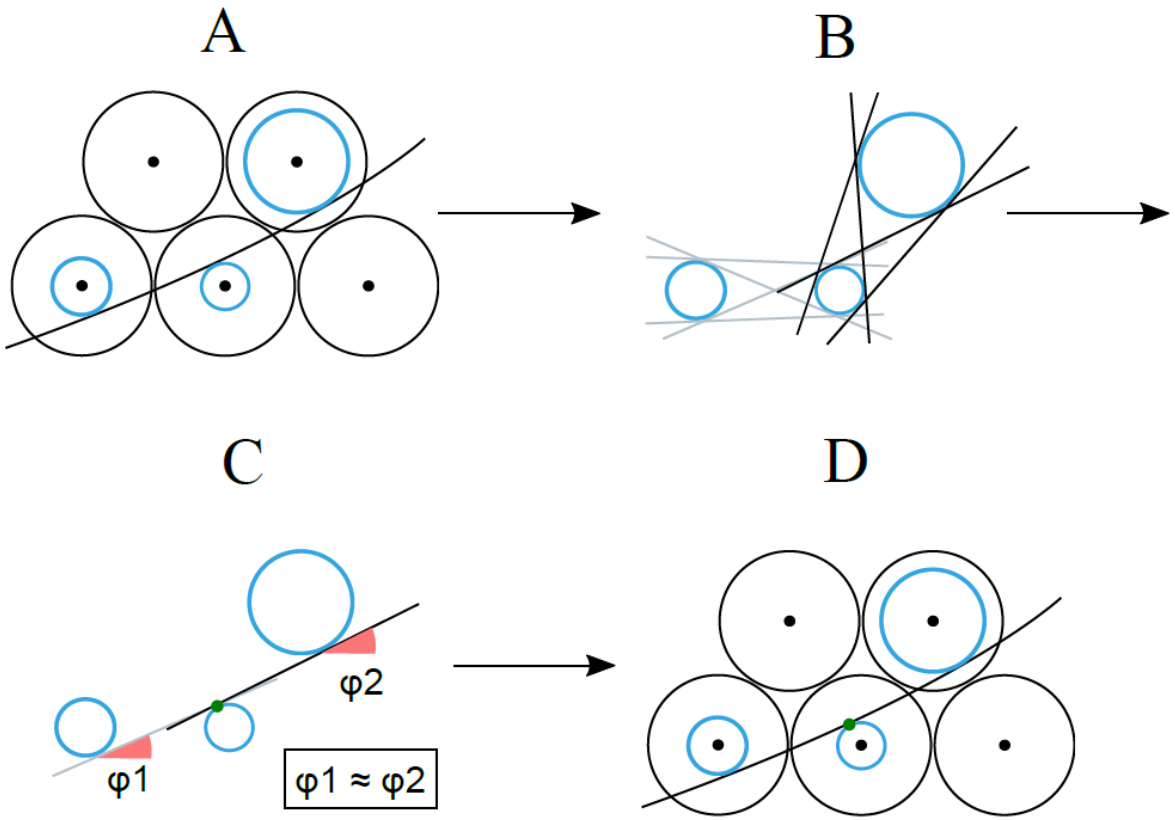
Isochrones

Circle with center in wire and going through POCA of track to wire



- If isochrones not included in track fitting, track is fitted to tube center
- Improve position resolution
- In real experiment, only isochrone will be available, not pint on isochrone tangented by track ->Need to calculate this

Isochrones in SttCellTrackFinder



A. Tracks traverse STT
B. Find lines which tangent two adjacent isochrones
C. Obtain angle of all lines. Keep the two lines (one gray and one black in figure) with smallest difference between angles
D. Position where these lines tangent center isochrone →corrected hit position

Assumption of stright line travel path between two isochrones

The Riemann Paraboloid Fit

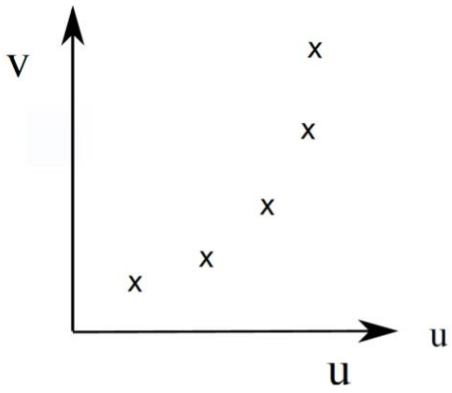
- Fit circle to points - Quadratic problem
- Fit plane to points on Riemann surface - Linear problem

Fitting a plane to points on paraboliod corresponds to fitting a circle to corresponding points in xy (uv) plane

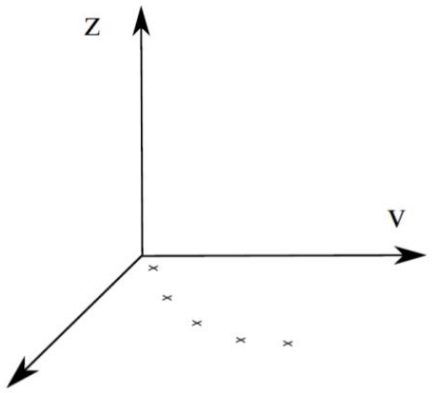
->Map hits onto Riemann surface (*e.g.* sphere or paraboloid)

- Generalization of standard Riemann sphere track fitting
- Yields equivalent results
- Advantage: both errors in RΦ and in R can be treated

The Riemann Fit

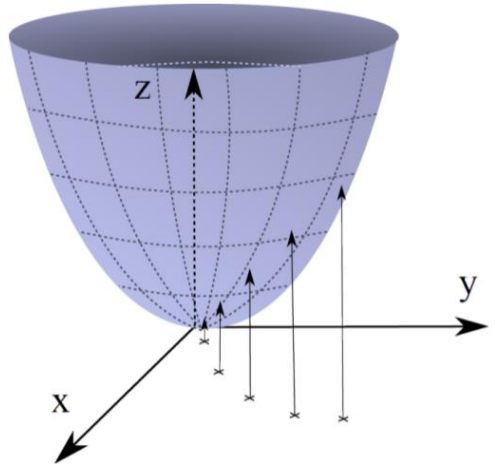


Points to be fitted



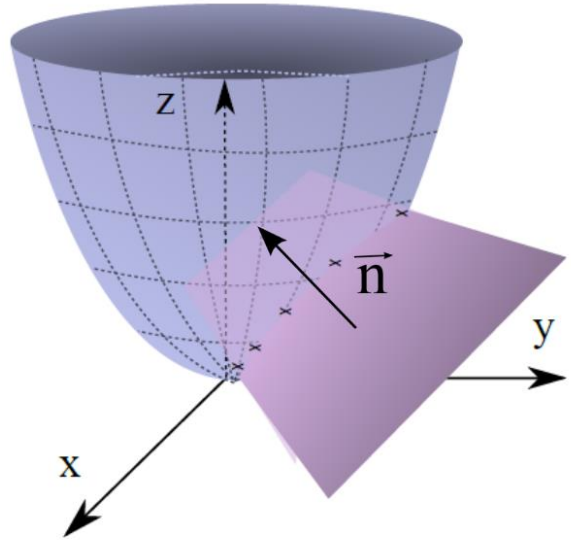
Add z-dimension

For STT, u=x, v=y



Map onto paraboloid

$z=x^2+y^2$



Calculation of plane
through 3D points
simple eigenvalue determination

From $\vec{n}$, cirlcle parameters are known:

$$\left.\begin{aligned} u_0 &= -\frac{n_1}{2n_3} \\ v_0 &= -\frac{n_2}{2n_3} \end{aligned}\right\} \text{ Circle center}$$

$$\rho^2 = \frac{1 - n_3^2 - 4cn_3}{4n_3^2} \quad \text{Radius}$$

$c+n_1x+n_2y+n_3z=0$

SttCellTrackFinder

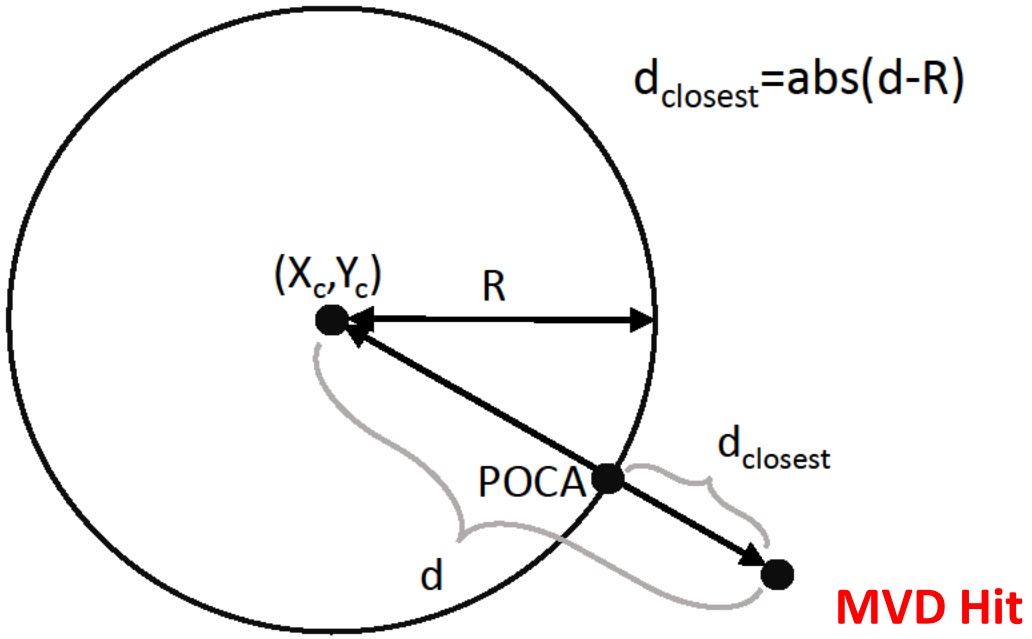
- Ambiguous hits added to track according to distance to Riemann track
- Tracklets combined into longer tracks according to distance between their Riemann tracks
- Extension to other detectors

MVD:

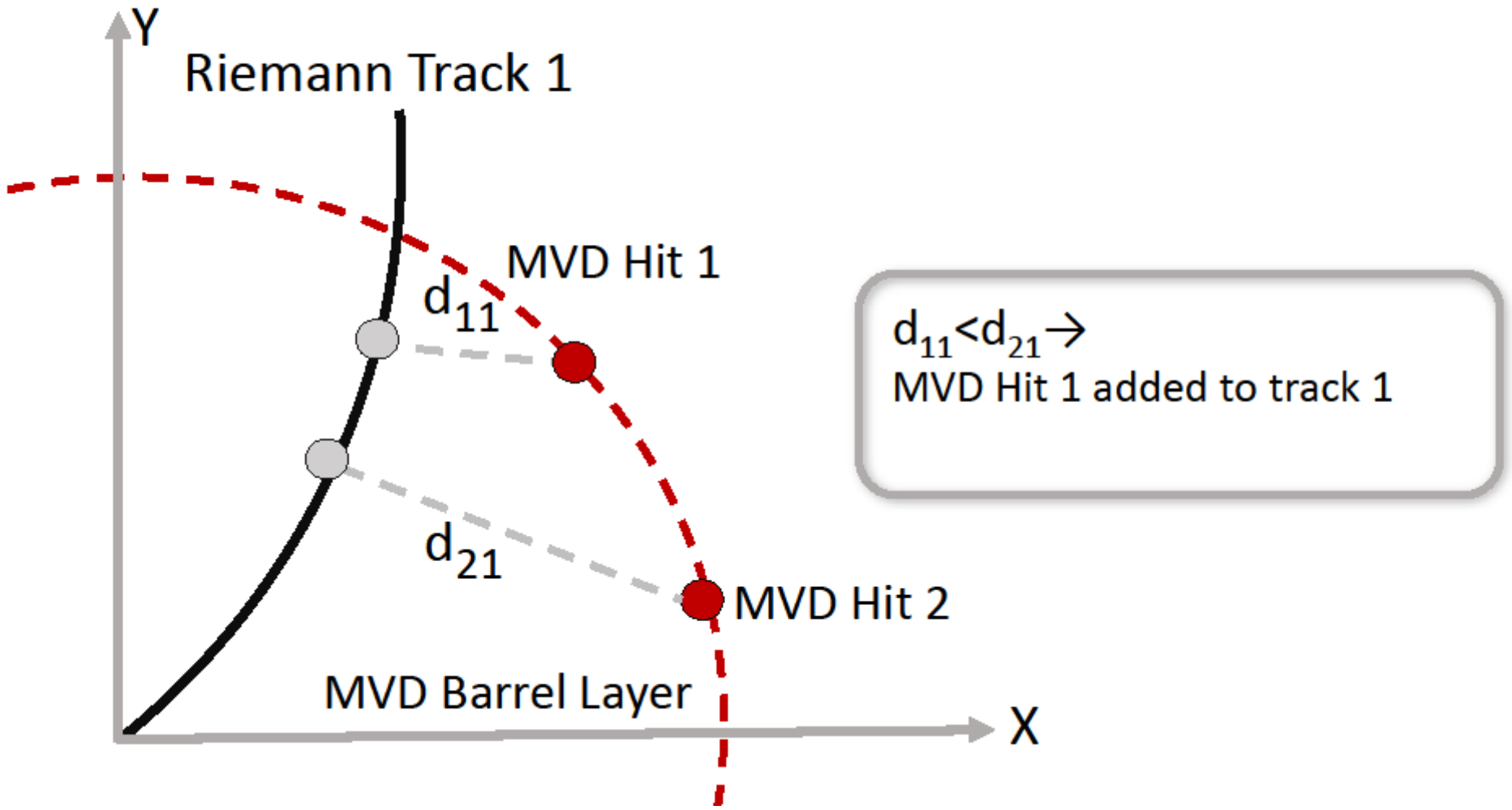
- MVD: 3 dimensional position information
- STT: mainly xy-position information is obtained
- Use xy-position information of MVD hits for every barrel layer individually and add closest hit in each layer to track

MVD Hits in the SttCellTrackFinder

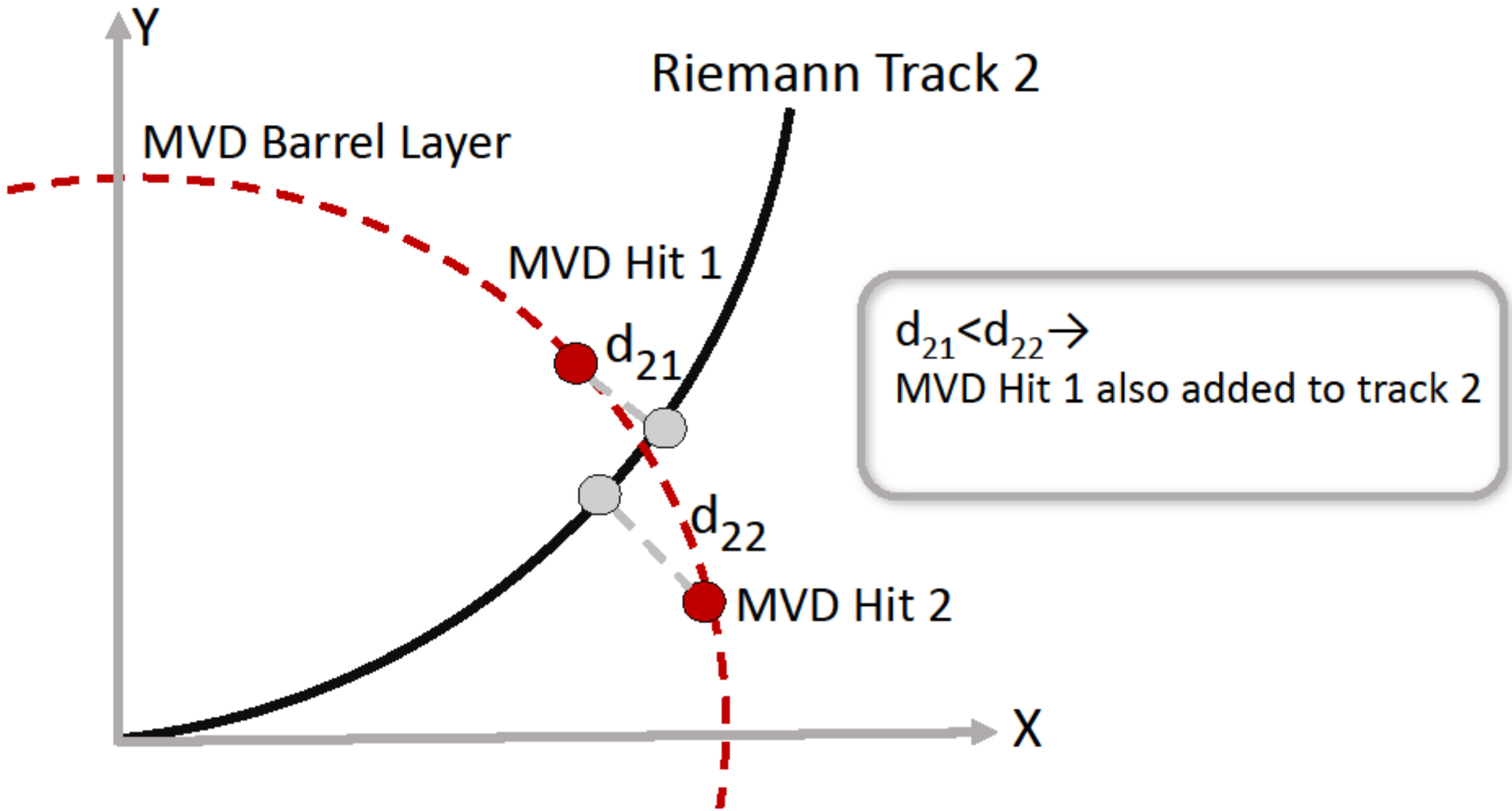
Riemann Circle Fit



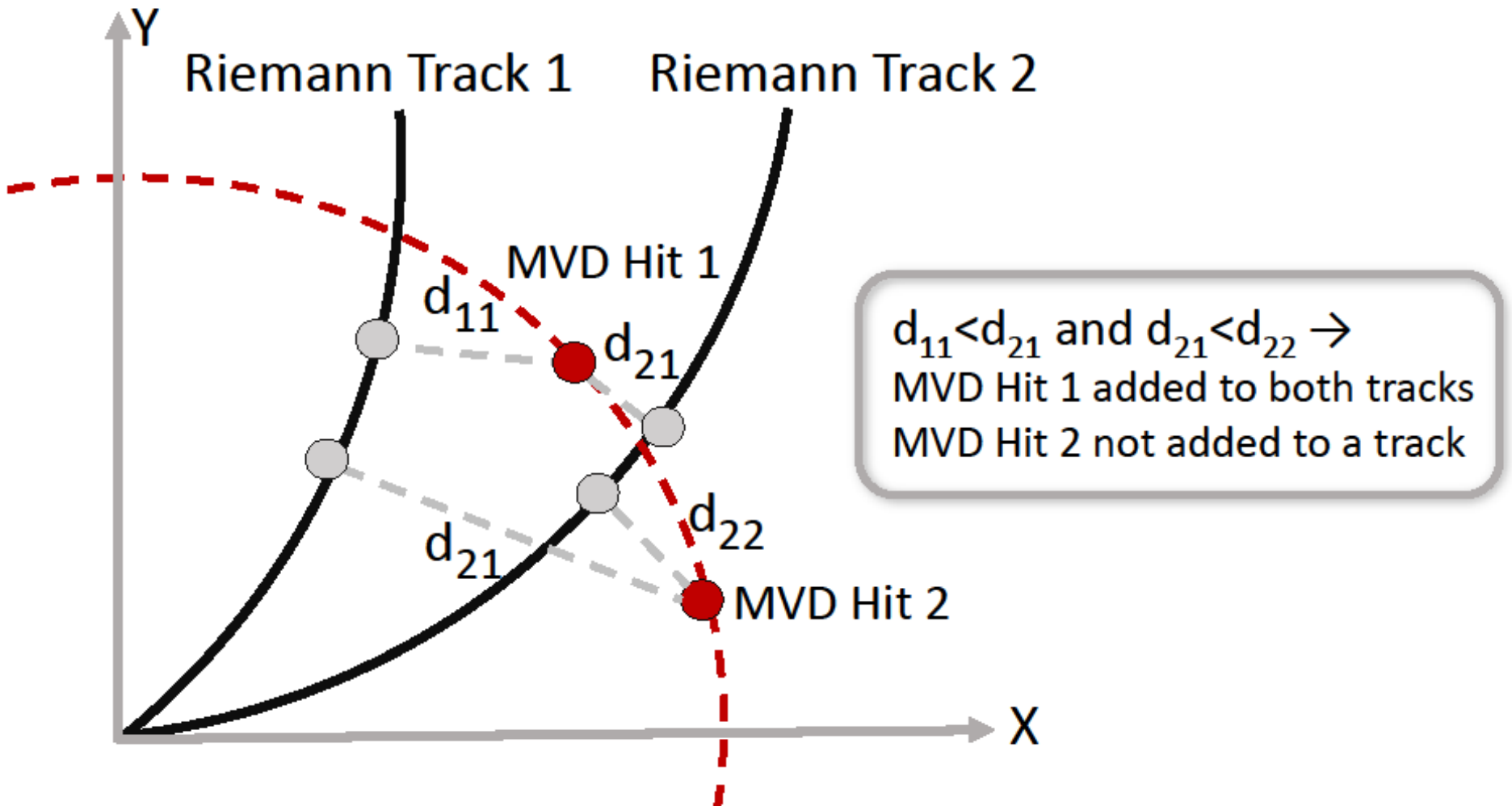
MVD Hits in the SttCellTrackFinder



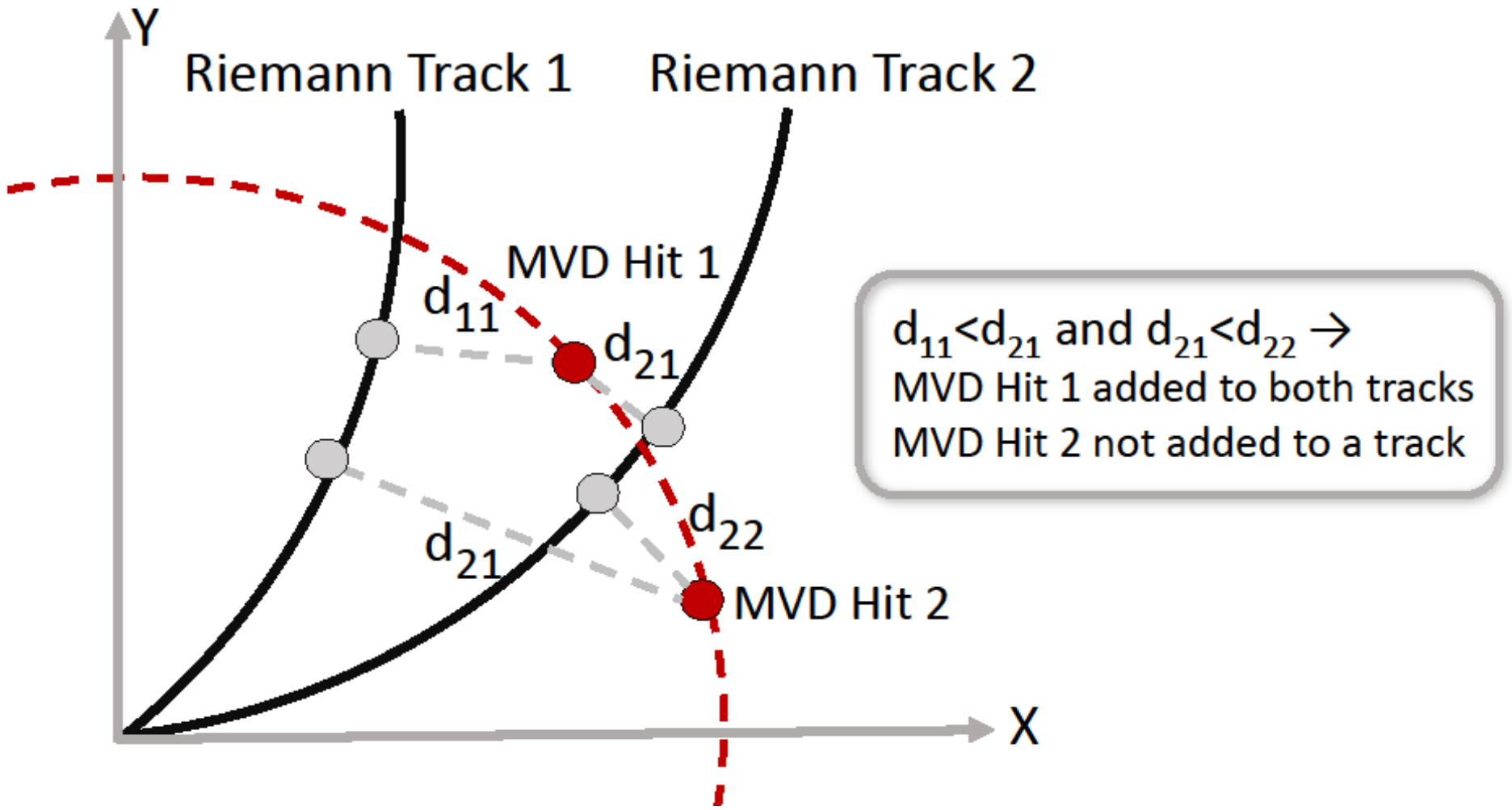
MVD Hits in the SttCellTrackFinder



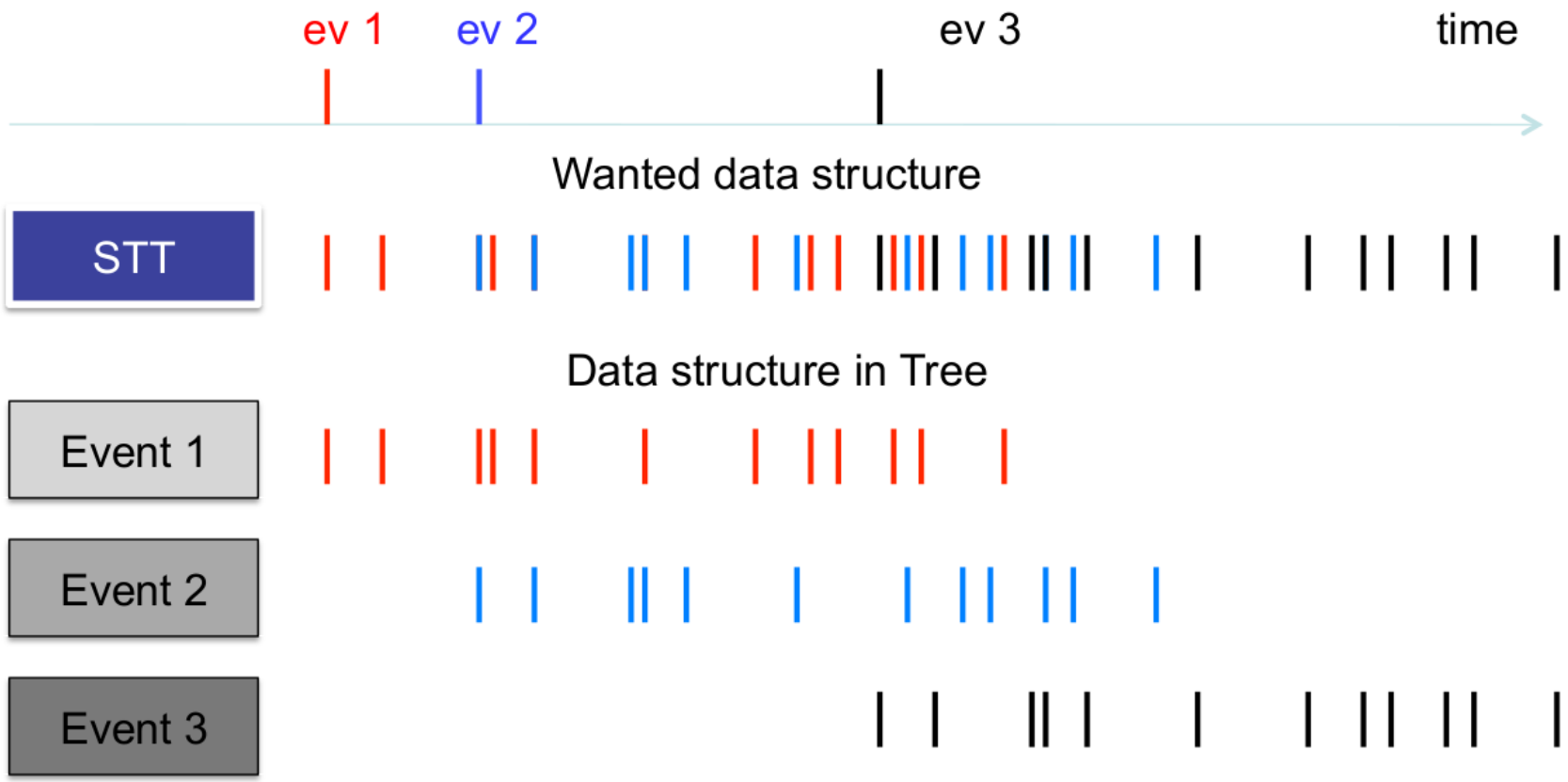
MVD Hits in the SttCellTrackFinder



MVD Hits in the SttCellTrackFinder

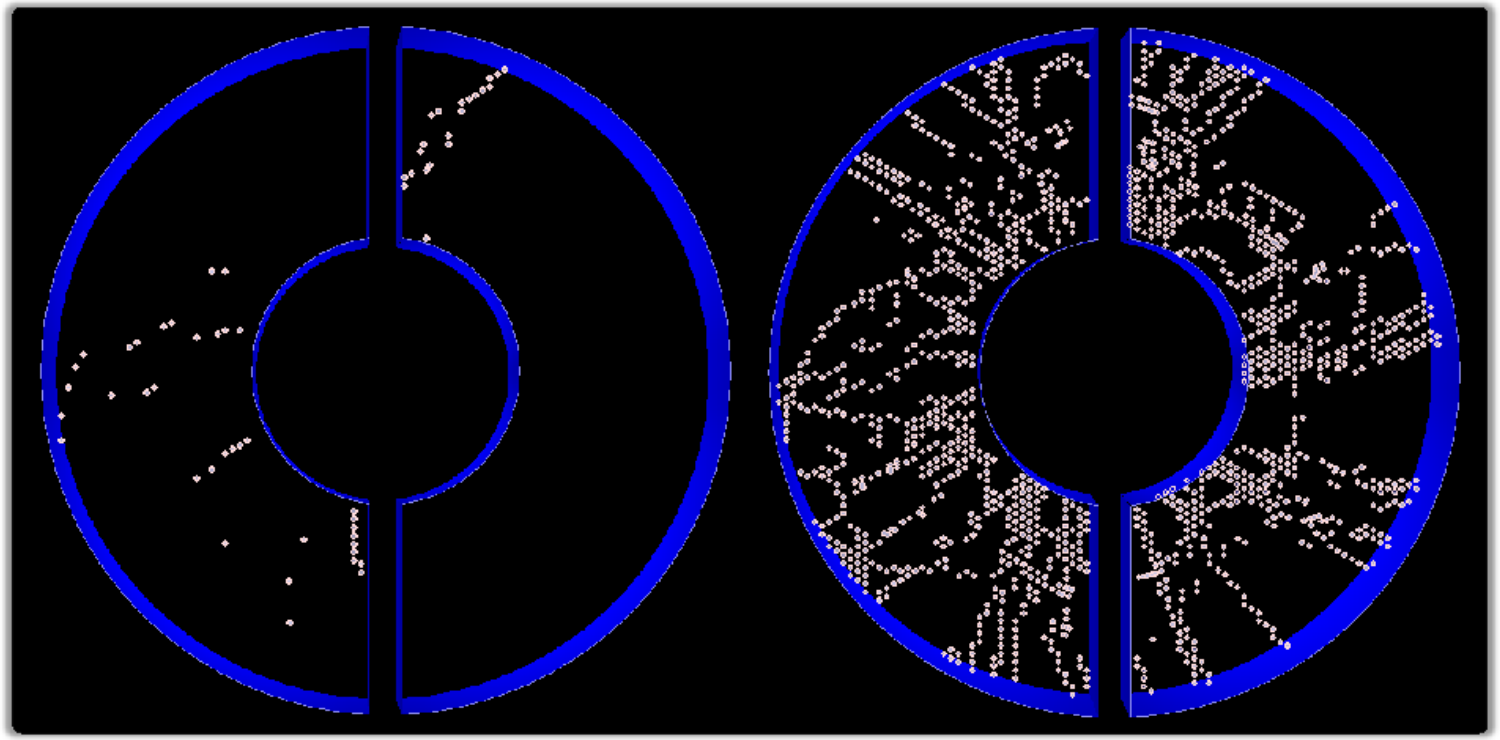


Event Mixing



Event Mixing

DPM sample



< 200 ns between timestamps

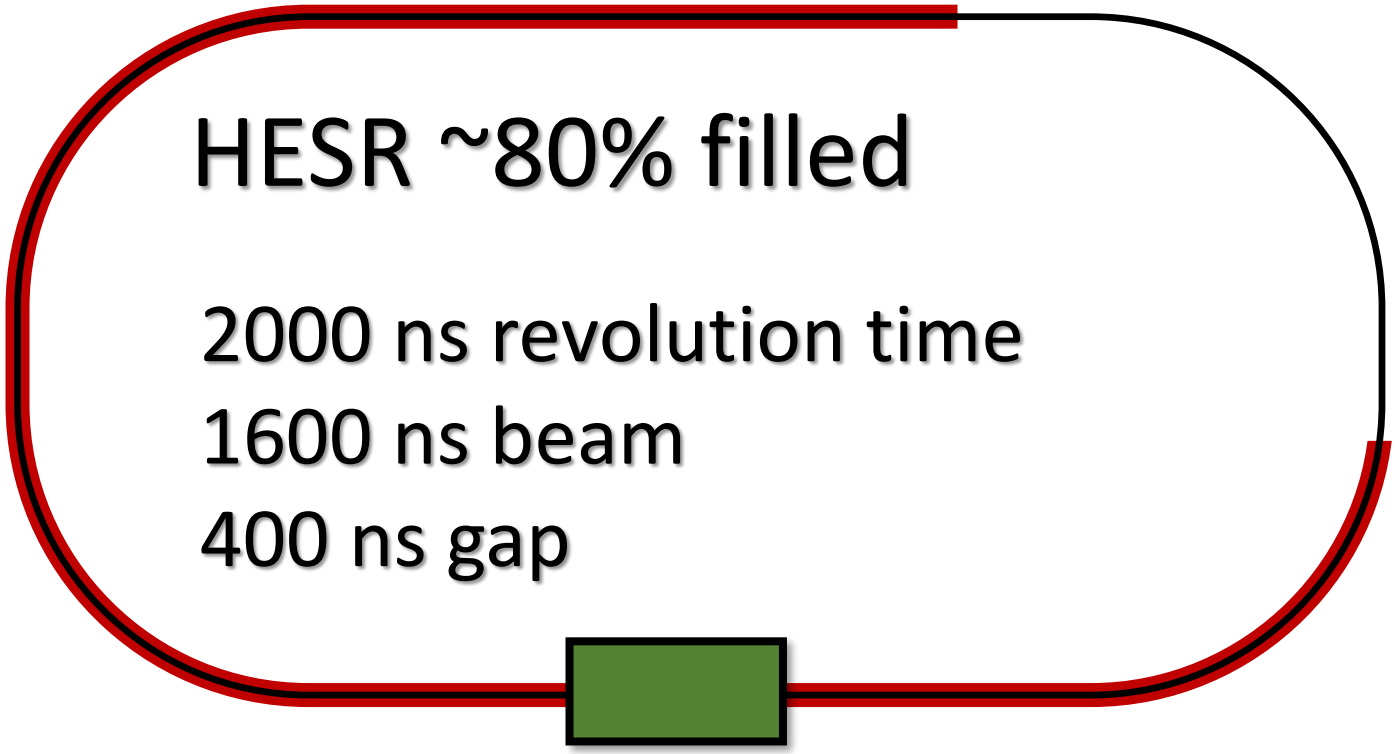
~ Event based

< 2000 ns between timestamps

~ Event mixing

Time Structure of Beam

Quasi continuous beam – Poisson distributed

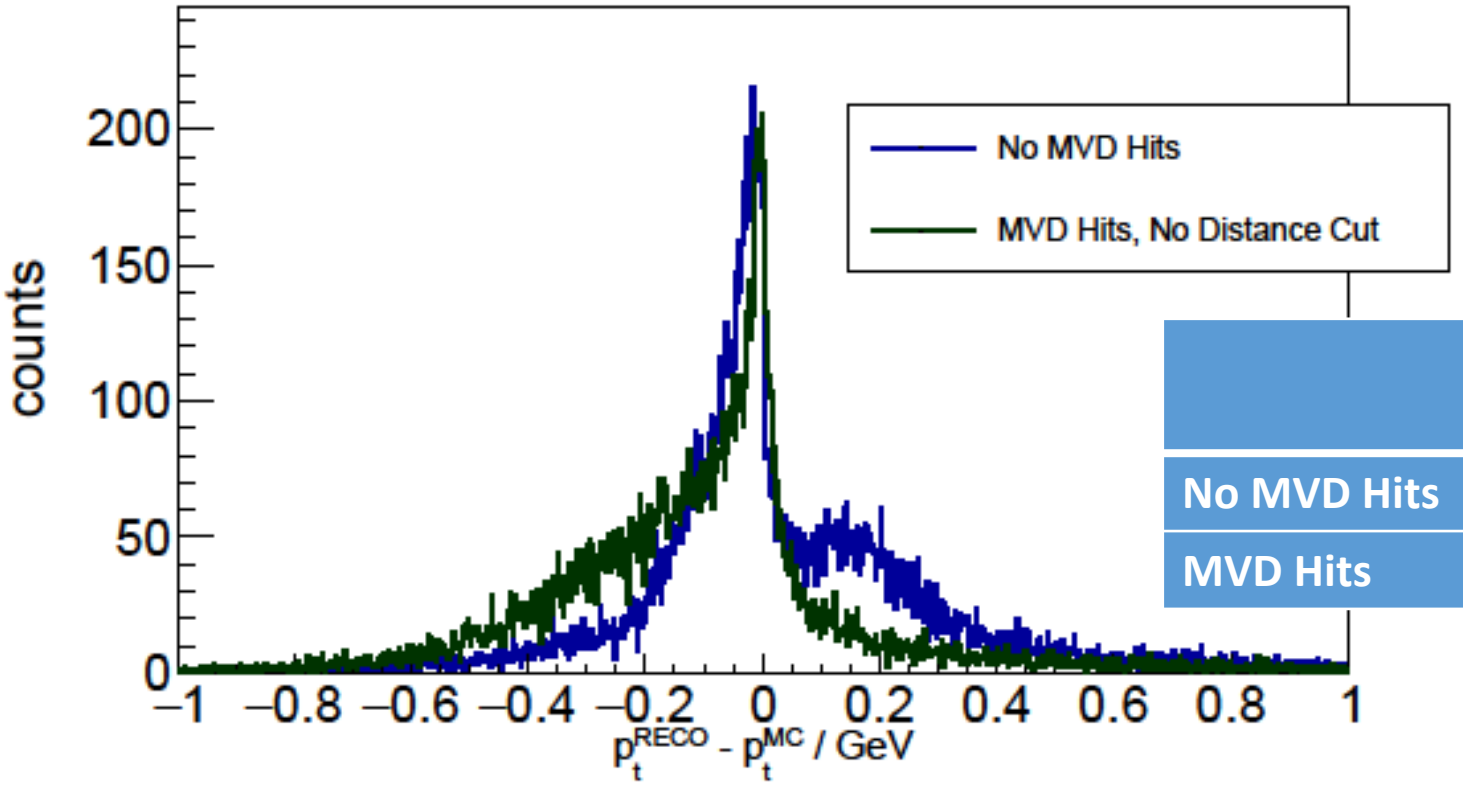


Event Based → Time Based

- Time based digitization works for most detector implementations
  - Mean time between events added to hit timestamps
- Time structure of HESR provides natural ”bunches” of data

Transverse Momentum Resolution

- DPM Sample, P_{beam}=5 GeV/c, 10 000 Events

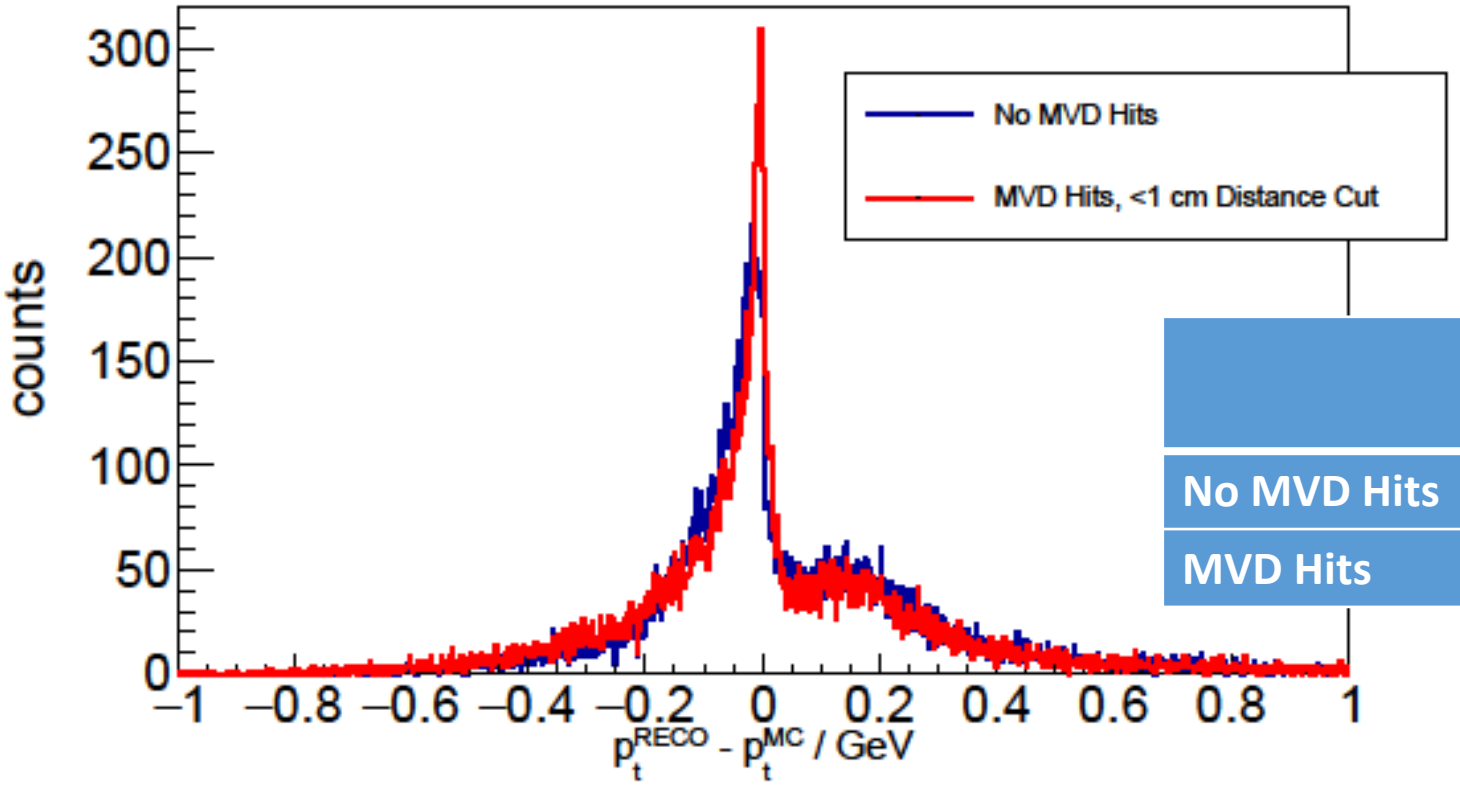


- Different qualitative shape of curves
- Peak somewhat narrower but much closer to zero when using MVD hits

	Peak Position (at peak maximum)	FWHM
No MVD Hits	-0.017	0.074
MVD Hits	-0.001	0.060

Transverse Momentum Resolution

- DPM Sample, P_{beam}=5 GeV/c, 10 000 Events



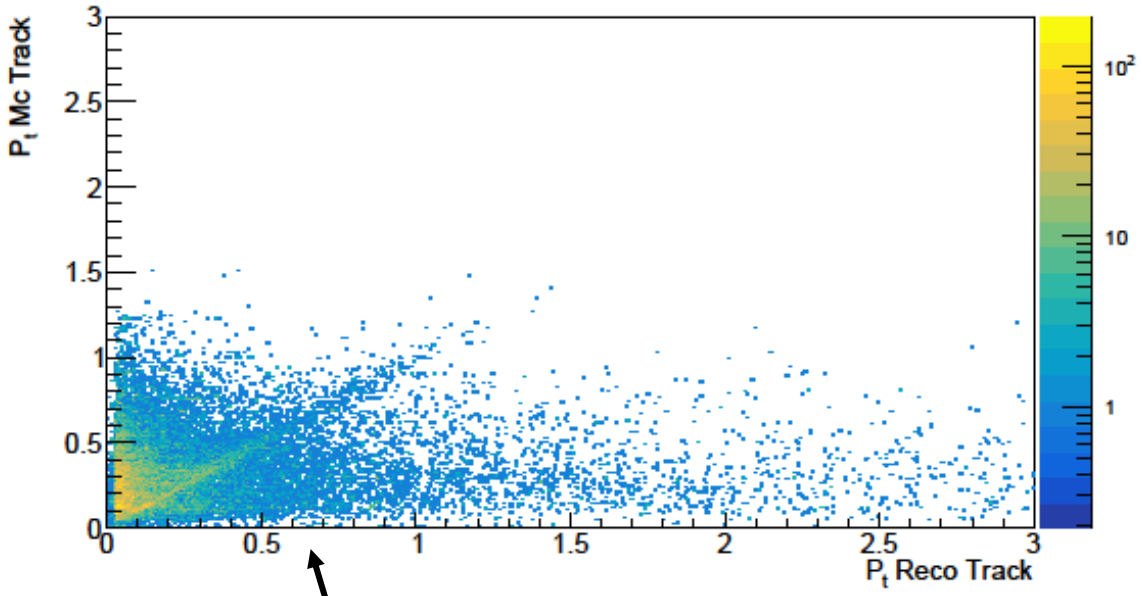
- Similar qualitative shape of curves
- Peak narrower and closer to zero when using MVD hits

	Peak Position (at peak maximum)	FWHM
No MVD Hits	-0.017	0.074
MVD Hits	-0.003	0.028

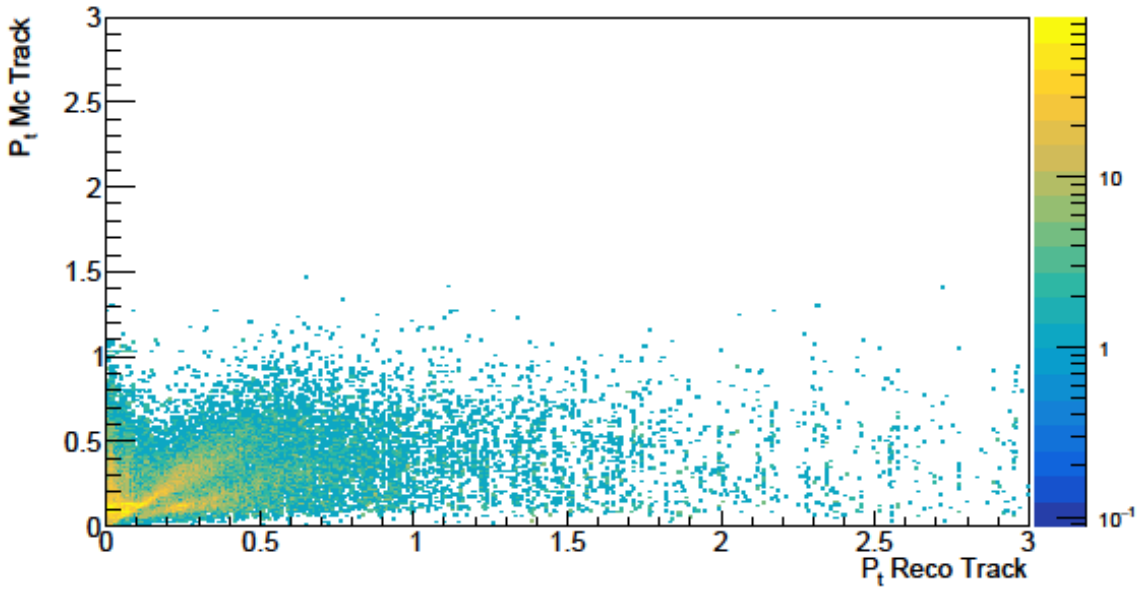
Transverse Momentum Resolution

- DPM Sample, P_{beam}=5 GeV/c, 10 000 Events

With MVD Hits, no distance cut



Without MVD Hits

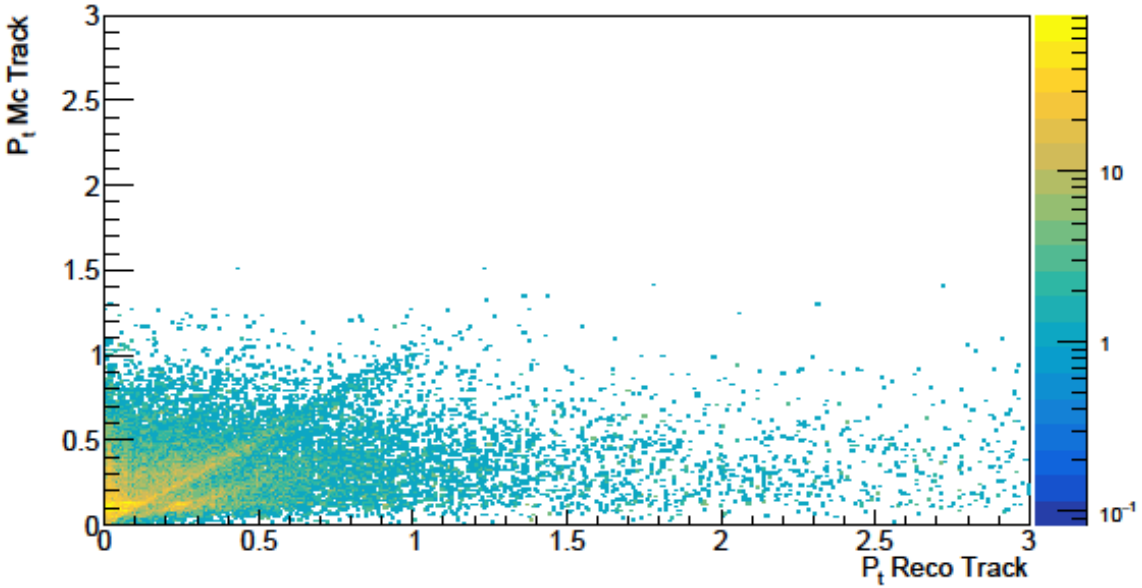


Sharper line around P_t(MC Track)=P_t(Reco Track)

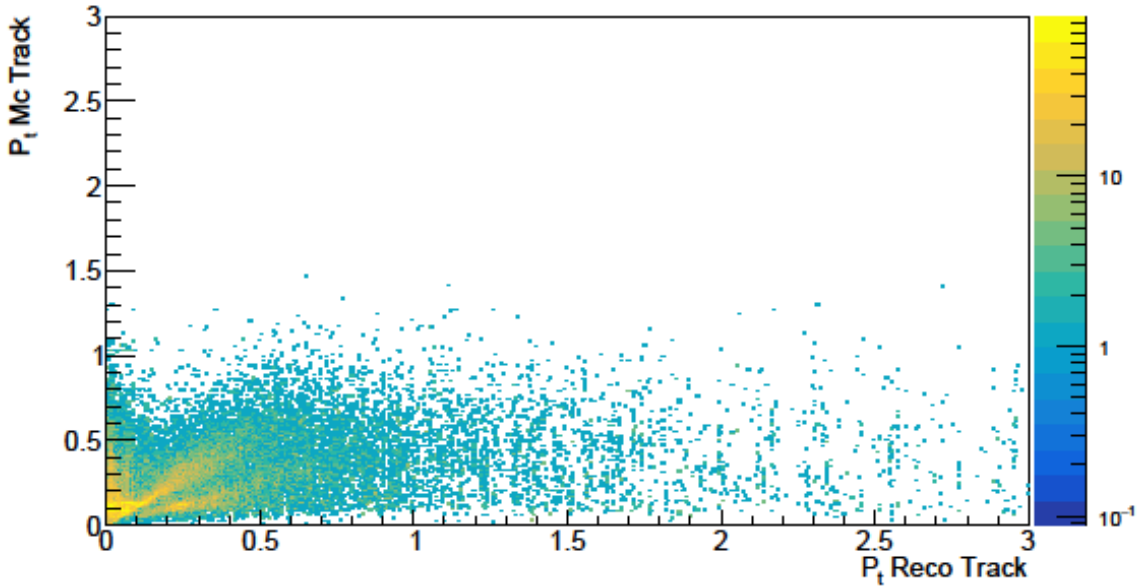
Transverse Momentum Resolution

- DPM Sample, P_{beam}=5 GeV/c, 10 000 Events

With MVD Hits, 1 cm distance cut



Without MVD Hits



Transverse Momentum Resolution

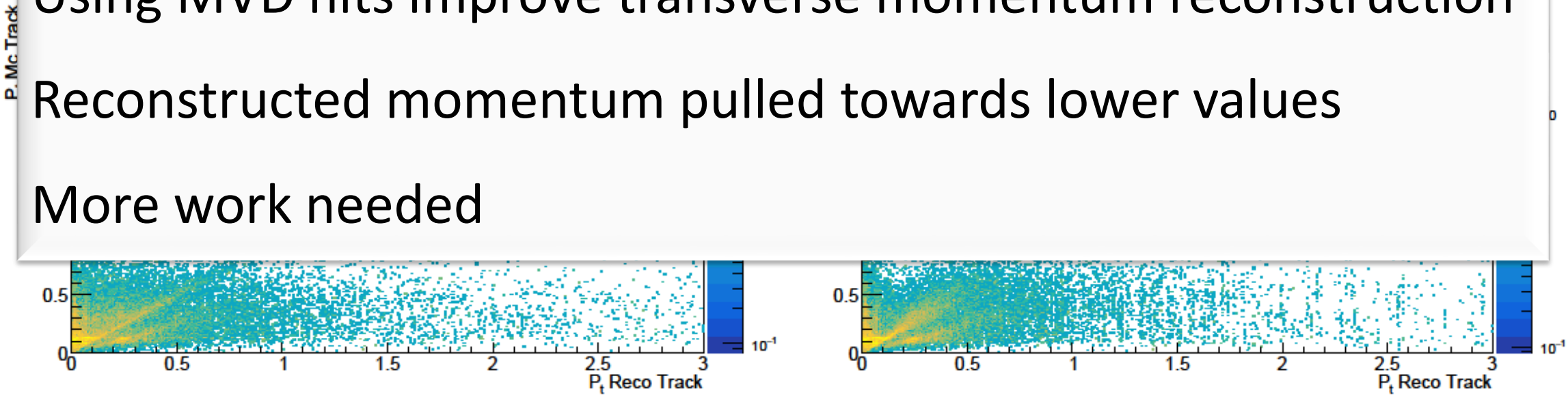
- DPM Sample, P_beam = 5 GeV/c, 10 000 Events

Conclusions:

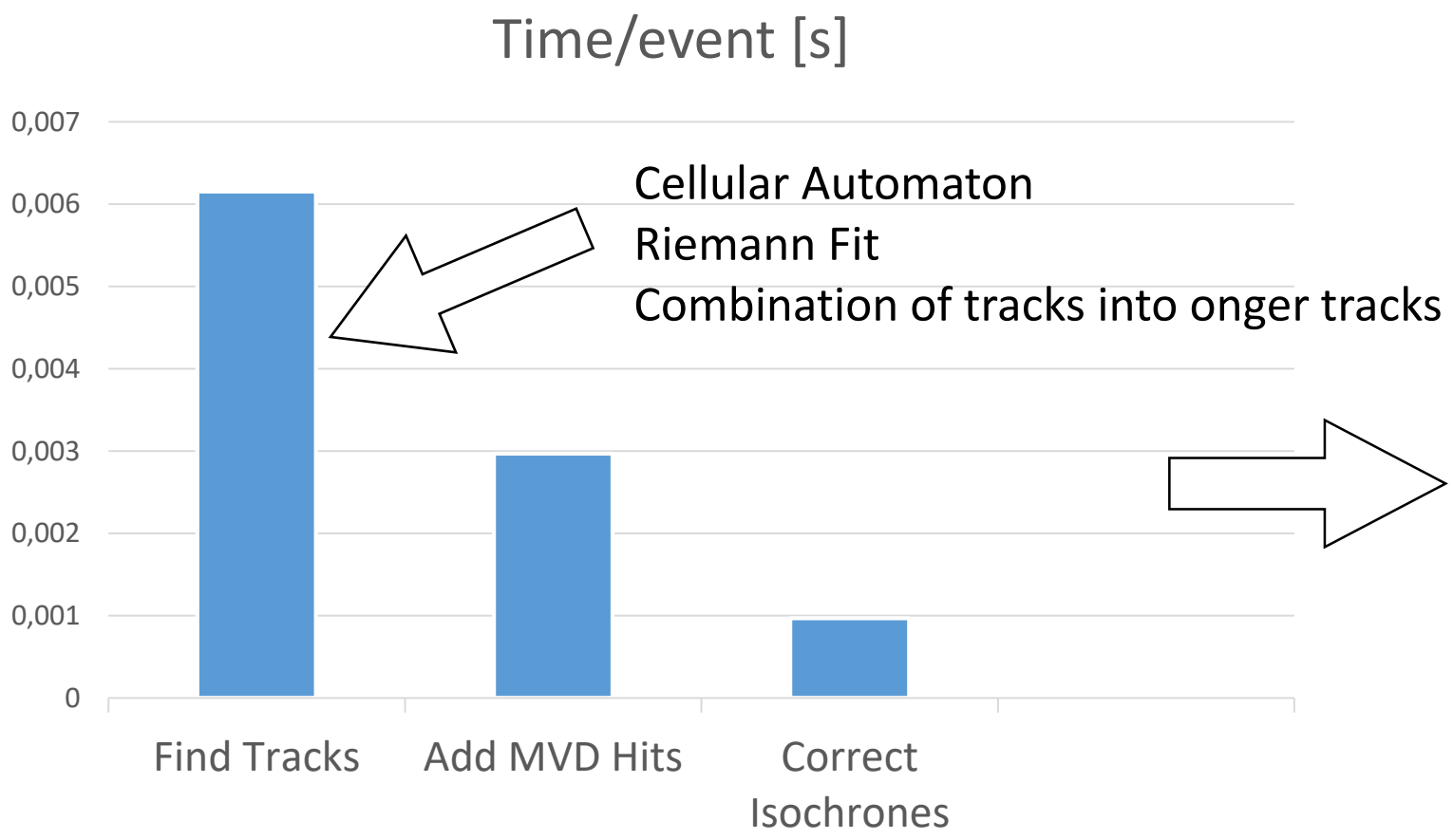
Using MVD hits improve transverse momentum reconstruction

Reconstructed momentum pulled towards lower values

More work needed



Performance Checks



Cellular Automaton
Riemann Fit
Combination of tracks into onger tracks

Room for optimizing code for speed

Summary

SttCellTrackFinder

- Track finder for secondary tracks
- Uses Cellular Automaton for track finding
  - Both spatial and time relations can be taken into account
- Uses Riemann fit for determining track parameters
- Have been extended to MVD

Outlook/Open Issues

- Add different requirements for MVD hit inclusion, *e.g.* one hit can only belong to one track
- Include Barrel ToF hits for time information
- Track propagation to GEM hits with helix propagator

Thank You!

Getting the Time Structure

```
PndBranchBurstBuilder_timeCut *combi = new PndBranchBurstBuilder_timeCut();
combi->AddInputBranch(”STTHit”);
combi->SetOutputPrefix(”Burst_tb”);
Combi->SetTimePeriod(2000);   // Time after which you want to place a cut
combi->SetPersistence(kTRUE);
fRun->AddTask(combi);
```

Need timestamps for STT hits! -> SttHitProducerRealFull

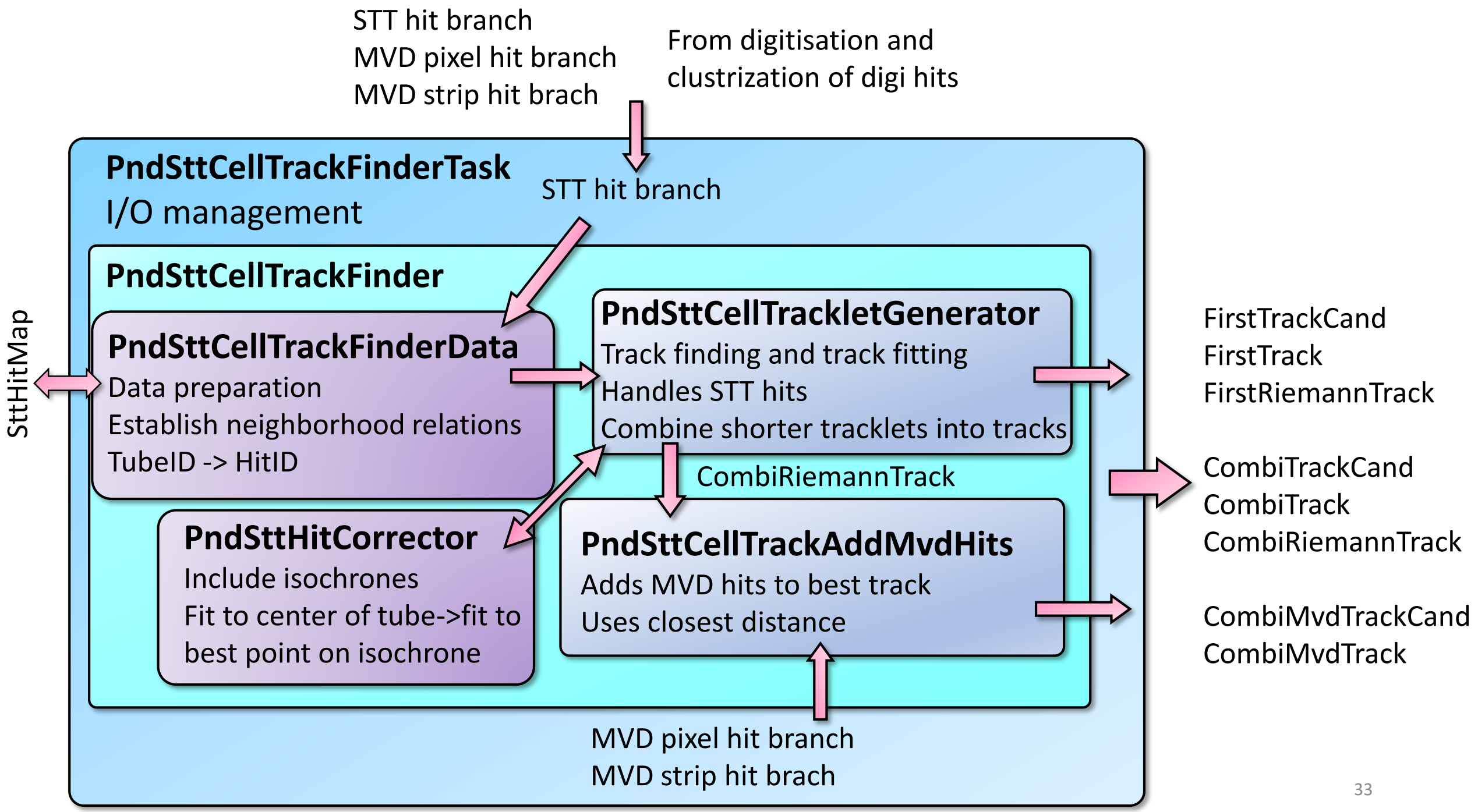
Running SttCellTrackFinder Timebased

Timing information included in hit clustering
Digitization task PndsttHitProducerRealFull produces time stamps

```
PndSttCellTrackFinder *cellTrackFinder = new PndSttCellTrackFinderTask();
cellTrackFinder->SetPersistence(kTRUE);
cellTrackFinder->AddHitBranch("Burst_tb_STTHit");   // only of stt hit type
cellTrackFinder->SetRunTimeBased(kTRUE);   // include timestamp
cellTrackFinder->SetClusterTime(300) ;   // in ns, 250 ns default
fRun->AddTask(cellTrackFinder);
```

Running SttCellTrackFinder With MVD Hits

```
PndSttCellTrackFinder *cellTrackFinder = new PndSttCellTrackFinderTask();
cellTrackFinder->SetPersistence(kTRUE);
cellTrackFinder->SetIncludeMvdHits(kTRUE);
fRun->AddTask(cellTrackFinder);
```


STT hit branch
MVD pixel hit branch
MVD strip hit brach
From digitisation and clustrization of digi hits
PndSttCellTrackFinderTask
I/O management
STT hit branch
PndSttCellTrackFinder
SttHitMap
PndSttCellTrackFinderData
Data preparation
Establish neighborhood relations
TubeID -> HitID
PndSttCellTrackletGenerator
Track finding and track fitting
Handles STT hits
Combine shorter tracklets into tracks
FirstTrackCand
FirstTrack
FirstRiemannTrack
CombiRiemannTrack
PndSttHitCorrector
Include isochrones
Fit to center of tube->fit to best point on isochrone
PndSttCellTrackAddMvdHits
Adds MVD hits to best track
Uses closest distance
CombiTrackCand
CombiTrack
CombiRiemannTrack
CombiMvdTrackCand
CombiMvdTrack
MVD pixel hit branch
MVD strip hit brach