Measurement of Jet fragmentation function in ALICE

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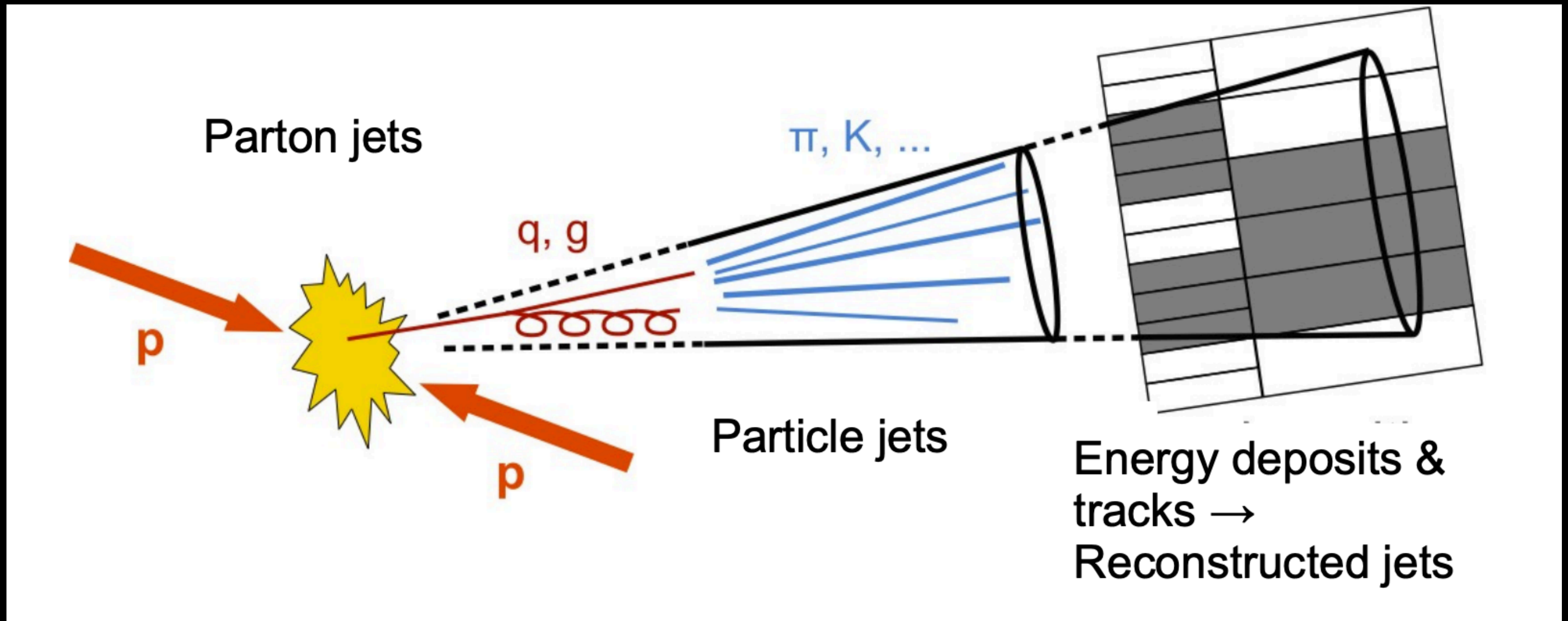
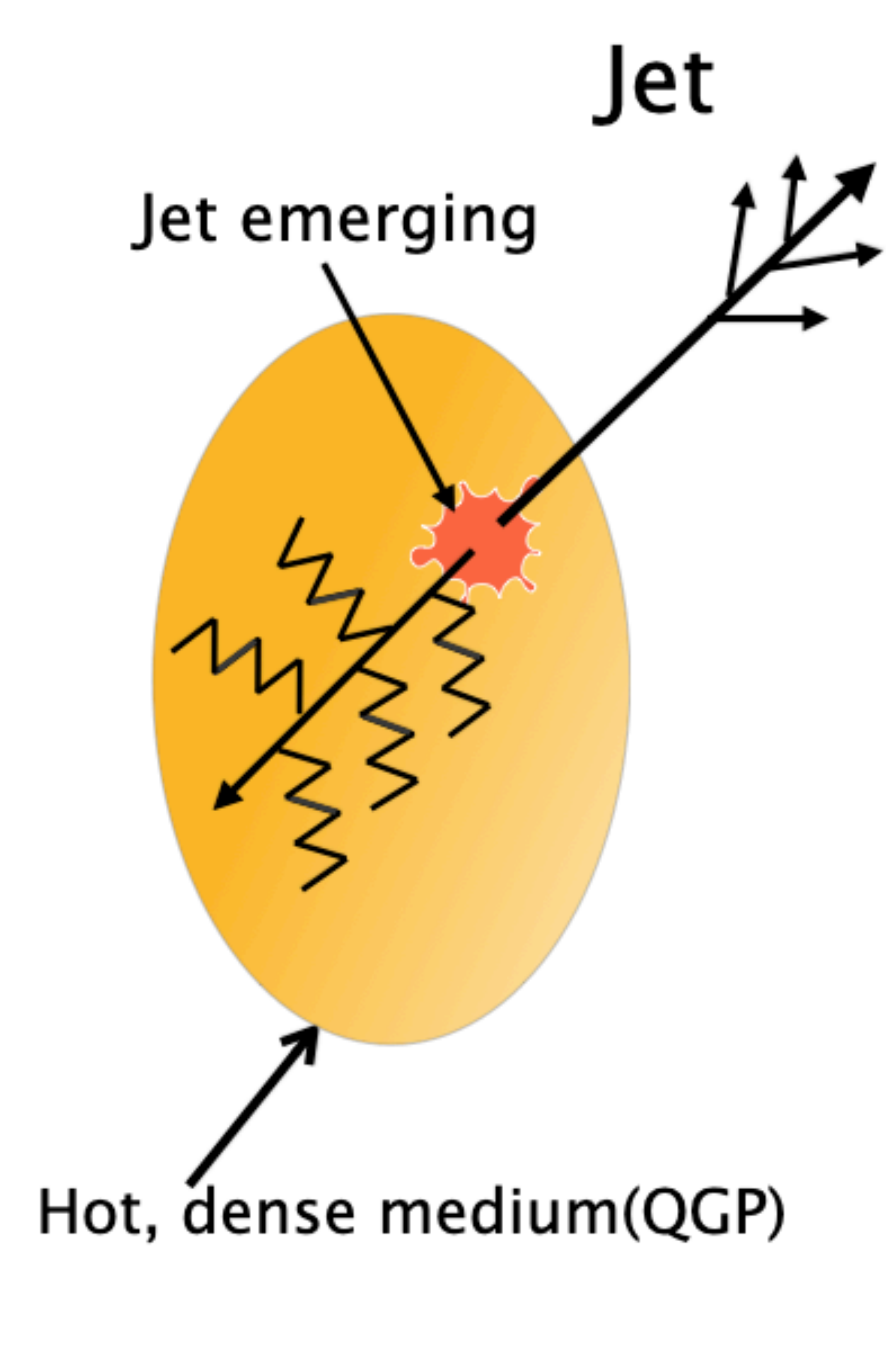
Physics Motivation

- Aim - QGP (Quark-Gluon Plasma)
- Probe - Jet

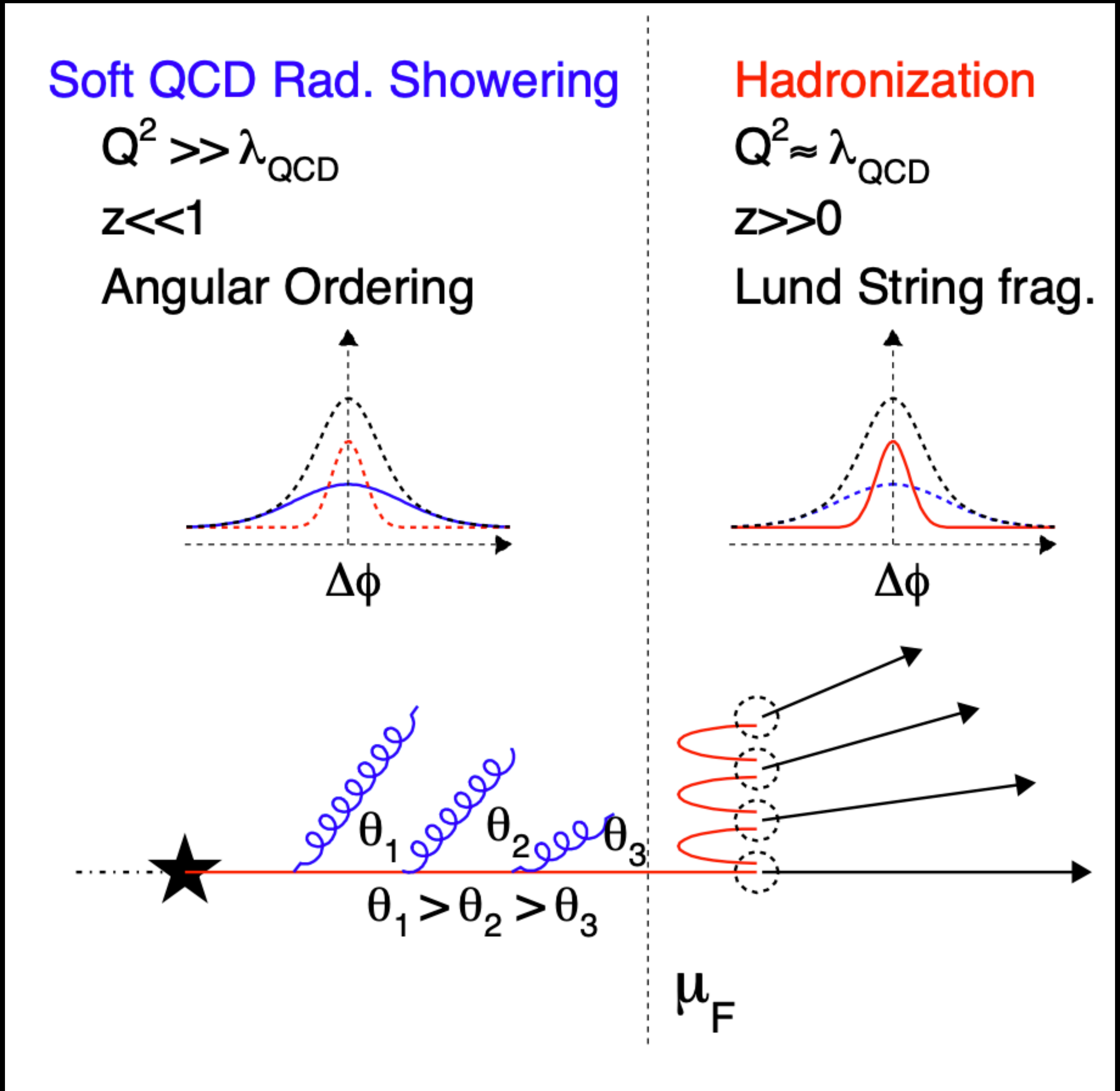




- Jet
  -Theoretically, high energy parton(q, g)
  -Experimentally, cluster of stable particles fragmenting (hadronizing) from q, g

Physics Motivation

- QCD prefers smaller angle radiation with increasing number of partons in the shower and lower virtuality
- First branchings have the largest angles
- Known as angular ordering
- Naive expectation is that angular ordering will enhance low j_T production
- In addition to the fragmentation process jet j_T comes from the hadronization process



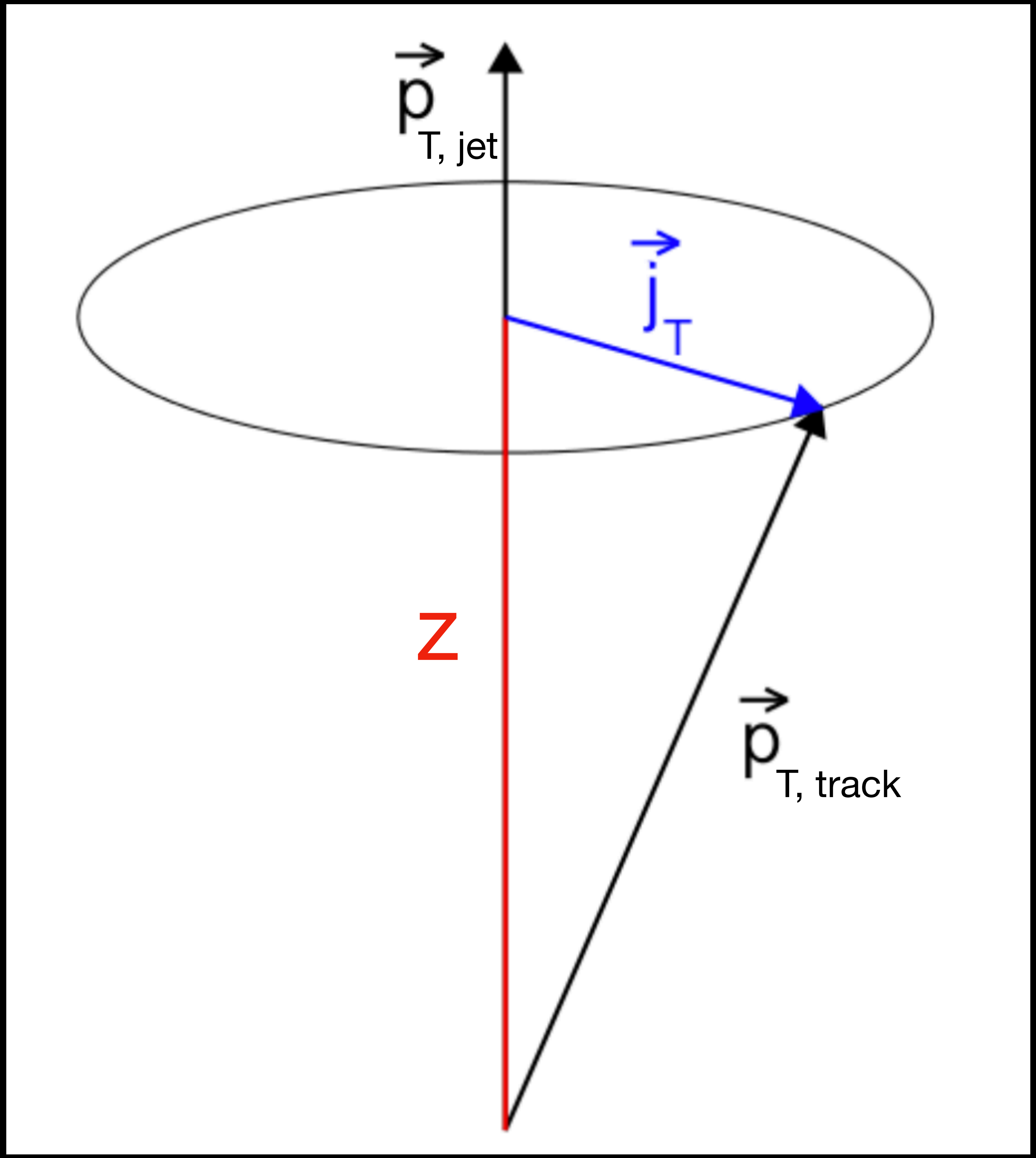
Physics Motivation

- Follow-up study of previous submitted paper on j_T distribution in pp, p-Pb collision.
  (arXiv:2011.05904v1 [nucl-ex] 11 Nov 2020)

- z dependence of j_T study is needed

- j_T is the transverse momentum of jet constituents with respect to jet axis

- z is the longitudinal momentum fraction of $\overrightarrow{p}_{T,\ track}$



Dataset
& Event/Track selection

Dataset

- pp collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
- Data period : LHC17p/pass1_FAST/AOD208/

  and LHC17p/pass1_CENTwoSDD/AOD208
- MC period : LHC18b8_fast and LHC18b8_woSDD

282343, 282342, 282341, 282340, 282314, 282313, 282312, 282307, 282306, 282305, 282304, 282303, 282302, 282247, 282230, 282229, 282227, 282224, 282206, 282189, 282147, 282146, 282126, 282123, 282122, 282119, 282118, 282099, 282098, 282078, 282051, 282031, 282030, 282025

Dataset
& Event/Track selection

Event/Track selection

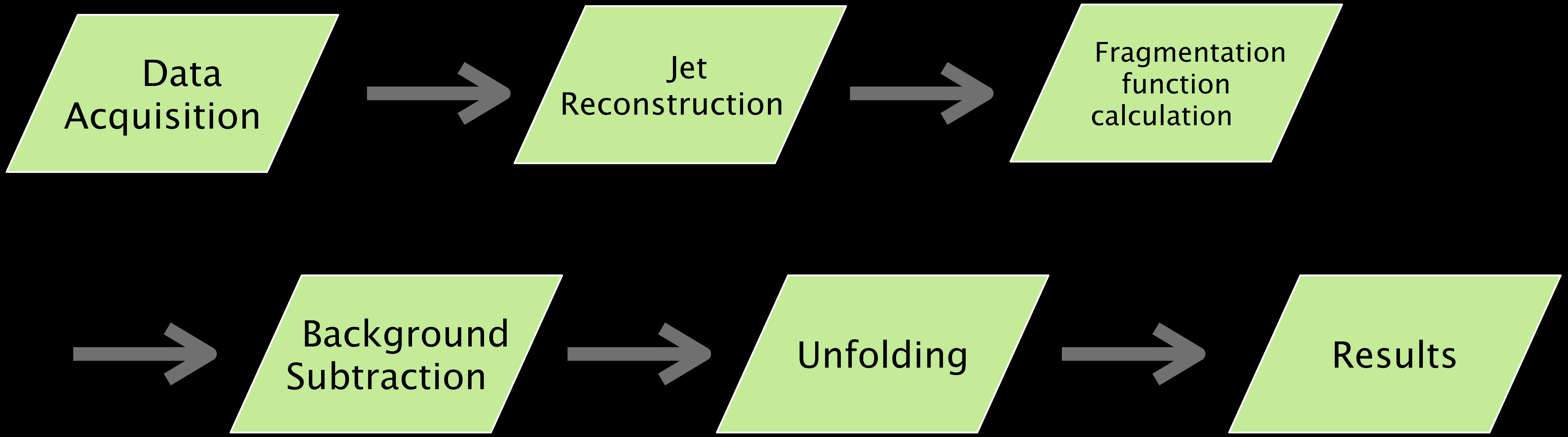
Event selection

Cuts	Parameter range
Trigger	kINT7
No EMCal jet trigger	
# of vertex contributors	> 0
$\|Z_{vtx}\|$	<10 cm
$Z_{vtx} - Z_{vtx,\,SPD}$	<0.5 cm

Track selection - Hybrid tracks(filterbit 768)

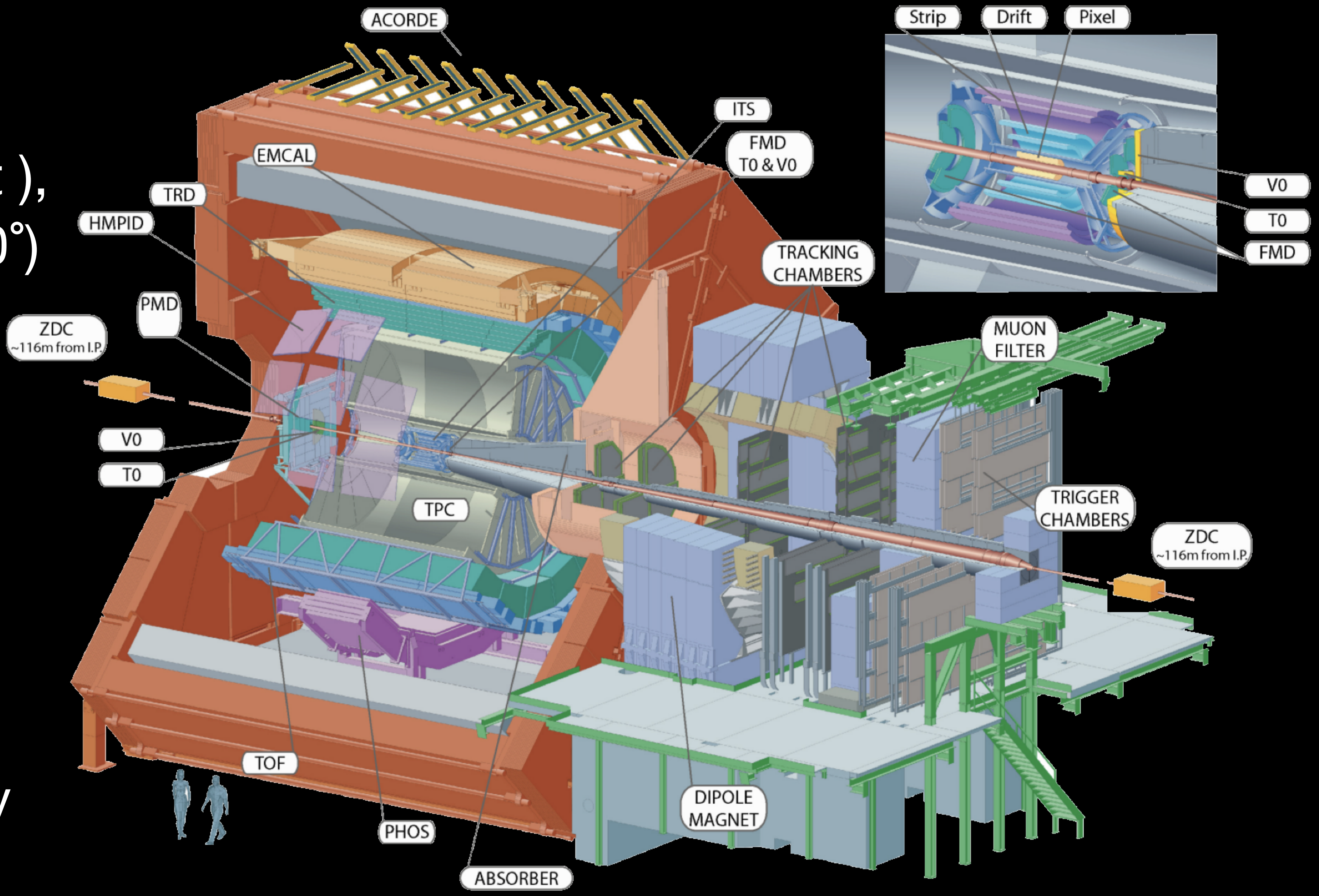
Cuts	Parameter range	or Cuts	Parameter range
DCA_z	< 3.2 cm	DCA_z	< 3.2 cm
DCA_r	< 2.4 cm	DCA_r	< 2.4 cm
# of minimum crossed rows in TPC	> 50	# of minimum crossed rows in TPC	> 50
Ratio of crossed rows over findable clusters in TPC Fraction of shared TPC clusters	> 0.8 < 0.4	Ratio of crossed rows over findable clusters in TPC Fraction of shared TPC	> 0.8 < 0.4
χ^2 per TPC cluster	< 4	χ^2 per TPC cluster	< 4
No thinks, TPC refit, ITS refit		Requirements of ITS refit	
At least one hit in the SPD		No requirements on the SPD hits	
χ^2 per ITS cluster	< 36	χ^2 per ITS cluster	< 36

Analysis flow



Jet reconstruction

- Jets reconstructed in ALICE ITS/TPC(charged tracks) ($|\eta| < 0.9$, $0 < \phi < 2\pi$), EMCal(neutral tracks) ($|\eta| < 0.7$, $\Delta\phi = 110°$)
- Anti-k_T algorithm with R = 0.4
- Only accept jets with $|\eta| \lesssim 0.25$ (Full jet)
- Minimum p_T cut for charged particles by ITS and TPC 0.15 GeV/c
- Minimum cluster p_T for energy clusters by EMCal 0.3 GeV/c

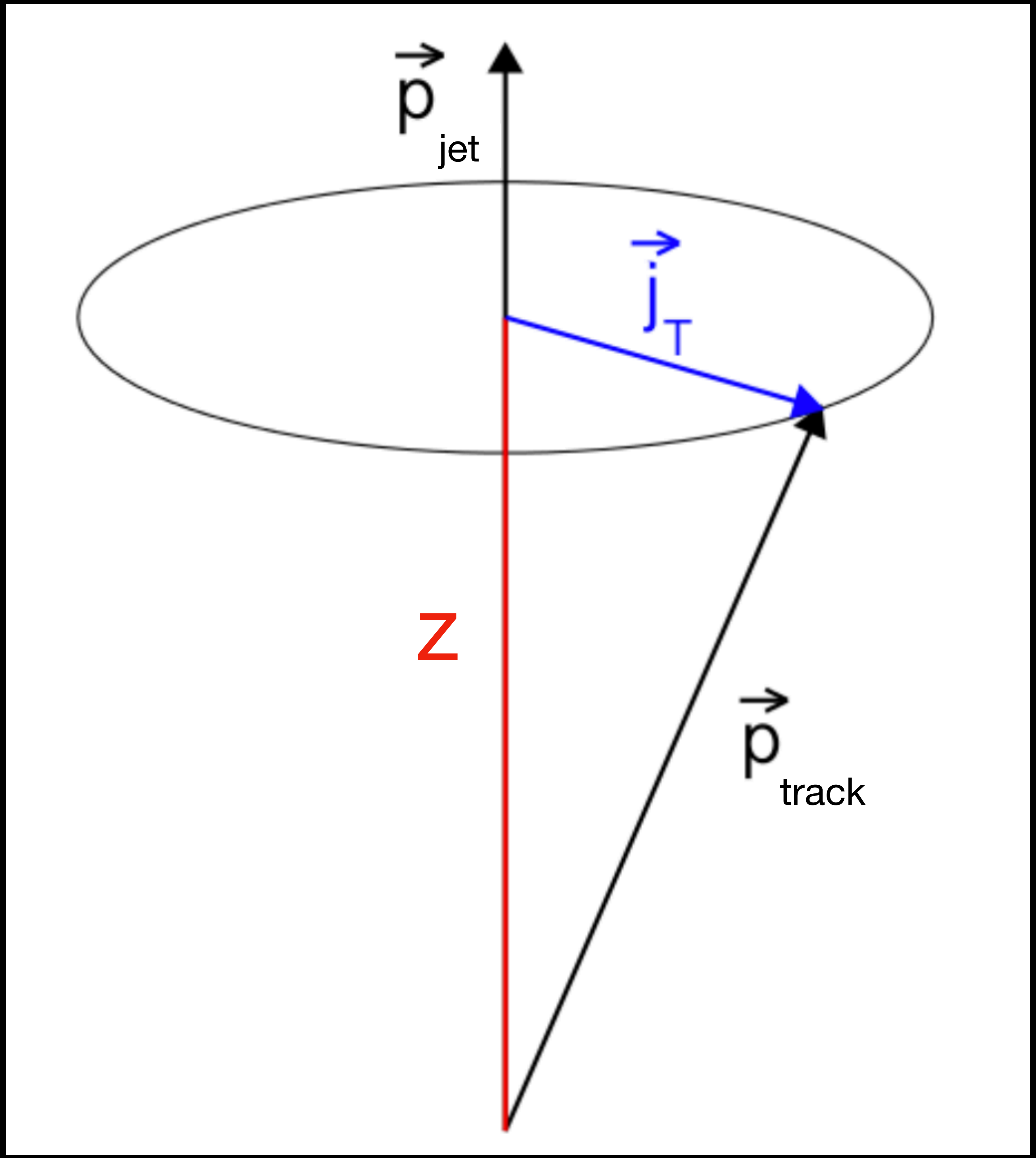


Calculate observables

Jet fragmentation function

j_T, z

- The reconstructed full/charged jet gives axis for j_T, z reference
- $j_T = \dfrac{|\vec{p}_{jet} \times \vec{p}_{track}|}{|\vec{p}_{jet}|}$
- $z = \dfrac{\vec{p}_{jet} \cdot \vec{p}_{track}}{p^2_{jet}}$



Background subtraction

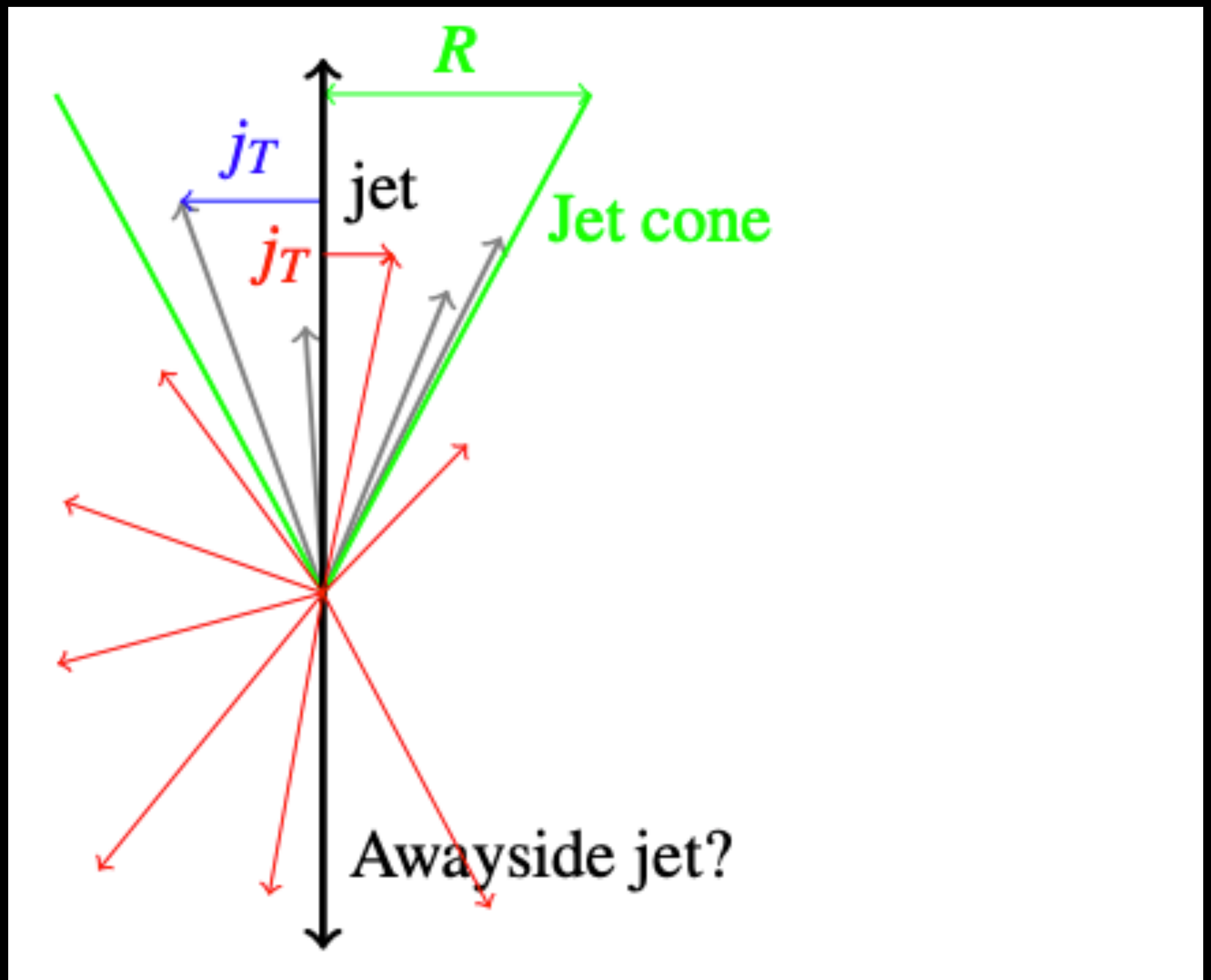
- Perpendicular cone

  - rotate the jet axis by $\frac{2}{\pi}$ in positive ϕ rotation

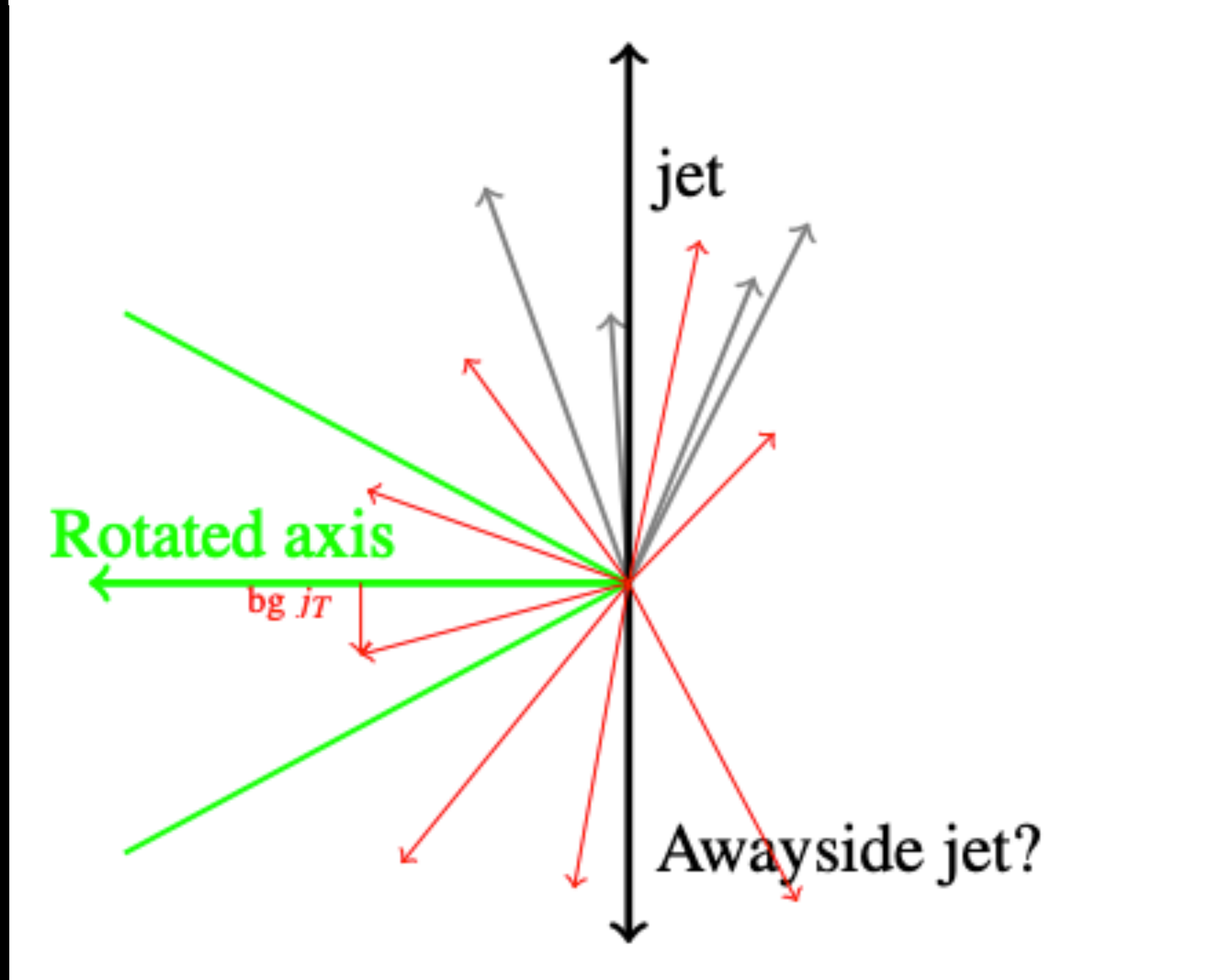
  - check if there are other jets closer than 2R to the rotated axis. If there are skip estimation.

  -if there are not estimate the background.

- Random background
- Auto-correlations are added



(a) Red is underlying event while grey tracks represent the signal

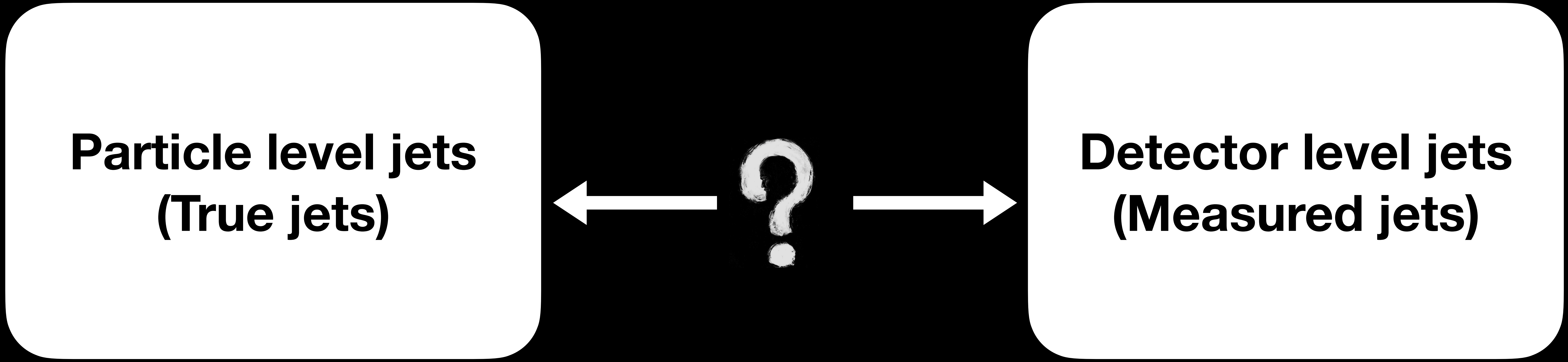


(b) We estimate the background using a cone where the axis is perpendicular to the jet axis

Unfolding

Overview

- Measured jet spectrum smeared by background energy density fluctuation
- By detector effect
- By the jet finding efficiency



Unfolding

Overview

- The technique which de-convolutes the measured jet spectrum to obtain the true jet spectrum is called unfolding.

- Mathematically

$$M(p_T^{rec}) = \int G(p_T^{rec}, p_T^{gen})\ T(p_T^{gen})\ \epsilon(p_T^{gen})\ dp_T^{gen}$$

Measured jet spectrum | Functional description of smearing | True jet spectrum | Jet finding efficiency

- Discretize and write in matrix form

$$M_m = G_{m,t} \cdot T'_t \qquad (T_t = T'_t \cdot \frac{1}{\epsilon_t})$$

Unfolding

Overview

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- Mathematically

M … $^{gen}_{T}) \; \epsilon(p_T^{gen}) \; dp_T^{gen}$

Me … s … jet … rum … Jet finding efficiency

- D … atrix form

M … $)$ … ϵ_t

Particle level jets (True jets)

Detector level jets (Measured jets)

$G_{m,t}$ is known as Response Matrix!

(Or combined response matrix)

Unfolding

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Particle level jets (True jets) ⟵ $G_{m,t}$ ⟶ **Detector level jets (Measured jets)**

- D… …atrix form

$M_{…}$ … $)$ ϵ_t

$G_{m,t}$ is known as Response Matrix!

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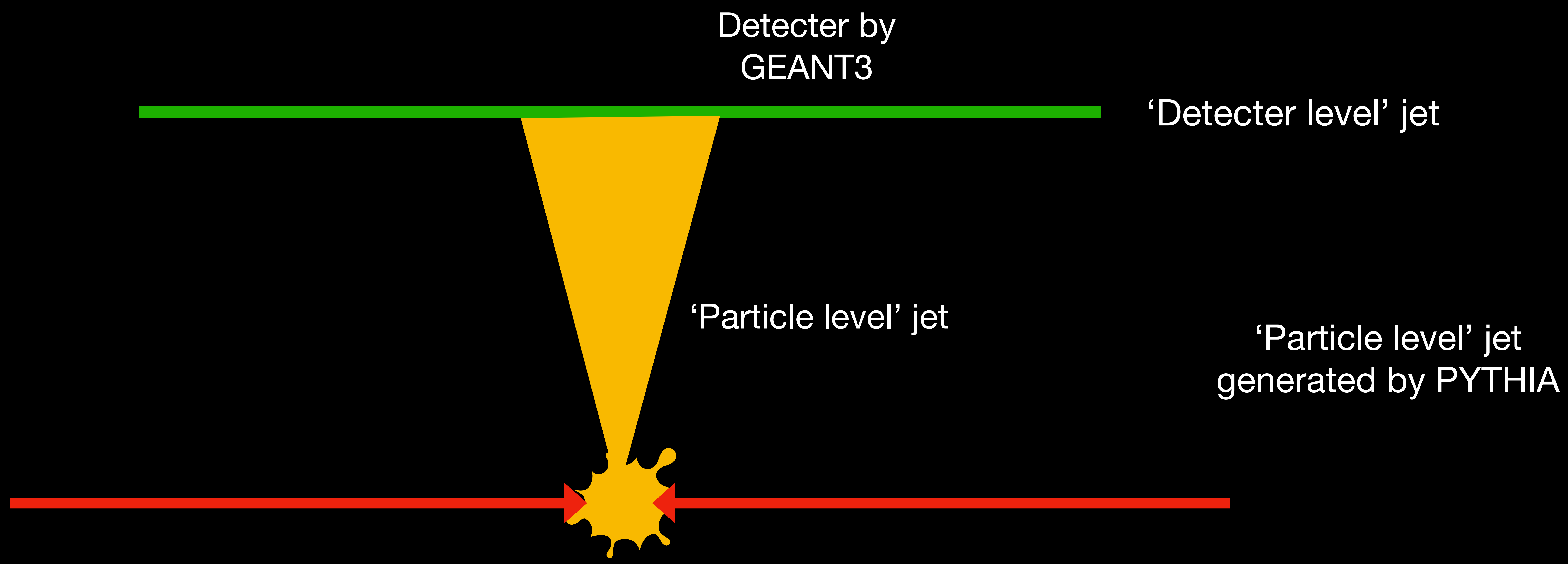
Unfolding

Response matrix



Unfolding

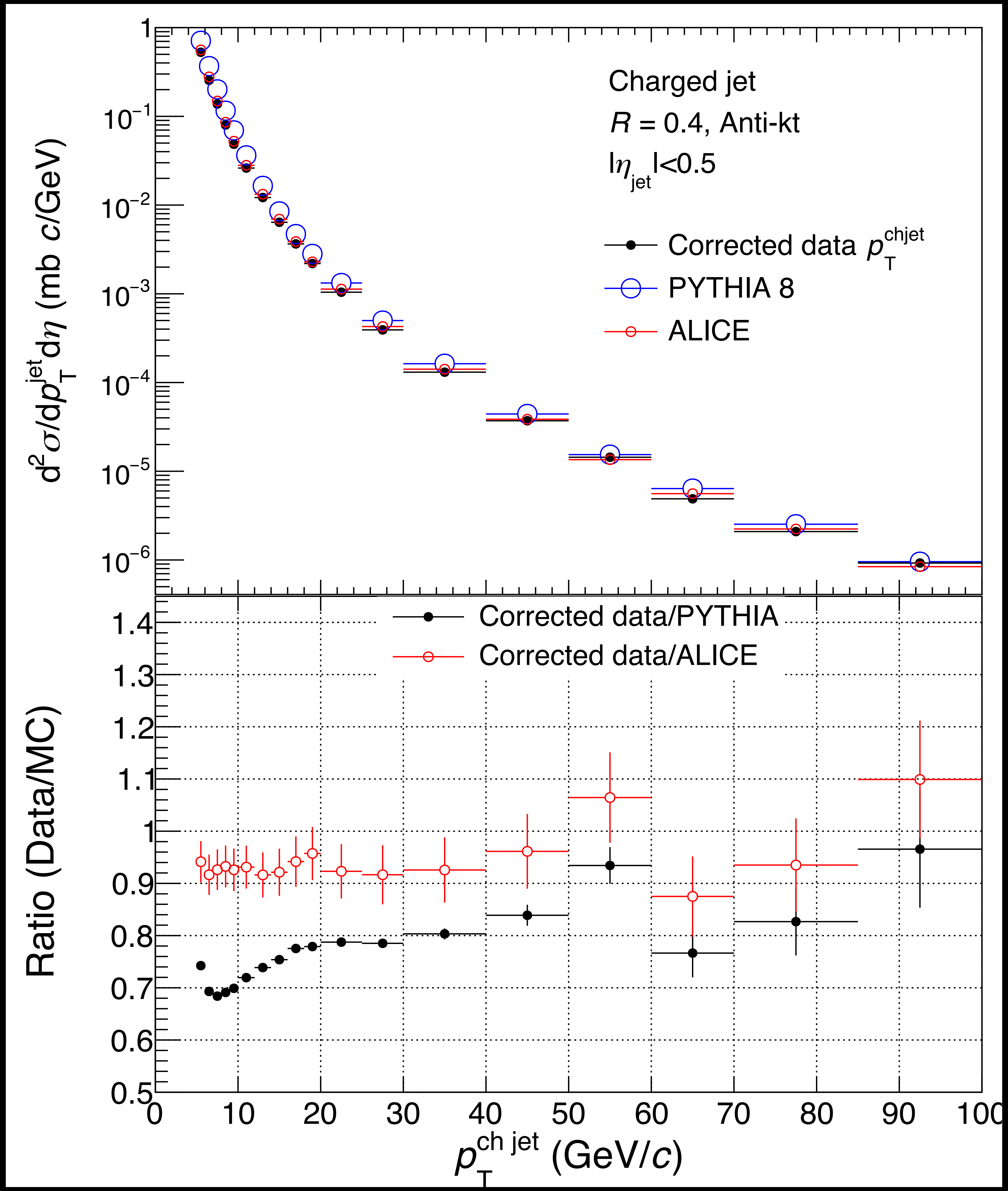
Unfolding techniques

- χ^2 unfolding / SVD unfolding / Bayesian unfolding ….
  Aliroot RooUnfold package

- 2D response matrix is filled for $p_{T,\,jet}$ and j_T for MC truth and MC reconstruction levels in a histogram as $(j_T^{obs}, p_{T,\,jet}^{obs}, j_T^{true}, p_{T,\,jet}^{true})$ by using PYTHIA8.

Status & plan

- Analysis code prepared.
- Confirmed that calculated cross section of charged jet and previous ALICE result are comparable.
- In the phase of j_T calculation, j_T calculation with z-cut
- Expand to p-Pb
- Aim for a paper proposal around June.



Summary

- Follow-up study of previous submitted paper on j_T distribution in pp, p-Pb collision.
- Analysis code has been prepared.
- z binned j_T distribution is in the calculating.
- Will extend on p-Pb collision.
- Aim for paper proposal around June.

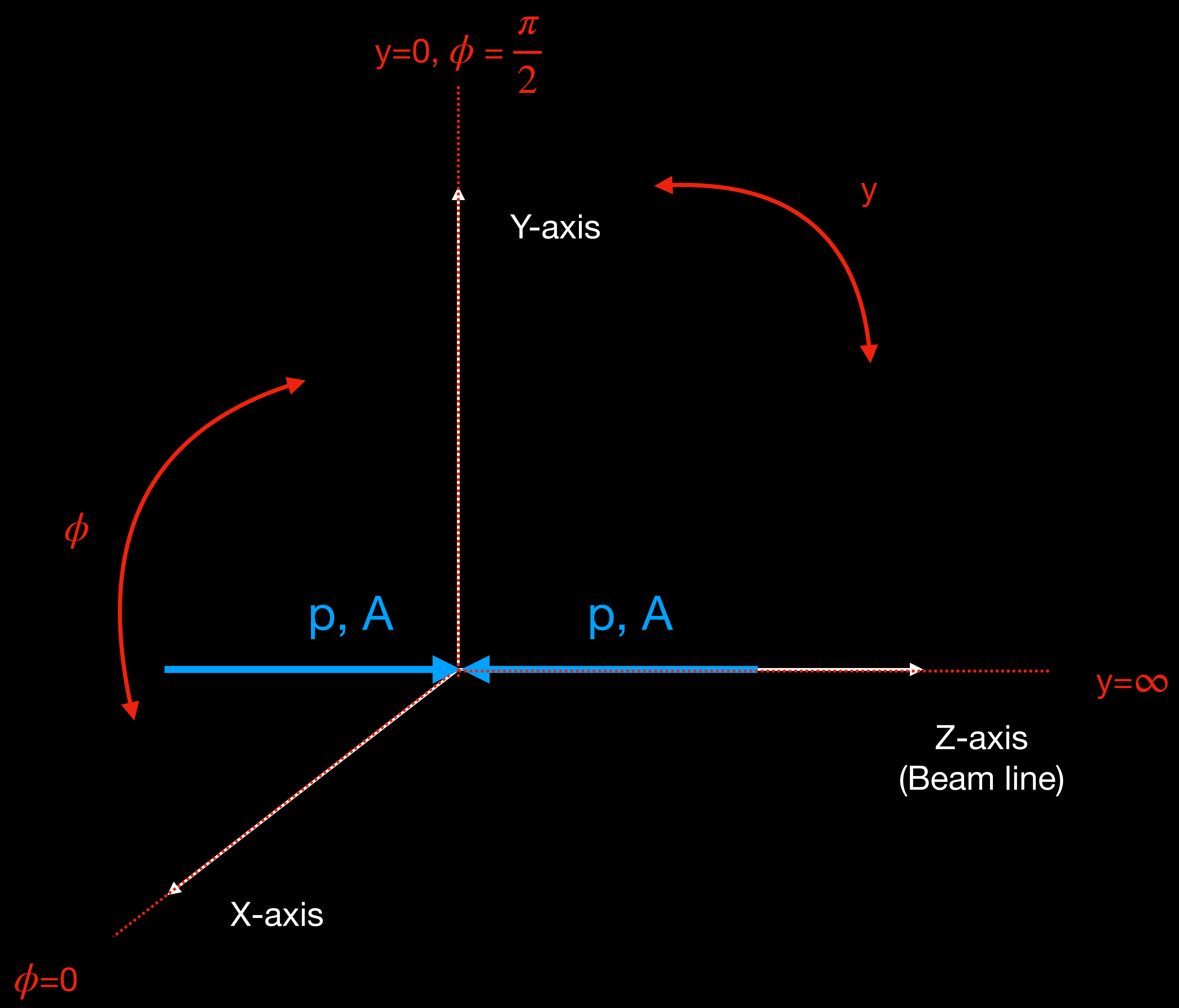
Thank you

for your attention

Back-up

Back-up

Geometry



Back-up

Jet reconstruction algorithms

Sequential recombination algorithms

- Compute all distances d_{ij} and d_{iB}, find the smallest
- If smallest is a d_{ij}, combine the two particles i and j, update distances, proceed finding next smallest
- If smallest is a d_{iB}, remove particle i, call it a jet
- Repeat

p=1 k_T algorithm
p=0 Cambridge/Aachen
p=-1. anti-k_T algorithm

$$d_{ij} = \min(k_{ti}^{2p}, k_{tj}^{2p})\frac{\Delta y^2 + \Delta\phi^2}{R^2}\,, \qquad d_{iB} = k_{ti}^{2p}$$

k_T algorithm (p=1)	anti-k_T algorithm (p=-1)
dominated by soft particles	dominated by hard particles
Susceptible to UE & PU (UE=Underlying Event, PU=Pile Up)	Relatively less susceptible to UE & PU
Used for background determination	Used for signal determination

Back-up

Jet reconstruction algorithms

$$d_{ij} = \min(k_{ti}^{2p}, k_{tj}^{2p})\frac{\Delta y^2 + \Delta\phi^2}{R^2}, \qquad d_{iB} = k_{ti}^{2p}$$

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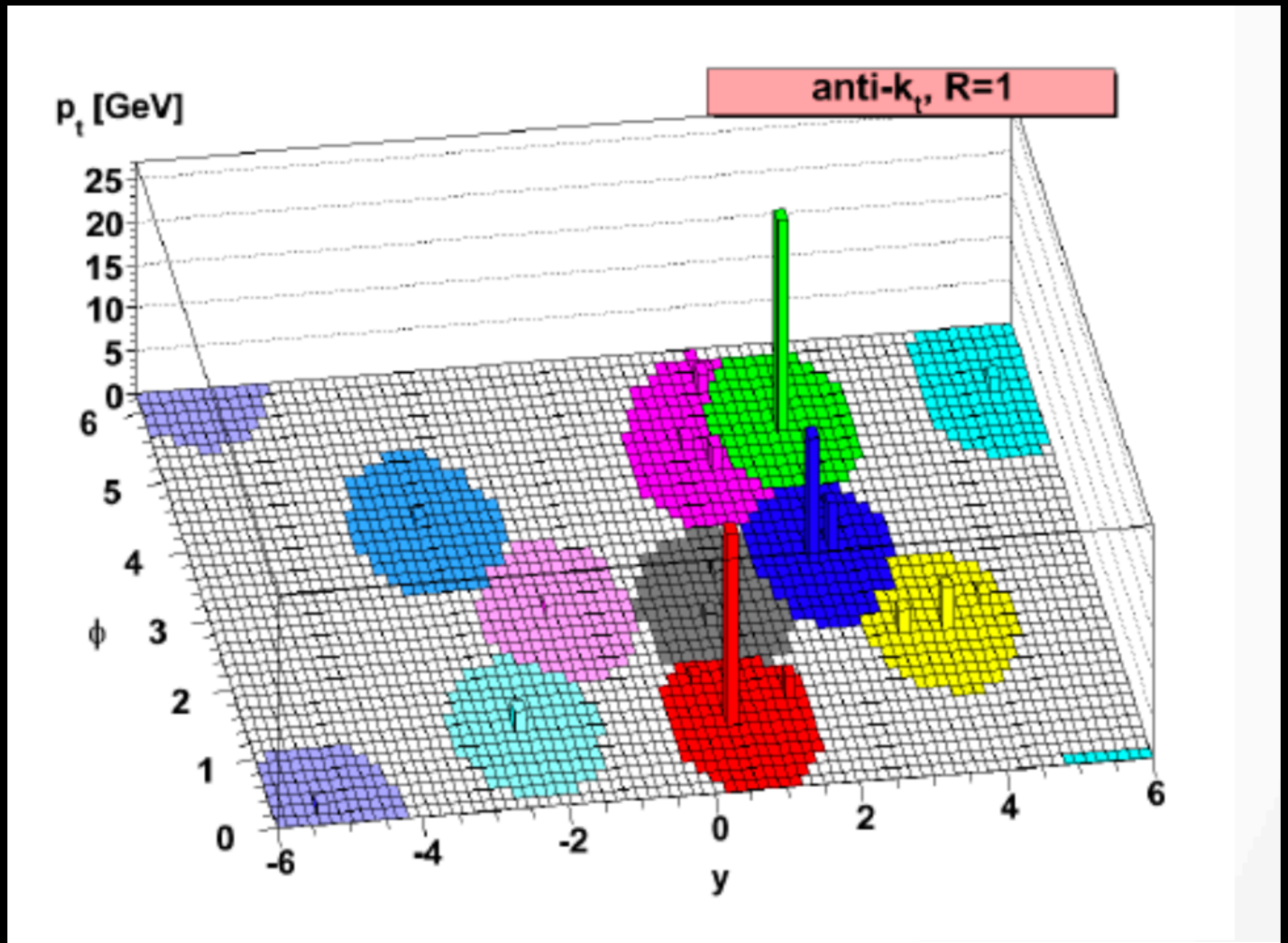

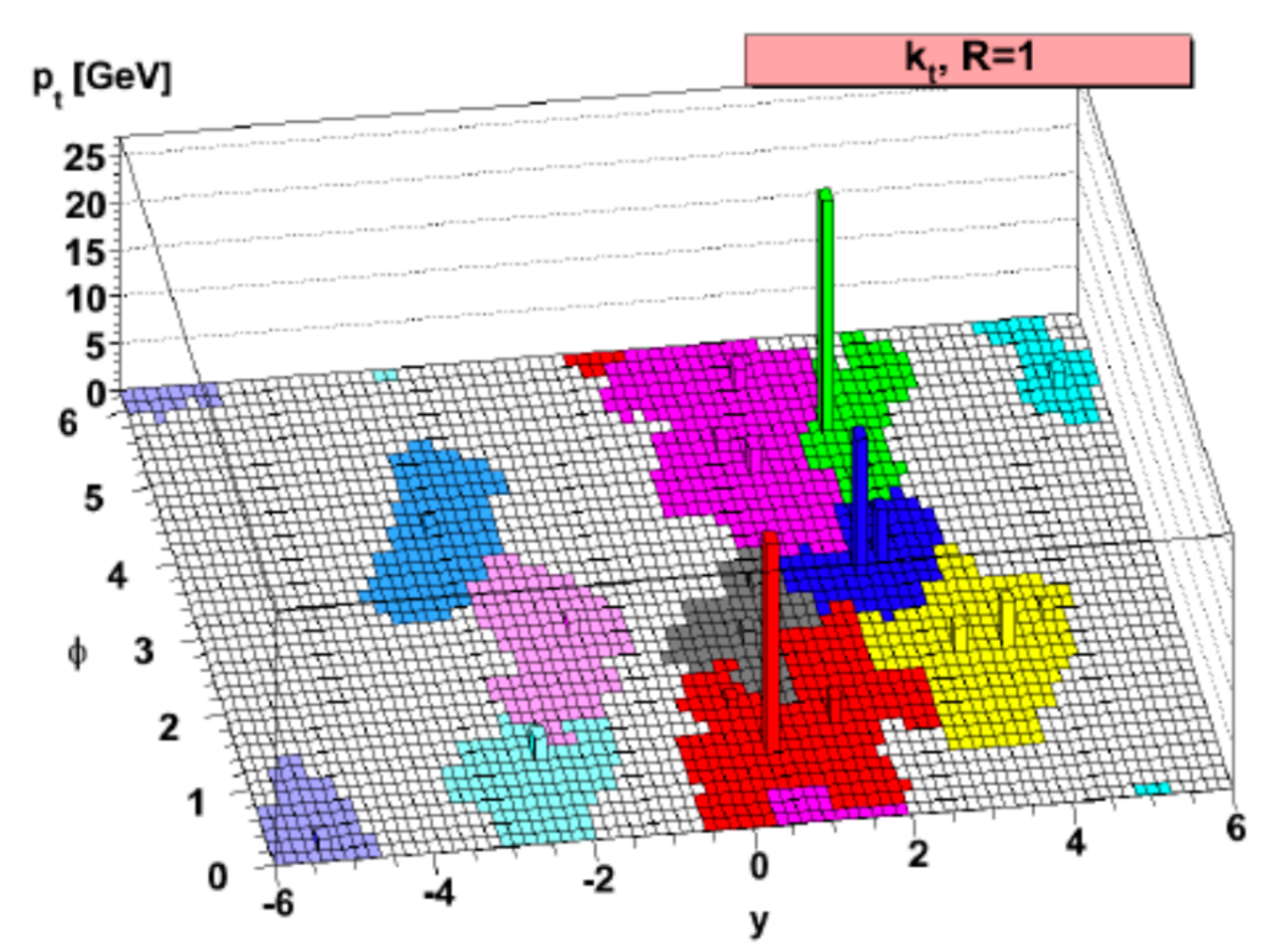

Back-up

Unfolding methods

- χ^2 unfolding - unfolds the spectrum by minimizing the difference between the measured(folded) and refolded spectrum.

  (Refolded spectrum is the convolution of the unfolded spectrum with the response matrix)

- SVD(Singular Value Decomposition) unfolding - the response matrix is inverted by decomposing the singular values. This decomposition gives a stable way of solving a regularized least-square minimization similar to that posed in the χ^2 unfolding, ensuring that only significant terms contribute to the unfolded spectrum

- Bayesian unfolding - Repeated application of Bayes' theorem is used to invert the response matrix.