INTT software

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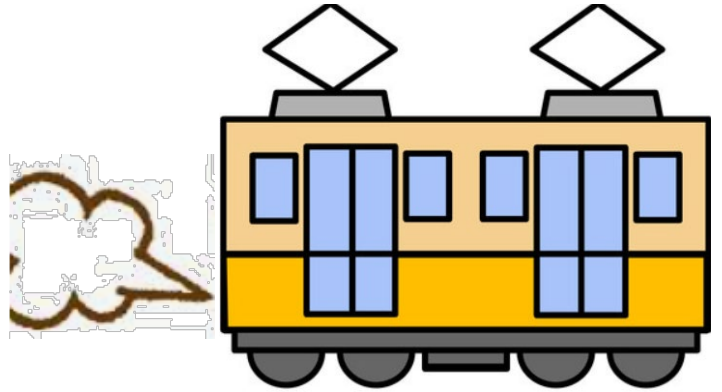
Before Introduction

Hello, Takashi!
Can we discuss about INTT workshop session a little bit?

午後 4:04

既読

Sure! I



One thing we would like to get is, review session for **INTT related software**.

The point of this session is, we don't have to learn how to use during the session. We want to get some info, **what kind of software(analysis module) we have in sPHENIX github**, and what is purpose fhat module.

Oh, can we have our InttMapping review as well?

2024/11/25

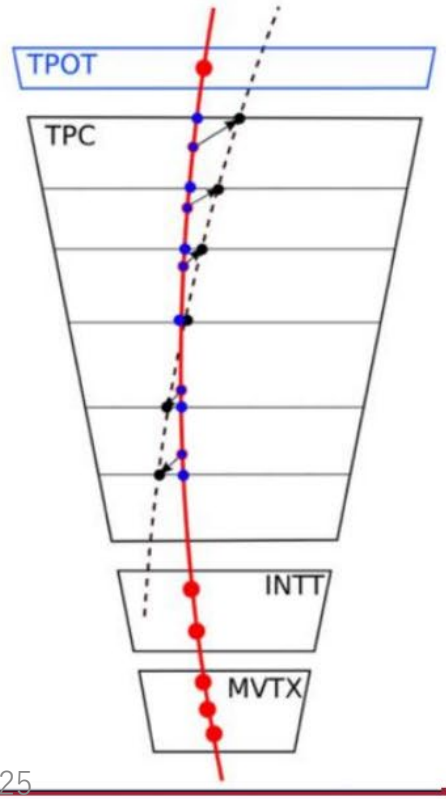
Purposes of INTT

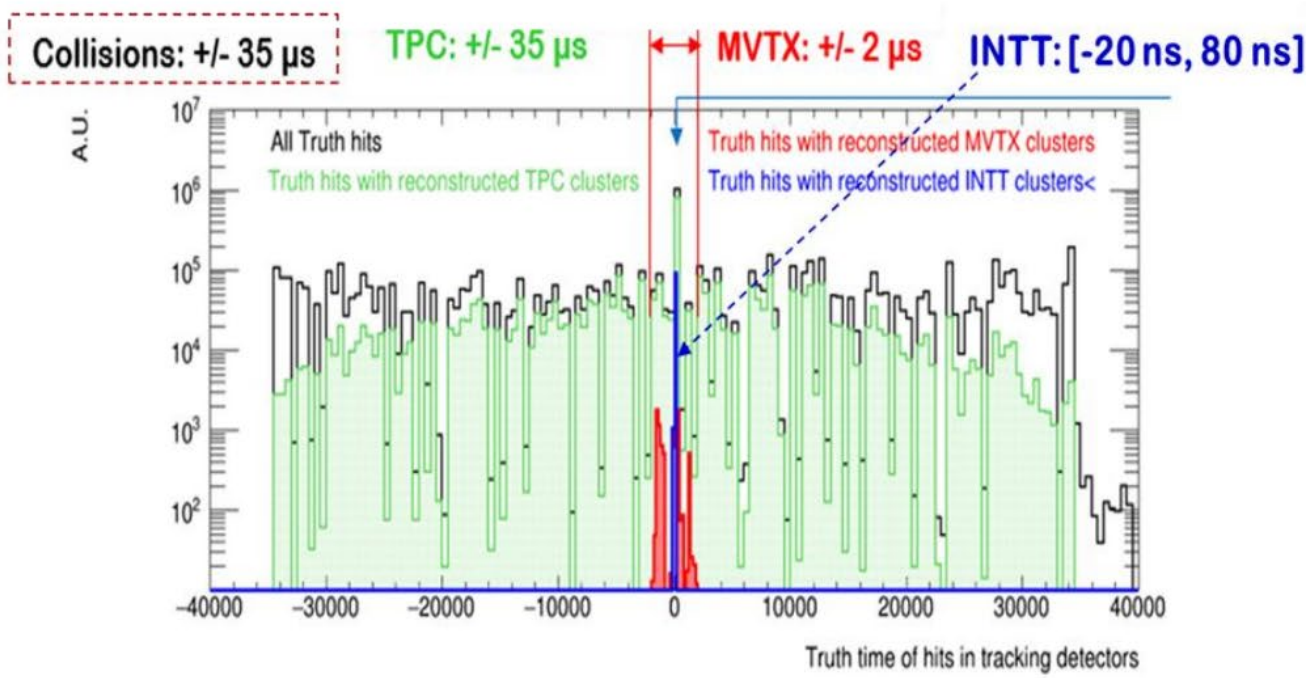
- Charged particle tracking
  - Together with MVTX, TPC, TPOT

Beam crossing Identification
Treso ~ 100ns (INTT), ~5us(MVTX), ~80us (TPC)

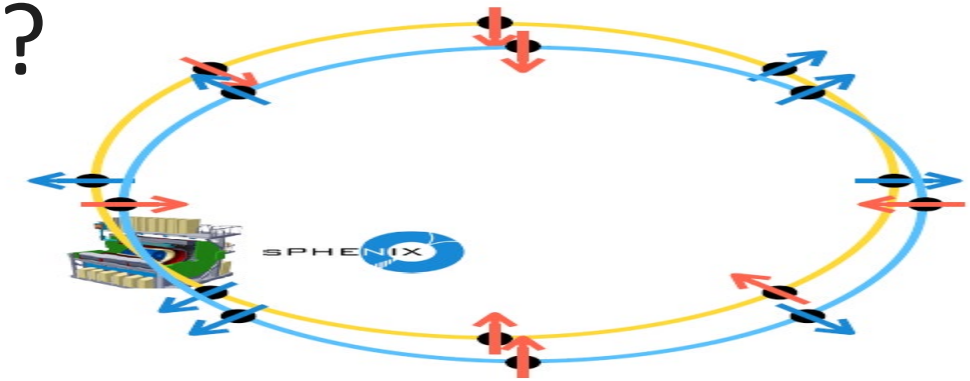
- More? Z-vertex, dN/deta, Reaction plane, Centrality for streaming data

Tracking Points and Timing





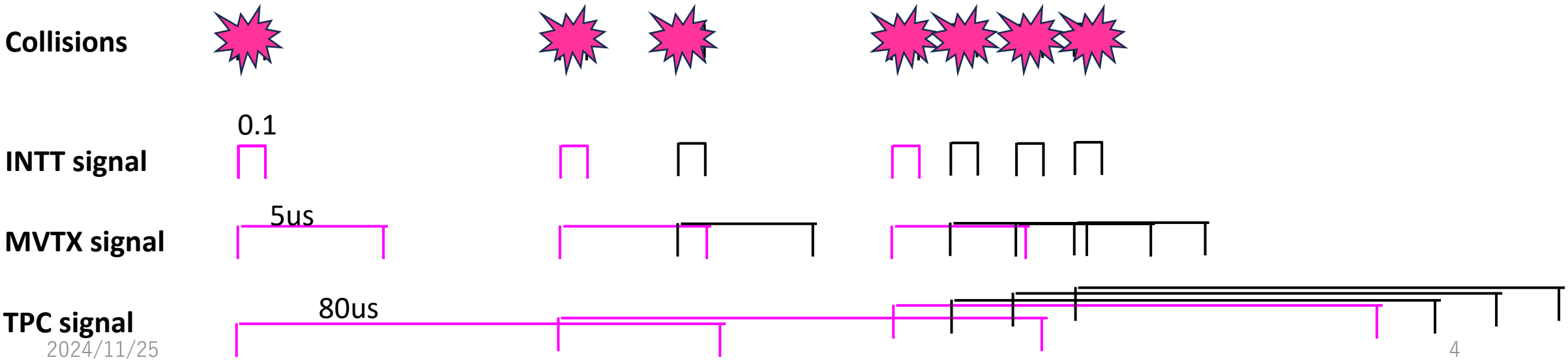
Why is beam crossing important?



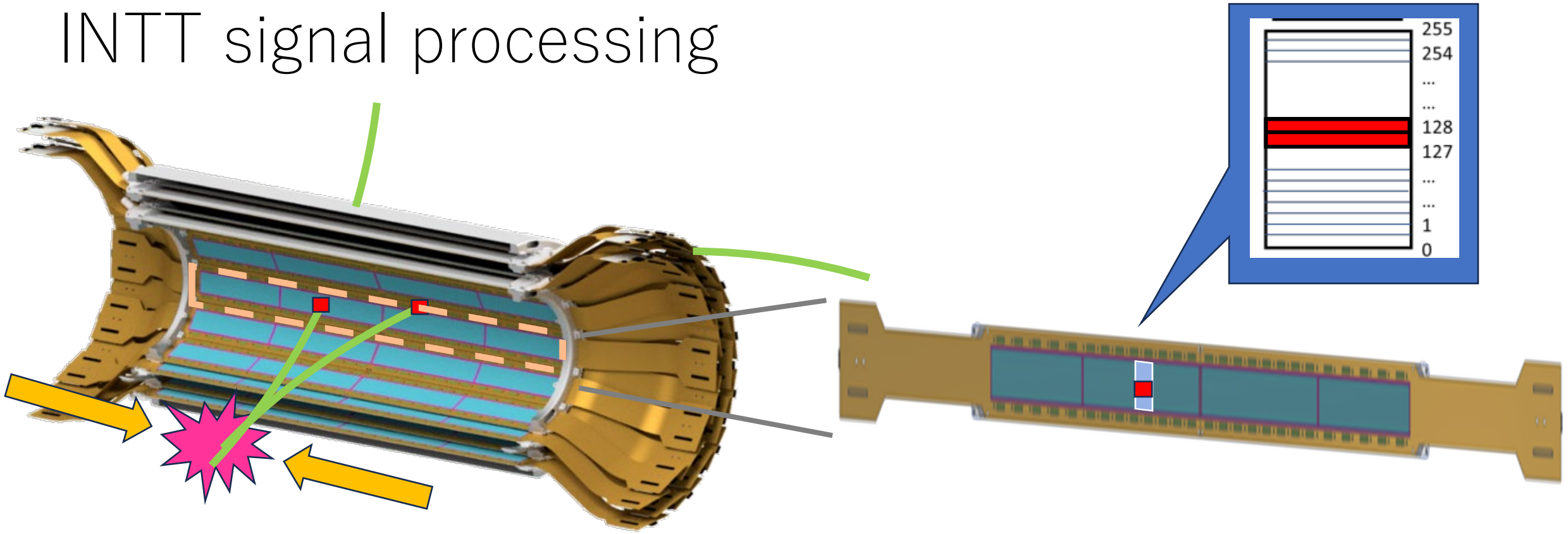
- The beam has a bunch structure
  - Bunch length is 106ns
  - Nbunchs is 120

- Treso ~ 0.1us(100ns) (INTT), ~5us(MVTX), ~80us (TPC)
  - Signals from different beam crossing mixed up
  - Physics we aim to measure is a quantity per COLLISION

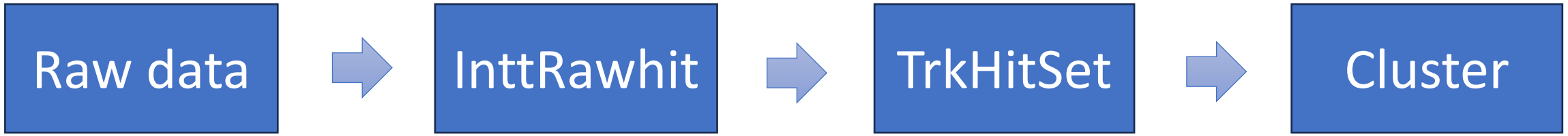
Timing Diagram



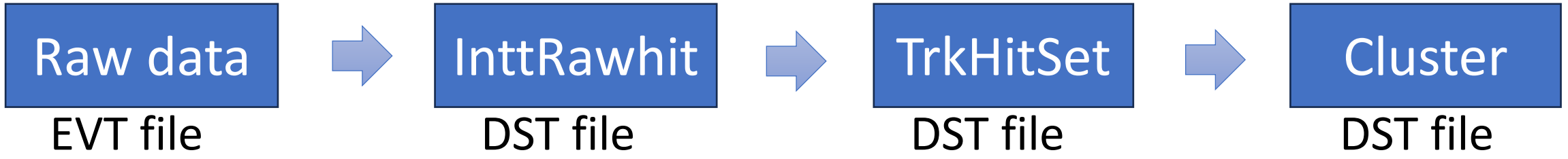
INTT signal processing



- Raw data is converted to 3D hit position step by step

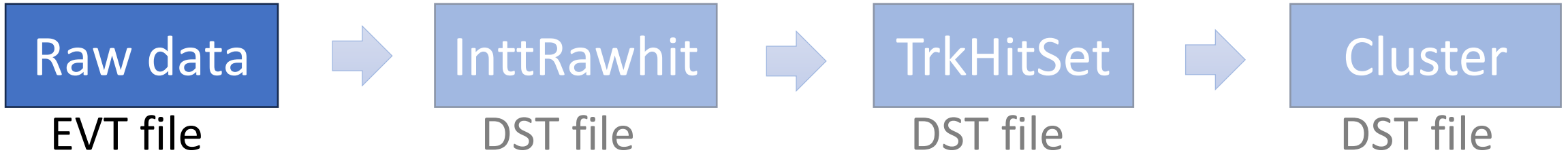


INTT data (format)



- Raw data: Binary data from INTT detector (FELIX)
  - a 32bit binary contains hit channel, chip, ladder, FELIX, ADC are stored in
  - Each FELIX server produce own EVT file -> INTT has 8 evt files
- InttRawhit: DST style data (C++ class)
  - Hit channel, chip, ladder, FELIX, adc are stored in the variables
  - Channel, chip, ladder, FELIX ID are defined by INTT team
- TrkrHitSet: DST style data but sPHENIX format for global tracking
  - Similar w/ InttRawhit
  - Channel, chip, ladder, FELIX ID are defined by sPHENIX tracking
- Cluster : DST style data
  - adjacent hits grouped to single cluster

INTT data (format)



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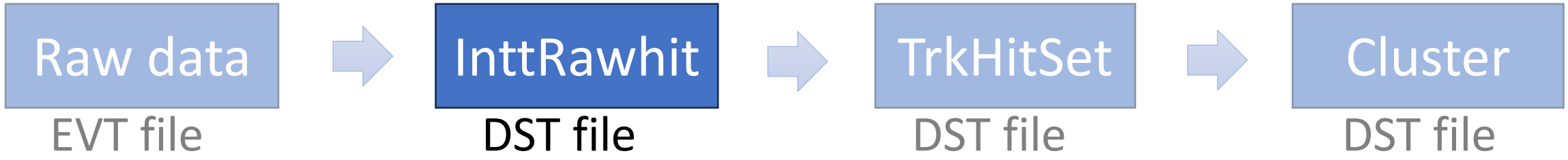
		31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	LSB16, MSB16が入れ替わっている
1		Header								fee				len				Header																header=0xF000CAF0
2	1	Hit-Header								BCO								Hit-Header																Hit-header
3	2	BCO																																
4	3	adc				chip_id				chan_id												AMPL			full ROC	full FPX		FPHX_BCO						hit
5	4	adc				chip_id				chan_id												AMPL			full ROC	full FPX		FPHX_BCO						hit
6	5	adc				chip_id				chan_id												AMPL			full ROC	full FPX		FPHX_BCO						hit
7	6	adc				chip_id				chan_id												AMPL			full ROC	full FPX		FPHX_BCO						hit
8	7	adc				chip_id				chan_id												AMPL			full ROC	full FPX		FPHX_BCO						hit

INTT raw data (format)



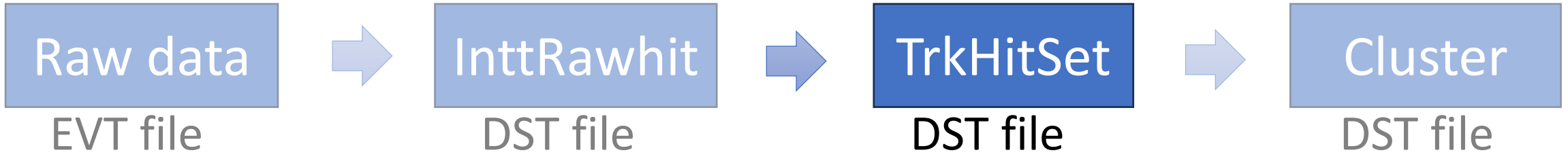
- InttRawhit: DST style data (C++ class)
  - Hit channel, chip, ladder, FELIX, adc are stored in the variables
  - Channel, chip, ladder, FELIX ID are defined by INTT team

InttRawhit in github

```
protected:
```

BCOFULL	`uint64_t bco = std::numeric_limits<uint64_t>::max();`
FELIX_ID	`int32_t packetid = std::numeric_limits<int32_t>::max();`
	`uint32_t word = std::numeric_limits<uint32_t>::max();`
Ladder	`uint16_t fee = std::numeric_limits<uint16_t>::max();`
Channel	`uint16_t channel_id = std::numeric_limits<uint16_t>::max();`
Chip	`uint16_t chip_id = std::numeric_limits<uint16_t>::max();`
Adc	`uint16_t adc = std::numeric_limits<uint16_t>::max();`
BCO	`uint16_t FPHX_BCO = std::numeric_limits<uint16_t>::max();`
	`uint16_t full_FPHX = std::numeric_limits<uint16_t>::max();`
	`uint16_t full_ROC = std::numeric_limits<uint16_t>::max();`
AMPL for calib	`uint16_t amplitude = std::numeric_limits<uint16_t>::max();`
Added in v2	`uint32_t event_counter = std::numeric_limits<uint32_t>::max();`

INTT TrkrHitSet(format)



- TrkrHitSet: DST style data but sPHENIX format for global tracking
  - Similar w/ InttRawhit
  - Channel, chip, ladder, FELIX ID are defined by sPHENIX tracking

TrkrDef.h, InttDef.h, TrkrHitv2.h

TrkrHitSet : double array [hitsetkey][hitkey] = ADC

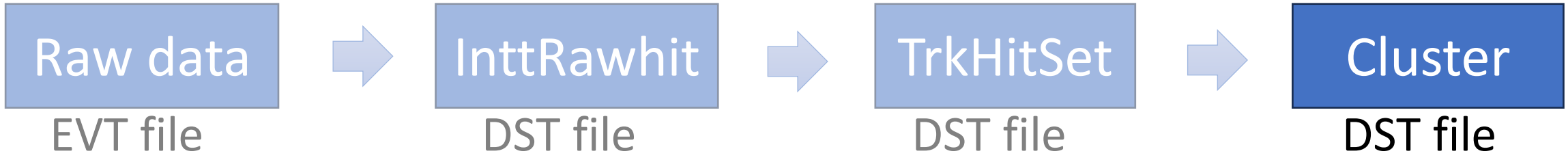
hitsetkey :

31-24	23-16	15-14	13-10	9-0
TrackerID	Layer	Z-ID	Ladder phi	BCO (time bucket)

hitkey : chip[] +channel[0-255 7:0]+BCO[]

Tracker ID and Layer are commonly used for INTT, MVTX, TPC, TPOT

INTT Cluster(format)



TrkrCluster : array [cluskey] of cluster

cluskey : hitsetkey[63:32] + clusid[31:0]

hitsetkey :

31-24	23-16	15-14	13-10	9-0
Tracker ID	Layer	Z-ID	Ladder phi	BCO (time bucket)

Clusid: i_cluster in the sensor

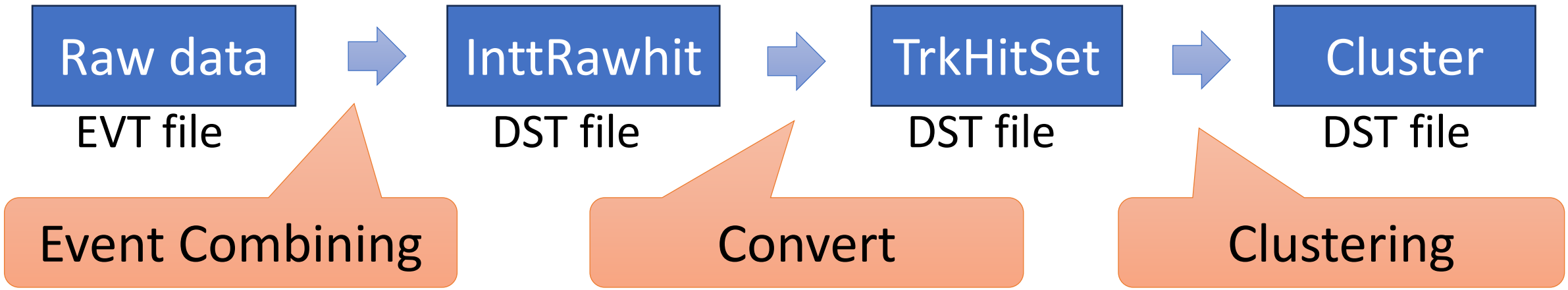
TrkrDef.h in github

TrkrClusterv5 in github

Cluster variables

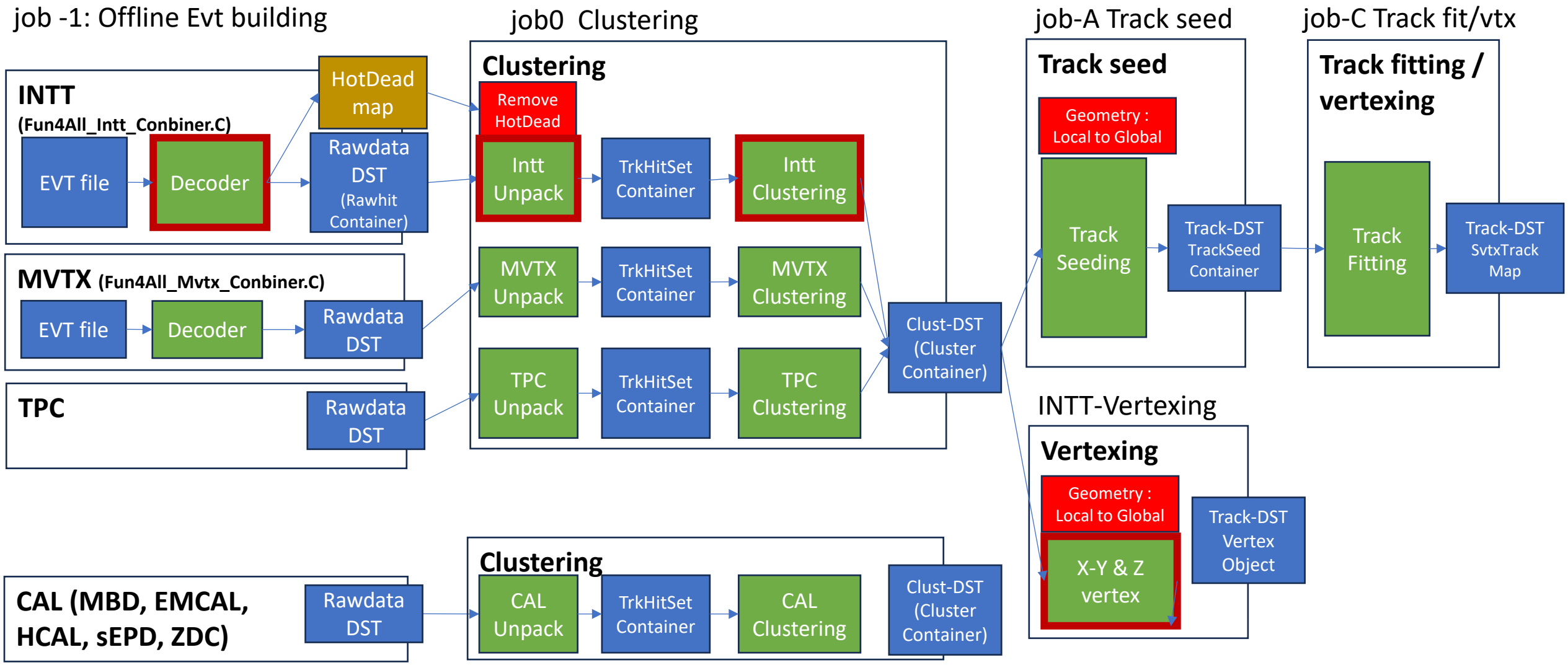
```
protected:
 float m_local[2]{};                    //< 2D local
 TrkrDefs::subsurfkey m_subsurfkey;     //< unique i
 float m_phierr;
 float m_zerr;
 unsigned short int m_adc;              //< cluster sum ad
 unsigned short int m_maxadc;           //< cluster sum ad
 char m_phisize;                        // 8bit
 char m_zsize;                          // 8bit
 char m_overlap;                        // 8bit
 char m_edge;                           // 8bit - cumul 2*
```

INTT data (format)



- Event Combining: SingleInttPoolInput.h
  - Convert rawdata to InttRawhit
  - Synchronize 8 FELIXs w/ BCOFULL
  - Synchronize INTT with GL1 and other detectors w/ BCOFULL
- Convert
  - Convert InttRawhit to TrkrHitSet
  - Hot/dead, BCO cut calibration applied to remove “BAD” hits
  - BCO -> Time (Timebacket)
- Clustering
  - Clustering hits sensor by sensor and time by time

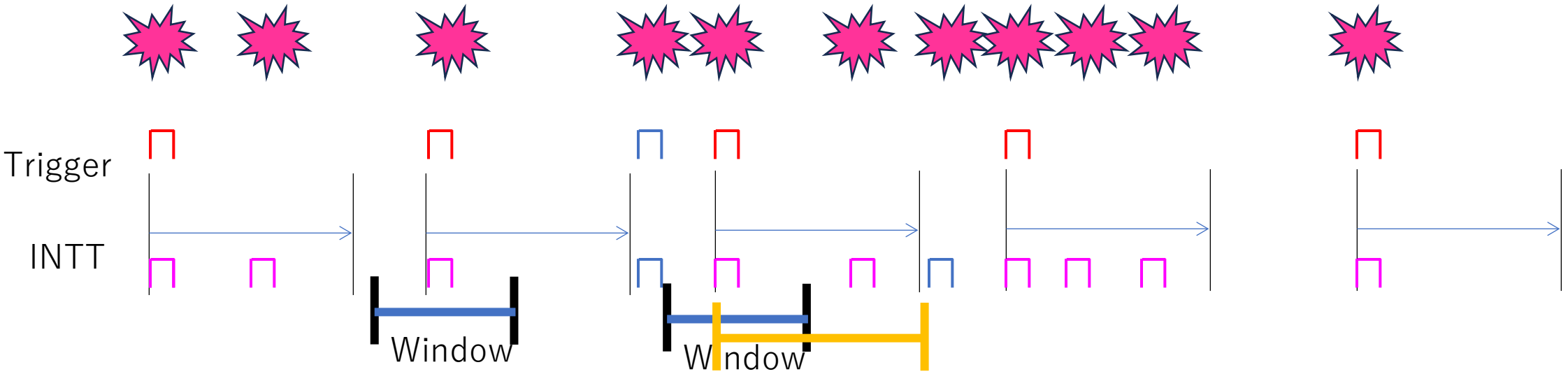
Workflow of DST production: Multi-stage



Event Combining

- Event combining is to combine data from other detectors using BCO(FULL)
  - The common method is applied for both (extended) trigger mode and streaming mode

- Method
  - Start with Reference BCOFULL (usually GL1)
  - Look for the hits having BCOFULL within “window” relative to Ref_BCOFULL



Link to macro

```
intt_sngl->SetNegativeBco(120-23);
intt_sngl->SetBcoRange(500);
```

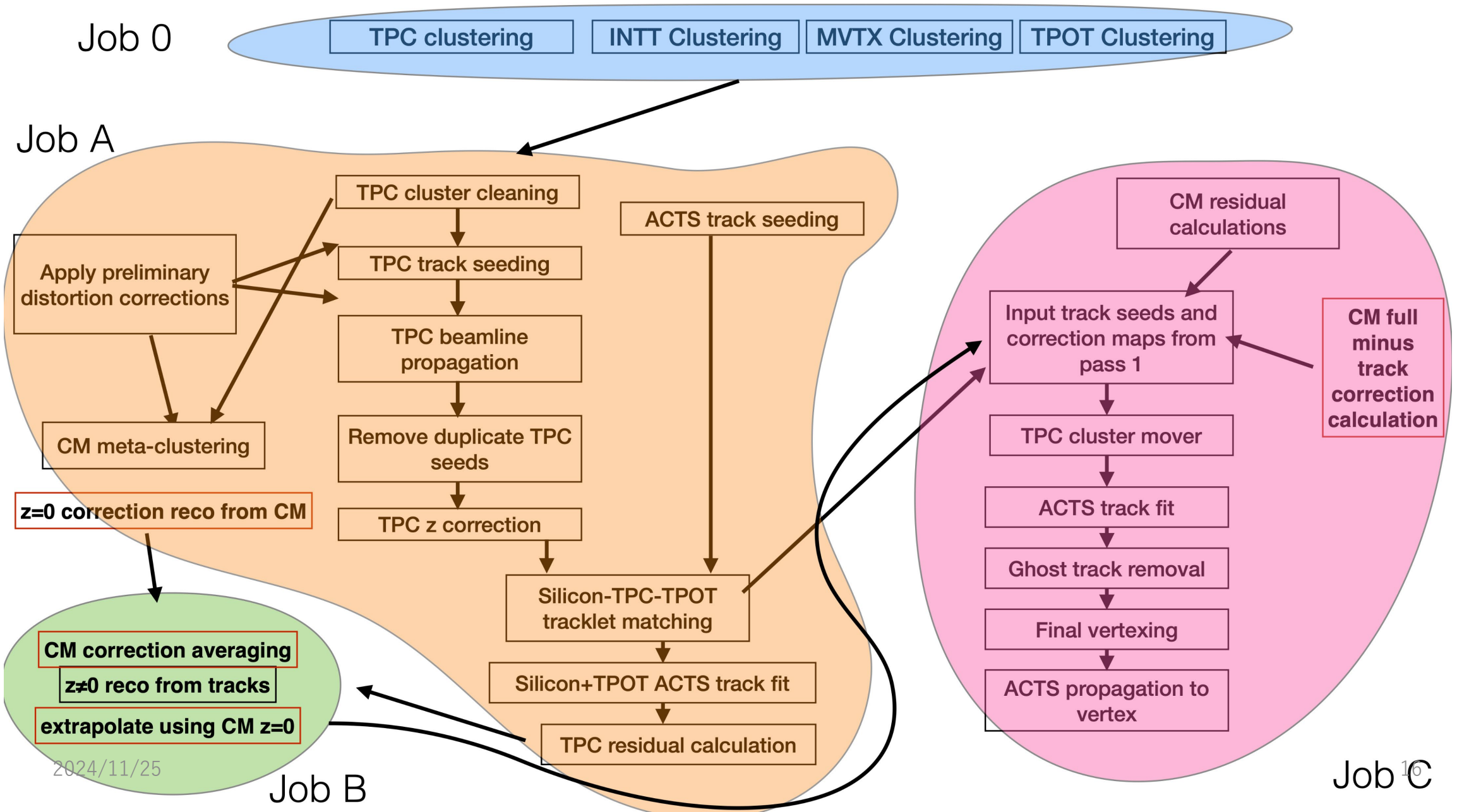
Convert

- Convert Ch in the detector(online) to Ch in sPHENIX software(offline)
- Convert BCO to Time (Timebacket)
  - Trigger: time = BCO – BCOFULL
  - Stream: time = BCOFULL(stream) + BCO – GL1BCO

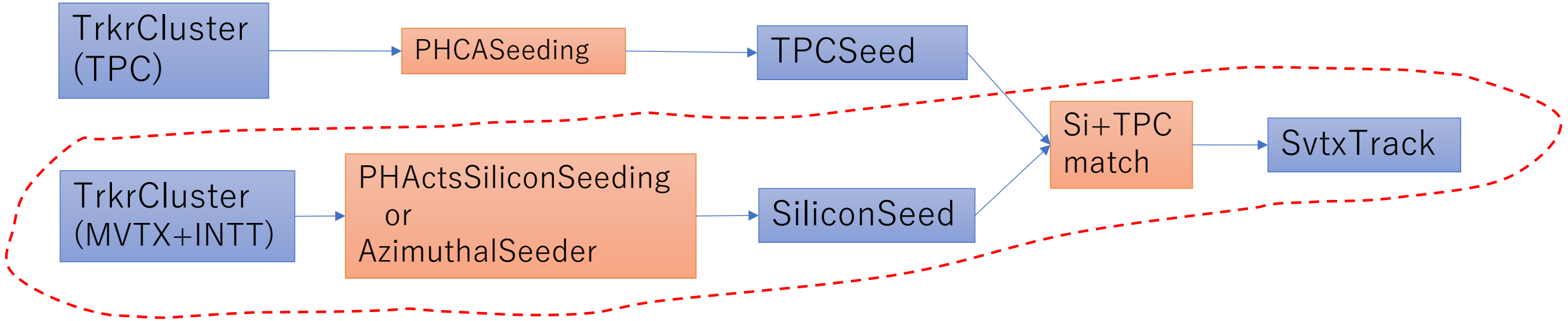
- Remove “BAD” channels using Hot/DeadMAP
- BCO Cut (optional)
  - BCO-BCOFULL cut was made for Run2023 analysis but probably no longer used for 2024-25 data since Fun4All prepared similar function (but not same)

Clustering

Detailed flow of track reconstruction

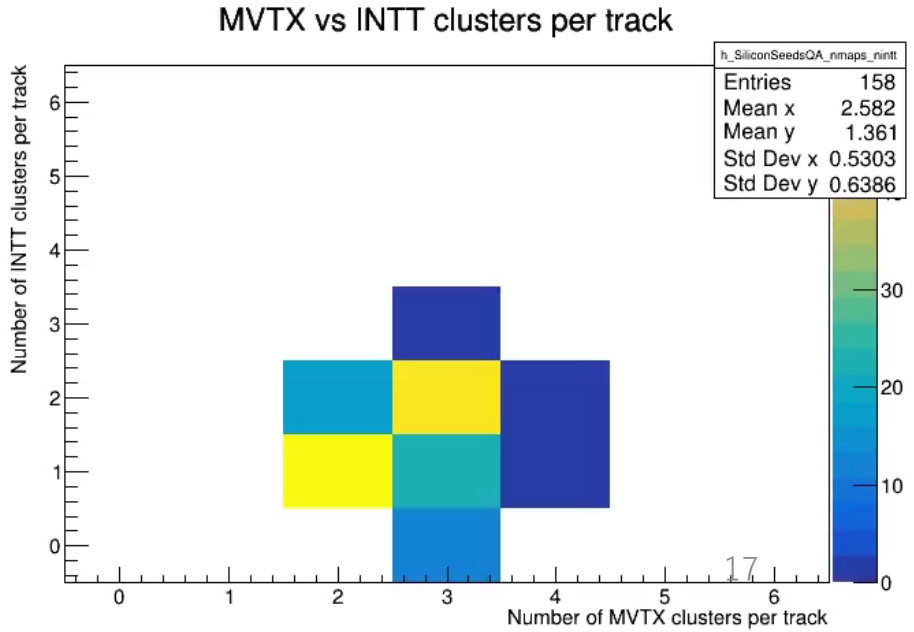


Silicon Seed



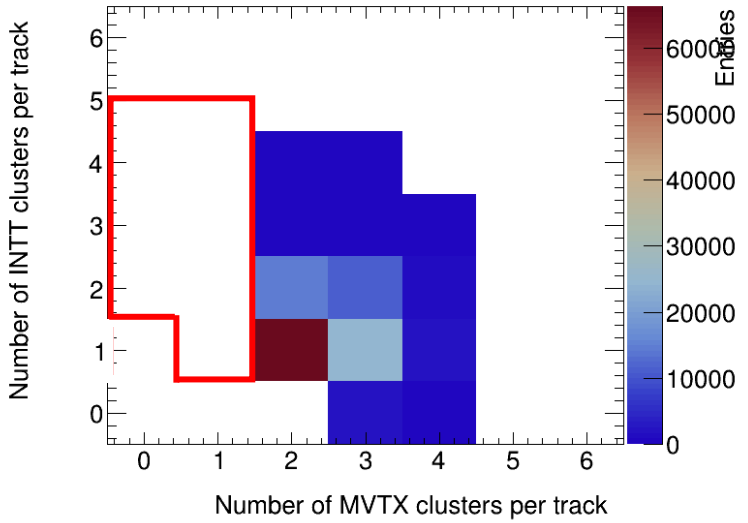
- https://github.com/sPHENIX-Collaboration/macros/blob/master/TrackingProduction/Fun4All_TrackAnalysis.C

- /gpfs/mnt/gpfs02/sphenix/user/hachiya/INTT/INTT/general_codes/hachiya/SiSeedAna/macro/Fun4All_TrackAnalysis.C



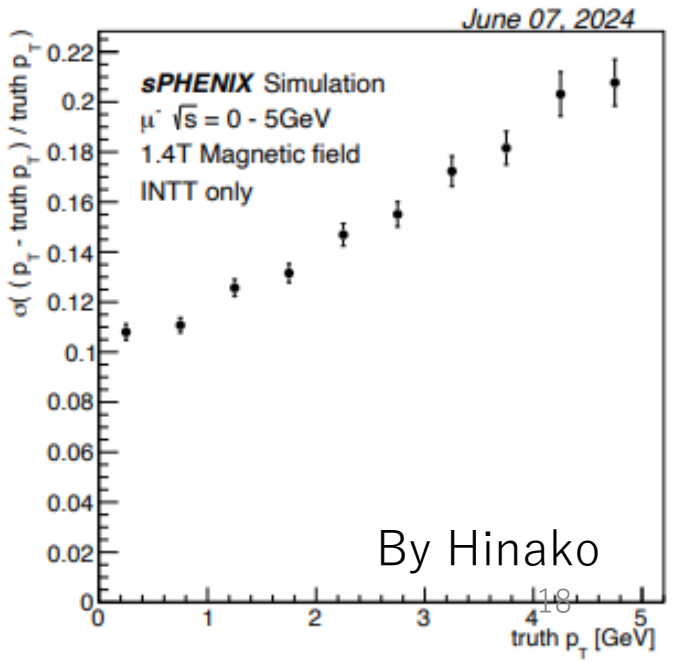
Silicon seeding in tracking algorithm

- Tracking(Silicon Seeding) requires at least 2 MVTX + 1 INTT clusters
  - For low multiplicity such as p+p, this can be extended and relaxed.
  - S/N cannot be very good. Confirmation by outer detector (EMCAL) is needed.



- Furthermore, the momentum resolution can be improved by using EMCAL cluster
  - Help measuring Quarkonia by electron pairs

- Based on MC study by Hinako (NWU), INTT tracklet shows 10% pT resolution at pT=1GeV/c.



Seed variable checking w/ offline QA code

- https://github.com/sPHENIX-Collaboration/coresoftware/blob/master/offline/QA/Tracking/SiliconSeedsQA.cc

- **SiliconSeedsQA.cc**
  - auto trackmap = findNode::getClass<SvtxTrackMap>(topNode, m_trackMapName);
  - SvtxTrack contents
    - virtual float get_p() const { return NAN; }
    - virtual float get_pt() const { return NAN; }
    - virtual float get_eta() const { return NAN; }
    - virtual float get_phi() const { return NAN; }

    - https://github.com/sPHENIX-Collaboration/coresoftware/blob/fb24f0a8d57e65c68ba0b442ac3a913b894e5207/offline/packages/trackbase_historic/SvtxTrack.h

Results

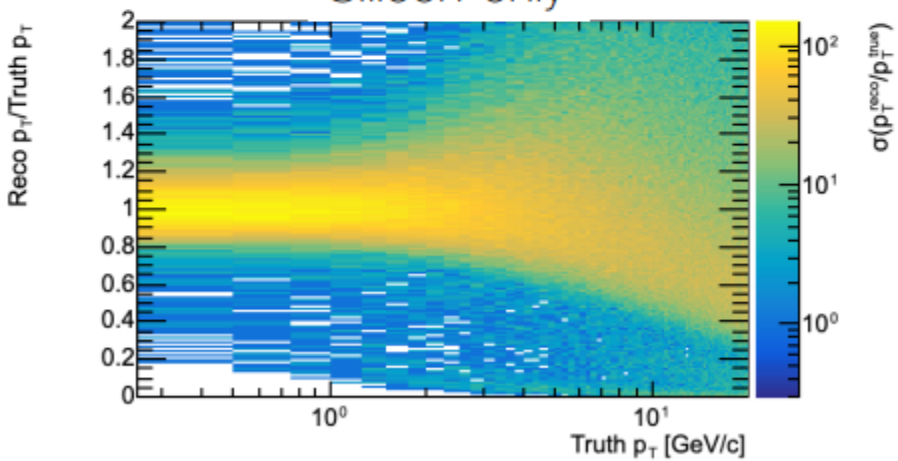
“Reference” is QA file from Jenkins (full tracking with TPC, TPOT and silicon)
“New” is single pion tracking with silicon-only

Thoughts

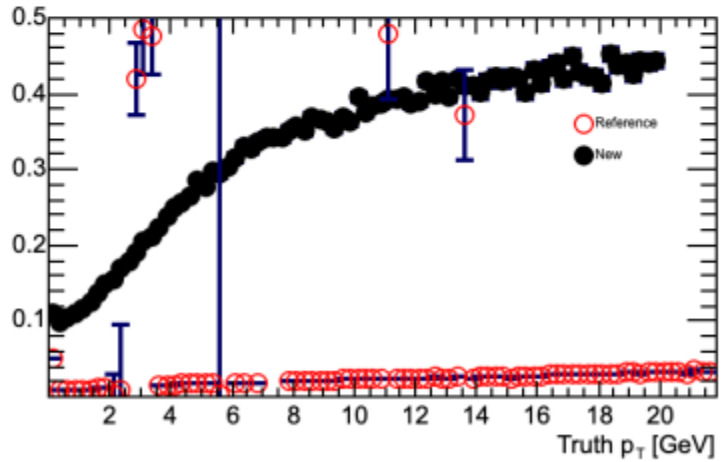
- Large divergence in reco to truth ratio (left) seems sensible at high pT where tracks are straighter so difficult to measure curvature
- Increase in momentum resolution (middle) without TPC seems sensible and gets to around 45%

Middle and right plots
Red circles – pion gun, full tracking (TPC+TPOT+Silicon)
Black circles – pion gun, silicon-only

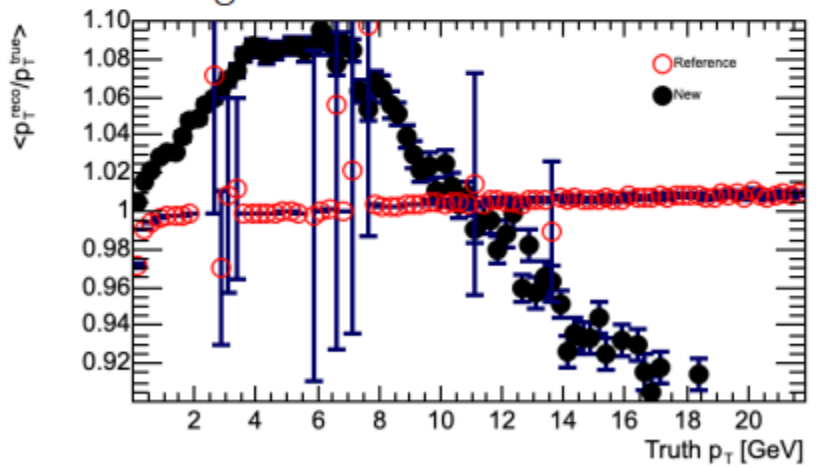
Silicon-only



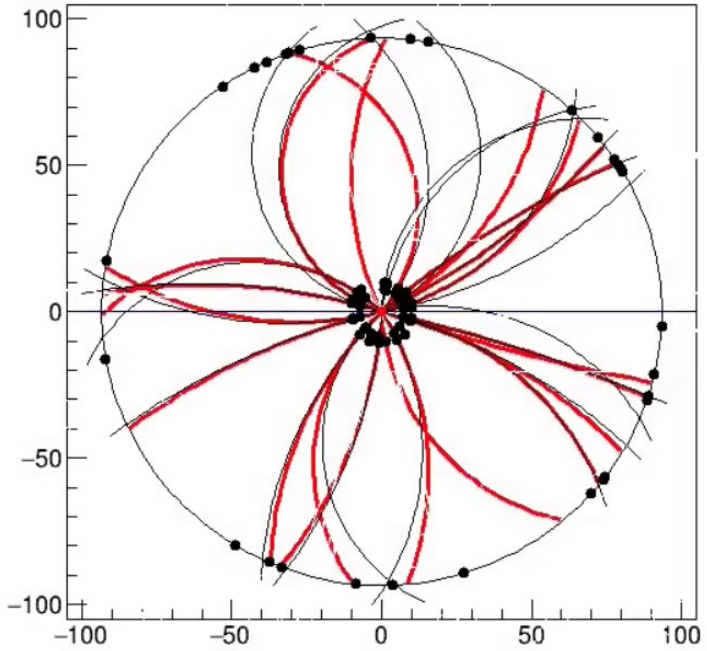
Momentum resolution

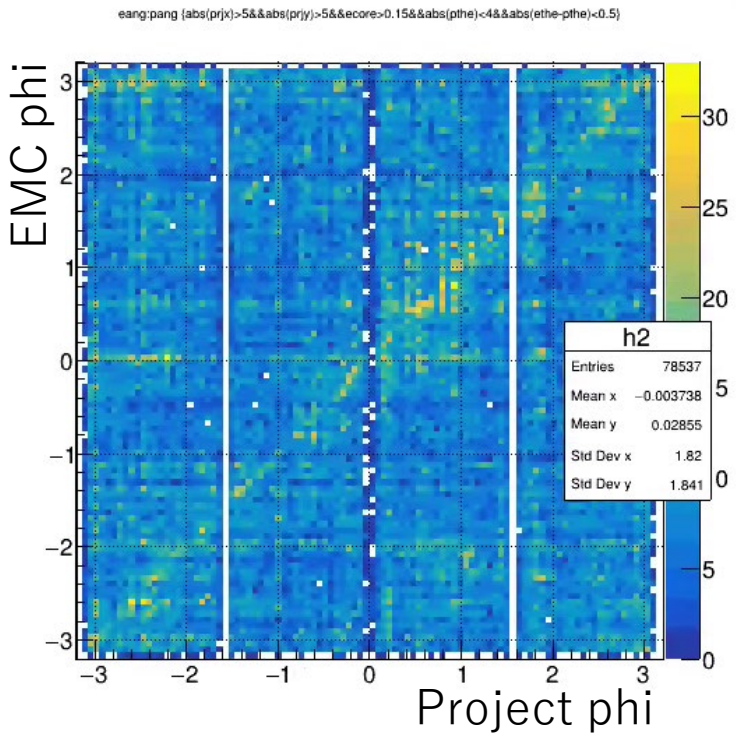


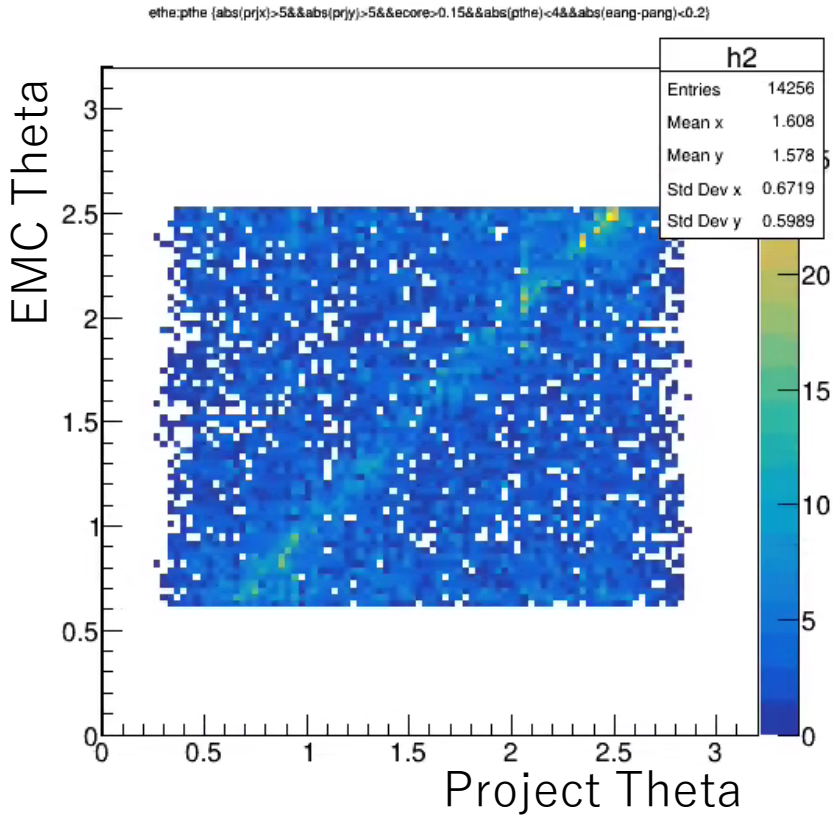
Average momentum reco/truth ratio



Projection of INTT tracklet to EMCAL



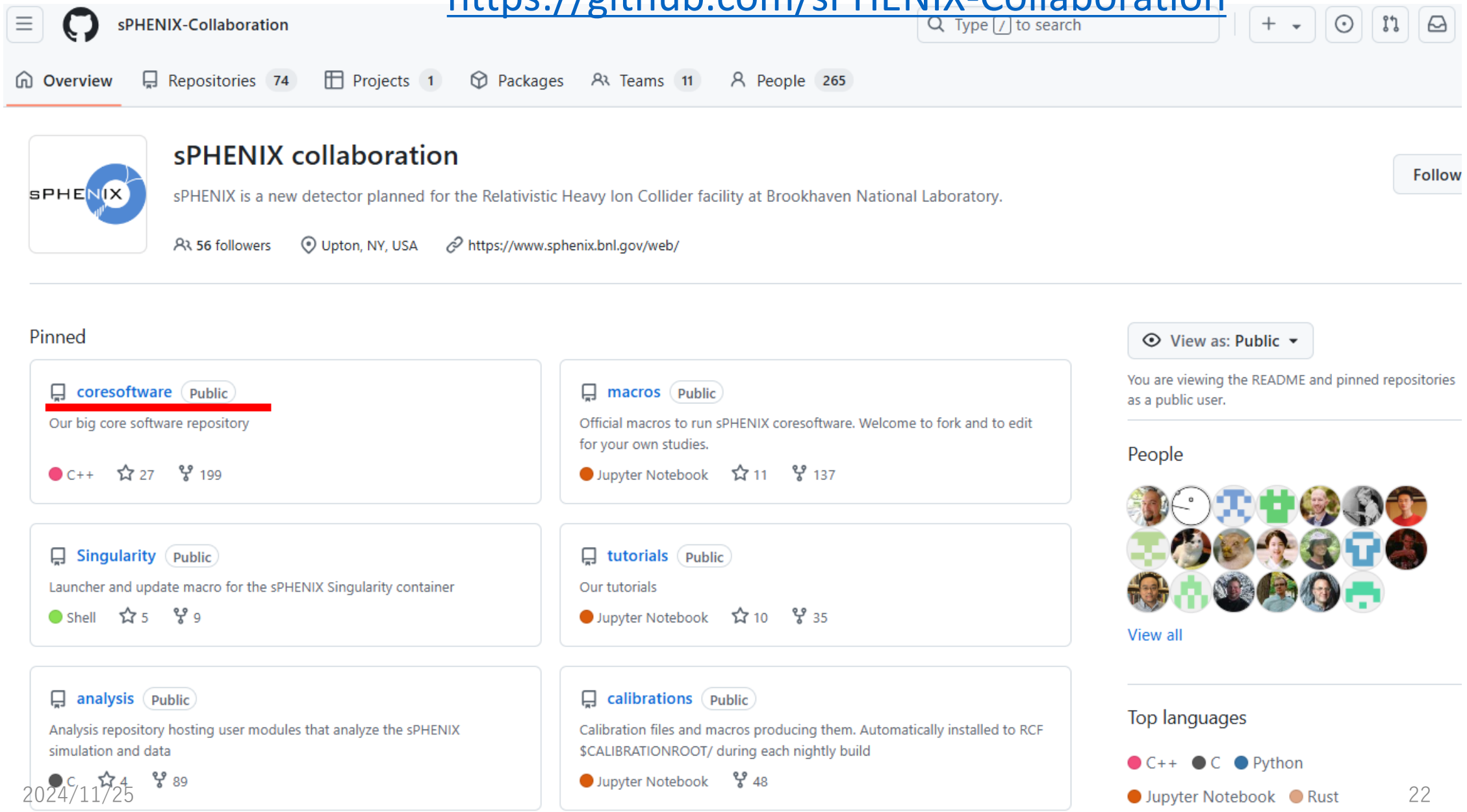




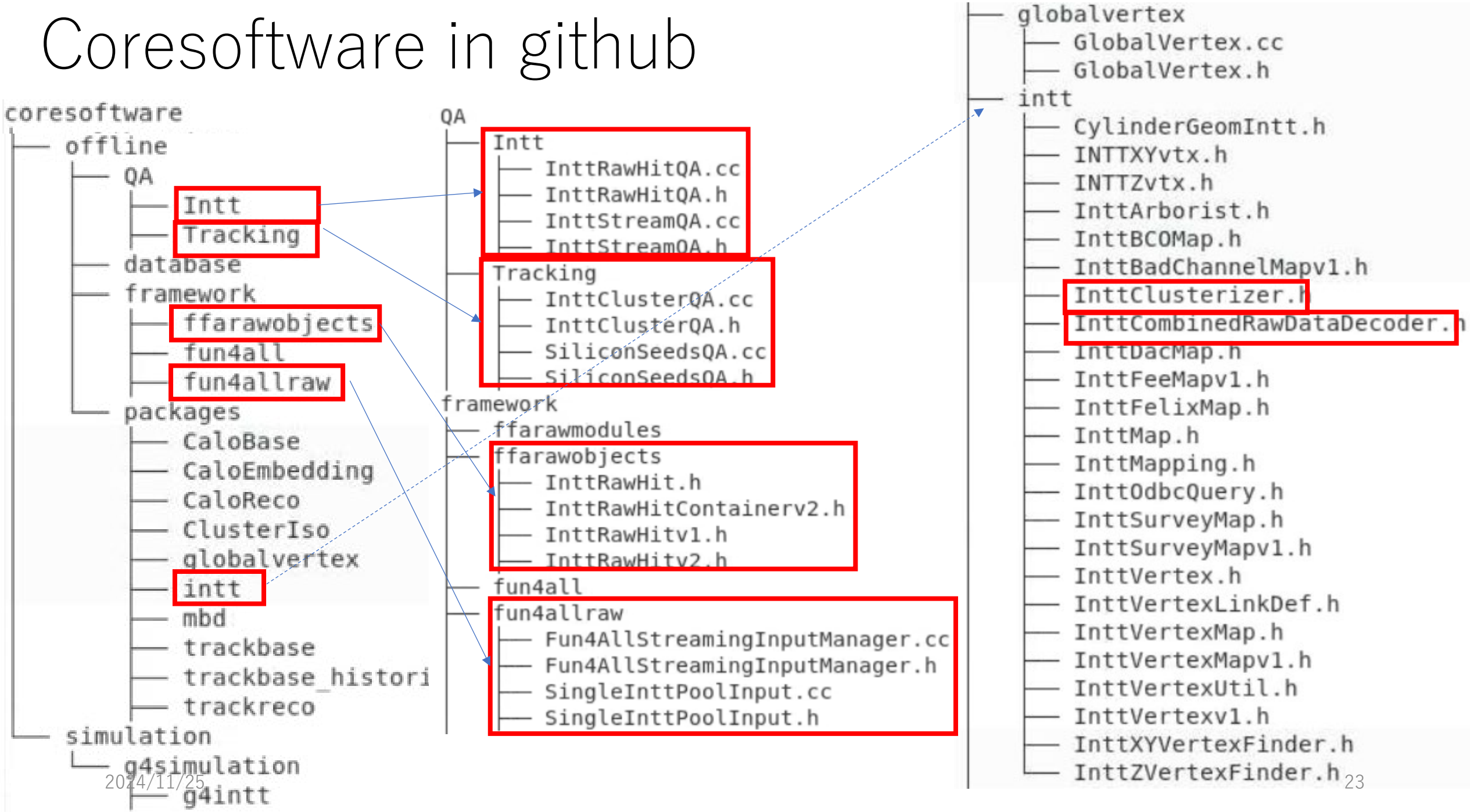
- MC(PYTHIA p+p MB)
  - Black line: INTT tracklet, Red: MC truth track
- INTT Tracklet is projected to EMCAL surface and search for the closest EMC cluster
  - INTT tracklet : 2 INTT clusters + XY vertex
  - Simple circle projection
- INTT + EMC matching works in p+p. Can be improved with MVTX

sPHENIX software on GitHub

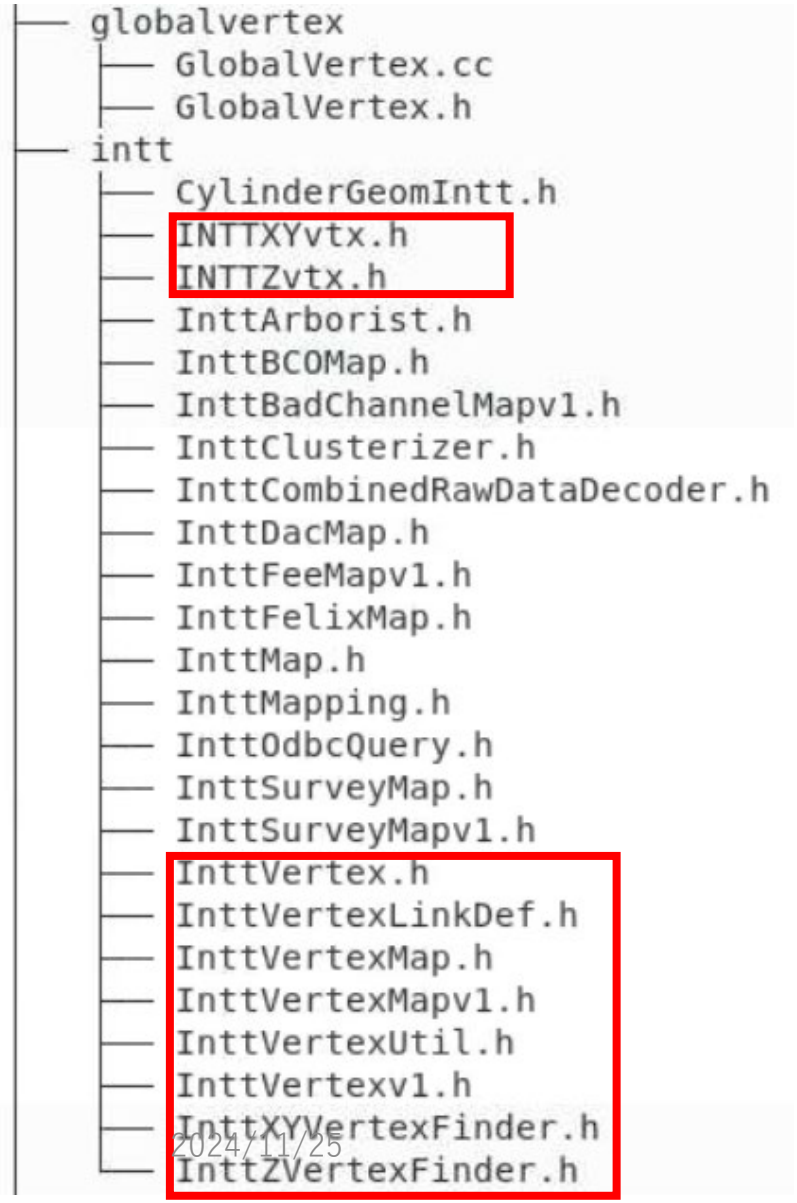
https://github.com/sPHENIX-Collaboration



Coresoftware in github



INTT vertex



- F4A module to calculate INTT XY and Z vertex available in sPHENIX-GITHUB
- These modules developed based on ChengWei's vertexing code
- It works but need to separate clusters by time (BCO)