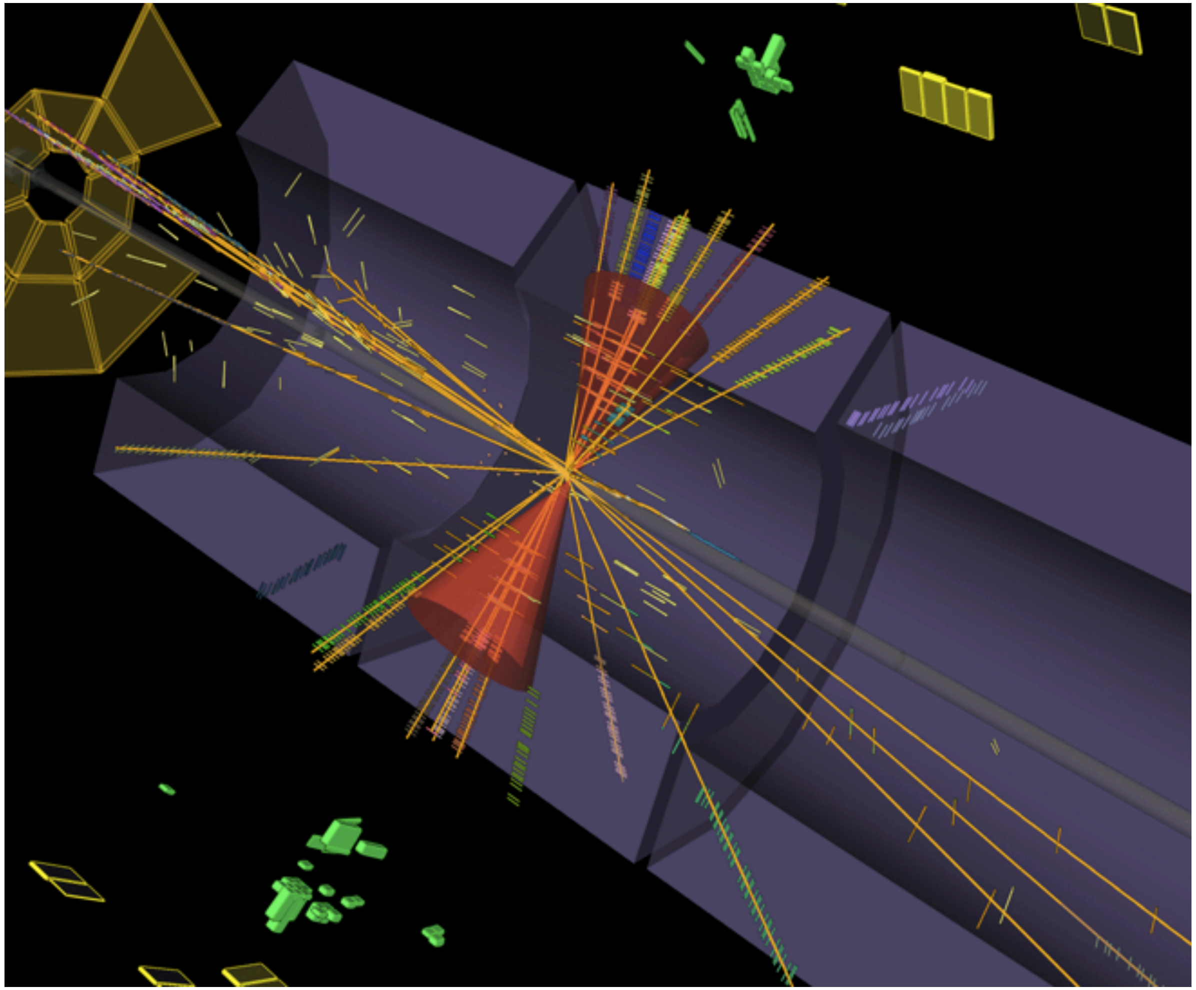
# Plan for next months

- Top Physics
- B-tagging
- D3PD Maker for tracking
- Vertexing (in this presentation)

Vincenzo

# Primary Vertex



# Beam Spot

- Spatial distribution of the interacting proton-proton pairs -

$$\sigma_{BS} = \frac{\sigma_{bunch}}{\sqrt{2}}$$

| **√s (TeV)** | **0.9** | **2.36** | **2.36** | **7** | **7** | **7** | **10** | **10** | **10** | **10** | **10** | **14** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beam energy (TeV) | 0.45 | 1.18 | 1.18 | 3.5 | 3.5 | 3.5 | 5 | 5 | 5 | 5 | 5 | 7 |
| **Beta* (m)** | **11** | **11** | **11** | **11** | **4** | **2** | **11** | **2** | **1** | **3** | **2** | **0.55** |
| Beam size (µm) | 293 | 132 | 175 | 105 | 63 | 45 | 88 | 38 | 27 | 46 | 38 | 17 |
| **Bunch length (cm)** | **11.24** | **8** | **8** | **6.00** | **6.00** | **6.00** | **5.41** | **5.41** | **5.41** | **5.41** | **5.41** | **7.55** |
| **Crossing angle (µrad)** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **300** | **285** | **285** |
| Gamma | 4.8E+02 | 1.3E+03 | 1.3E+03 | 3.7E+03 | 3.7E+03 | 3.7E+03 | 5.3E+03 | 5.3E+03 | 5.3E+03 | 5.3E+03 | 5.3E+03 | 7.5E+03 |
| **Normalized emittance (π µm rad)** | **3.75** | **2** | **3.5** | **3.75** | **3.75** | **3.75** | **3.75** | **3.75** | **3.75** | **3.75** | **3.75** | **3.75** |
| Emittance (π m rad) | 7.8E-09 | 1.6E-09 | 2.8E-09 | 1.0E-09 | 1.0E-09 | 1.0E-09 | 7.0E-10 | 7.0E-10 | 7.0E-10 | 7.0E-10 | 7.0E-10 | 5.0E-10 |
| F (luminosity reduction factor due to crossing angle) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.98 | 0.98 | 0.84 |
| **Transverse beam spot size σ_x,y (µm)** | **207** | **94** | **124** | **74** | **45** | **32** | **62** | **27** | **19** | **32** | **27** | **12** |
| **Longitudinal beam spot size σ_z (cm)** | **7.9** | **5.7** | **5.7** | **4.2** | **4.2** | **4.2** | **3.8** | **3.8** | **3.8** | **3.8** | **3.7** | **4.5** |

Beam spot size for different LHC machine parameters.

# Luminosity/Pile-up

Luminosity as a function of geometrical charateristics of the colliding bunches & machine param

$$L = \frac{N_b^2 n_b f_{rev} \gamma_r}{4\pi \epsilon_n \beta^*} F$$

$$F = \left(1 + \left(\frac{\theta_c \sigma_z}{2\sigma^*}\right)^2\right)^{-\frac{1}{2}}$$

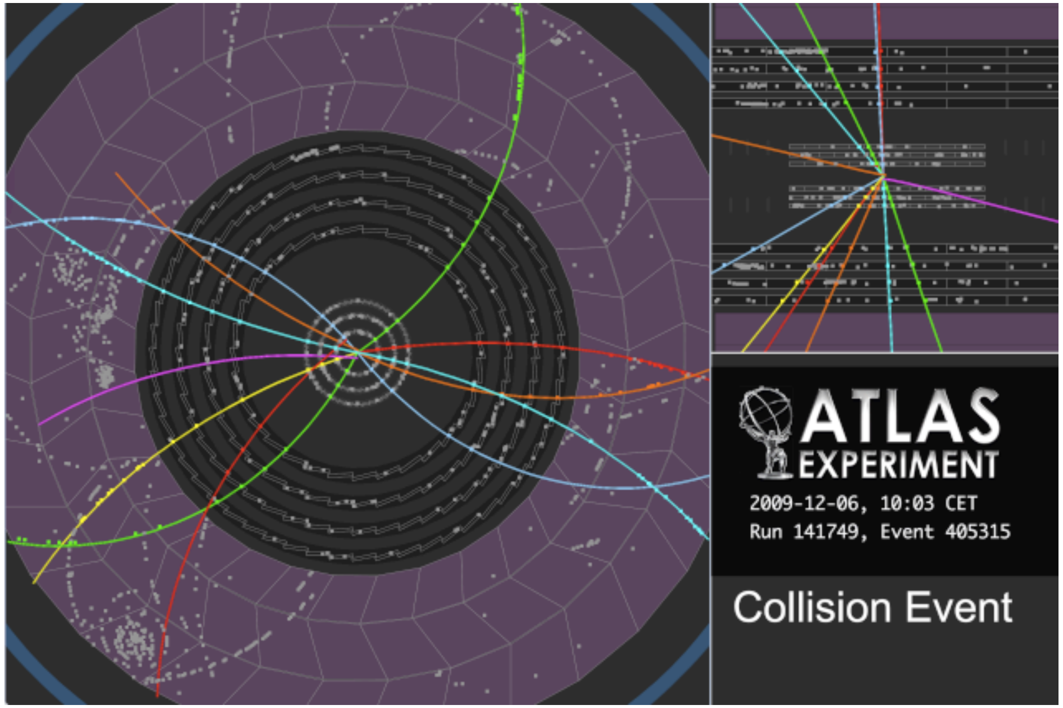
$$R = \sigma_{MB} \cdot \mathcal{L} \cdot \frac{\Delta t_{BC}}{1 - f_{empty}}$$

Low-luminosity scenario @ 7 TeV almost 4.6 pile-up events per bunch-crossing are expected

# Primary interaction vertex

can be usually distinguished in two different stages:

1. Vertex Finding
2. Vertex Fitting



# Vertex Finding

- correctly clustering tracks into multiple vertices, doing the tracks to vertices association properly.
- Optimal distinction of primary from secondary tracks
- Optimal separation of tracks originating from different but closely positioned vertices from the signal or additional pile-up events

# Vertex Fitting

- Deal with the problem of getting the best estimate of the vertex position, once a certain set of tracks is defined.
- Some methods for vertex fitting, however, deal intrinsecally also with part of the vertex finding problem, creating a vey close interplay between finding and fitting tasks.

# Primary Vertex @ ATLAS

- The trans. resolution of the primary vertex is comparable to the transverse size of the BS
- Reconstruction of the primary vertex position along the longitudinal direction is essential:

  it permits to improve longitudinal resolution from the nominal 4-5 cm to 30-50 μm.

- The distinction of primary and secondary tracks is of utmost importance not only for b-tagging but also for τ-tagging, photon-lepton identification, etc...

Pile-up events will be produced randomly spread across the interaction region, givent that the longitudinal size of of the beam-spot is much larger than the longitudinal primary vertex Resolution of tipical min bias events several vertices can be separated along the z axis and Reconstructed on an event by event basis; one of them will correspond to the high PT event of interest.

It's not straighforward, after all primary vertices corresponding to a single recorded bunch crossing are recostructed, to identify the vertex containing the physics event of interest as the ATLAS reconstruction software needs to remain very generic (generic event properties)

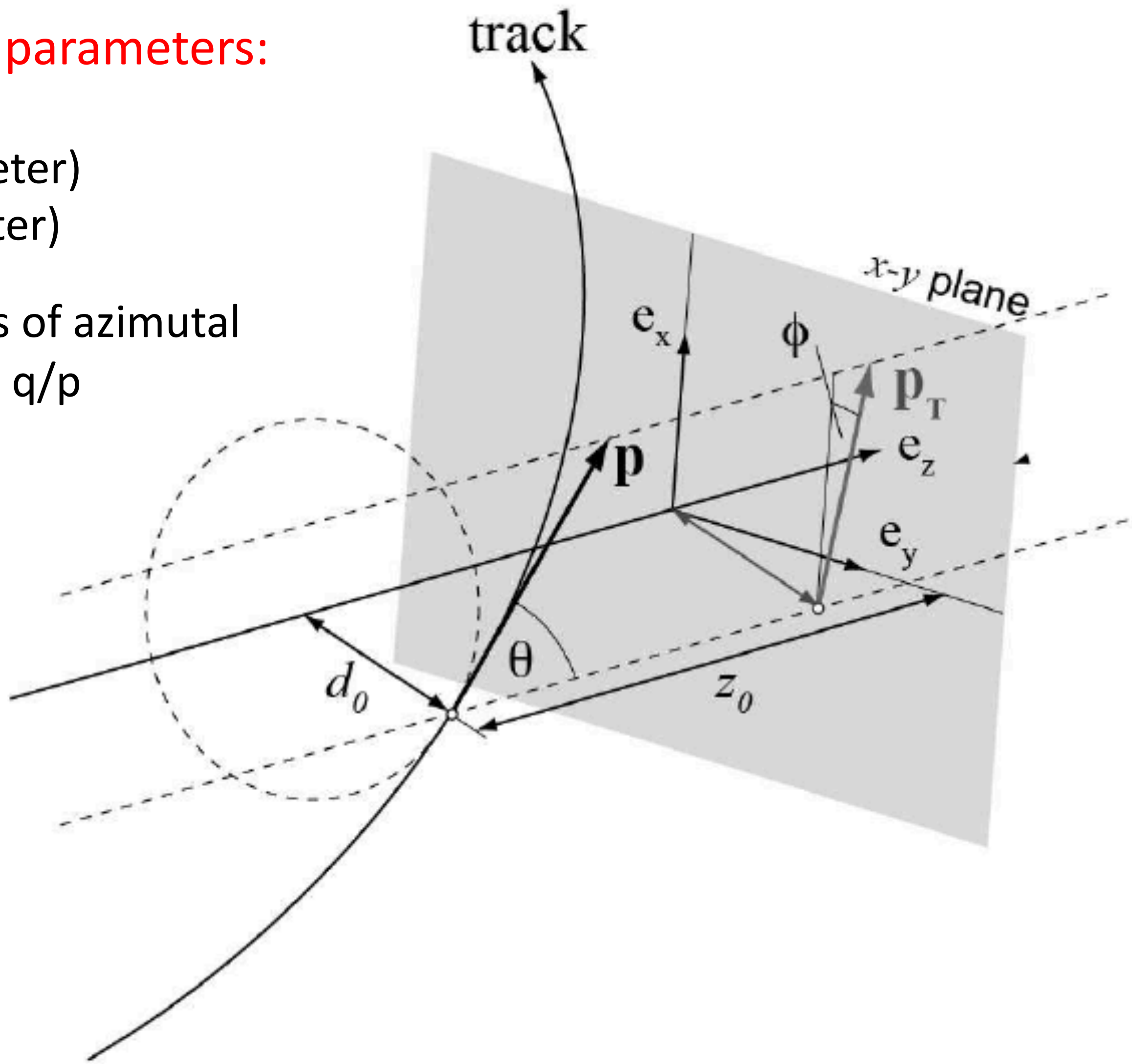
# Perigee representation

Mathematical determination of the vertex position

Trajectory specified by five parameters:

$z_0$ (longitudinal impact parameter)
$d_0$ (transverse impact parameter)

and track momentum in terms of azimutal angle $\phi$, polar angle $\theta$ and q/p



# Vertex fit

Well defined task:

N input tracks -> determining intersection:

vertex and its error

(Doesn't care wheather the hypotesis that N input tracks intersect a single point is correct or not)

$$\chi^2(\vec{r}) = \sum_{i=1}^{N_{trk}} (\vec{r} - \vec{r}_i(\hat{\phi}_{p,i}))^T \mathrm{cov}^{-1}_{3\times 3,i}(\hat{\phi}_{p,i})(\vec{r} - \vec{r}_i(\hat{\phi}_{p,i}))$$

$\chi^2$ estimator, minimize this function numerically

Global $\chi^2$ fit

# Vertex Fitting

- Global $\chi^2$ minimization
- Billoir method (complexity $N_{trk}$ instead of $N_{trk}^3$)
- Kalman Filter (single step k adds a trk to the V)
- Adaptative methods:
  1. Adaptive vertex fitter
  2. Adaptive Multi-Vertex fitter

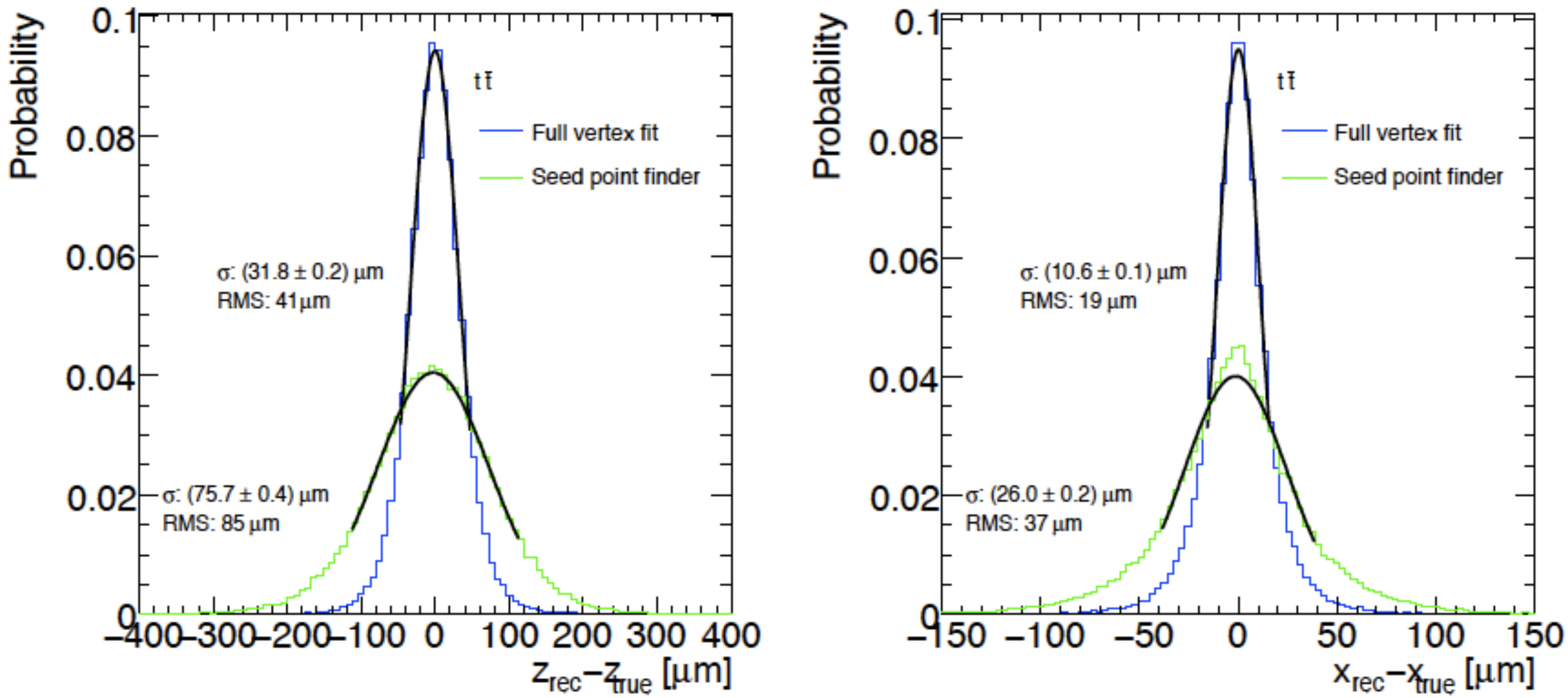
$$\omega(\hat{\chi}^2) = \frac{1}{1 + \exp\left(\frac{\hat{\chi}^2 - \chi^2_{cutoff}}{2T}\right)}$$

# Vertex Finding

- Default Vertex Finder (fitting after finding)
  - Once z position for each track is known -> vertex clustering tool
  - Many implementation (sliding window, 5 mm),
  - Tracks with $\chi^2 > 6$ rejected
  - Tracks rejected are lost

- Adaptive Vertex Finder & Adaptive Multi-Vertex Finder (finding through fitting)
  - Seed finder (3D,  z-scan) used to find first seed for Vtx
  - Vtx fitter (tipically AVF) to fit new Vtx cand
  - incopatible trks used to find a new vtx seed until no trks are left
  - complete set of fitted vertices
  - AMVF, the new vertex is fitted simultaneously with all previous vertices

# Perform. of seed finders

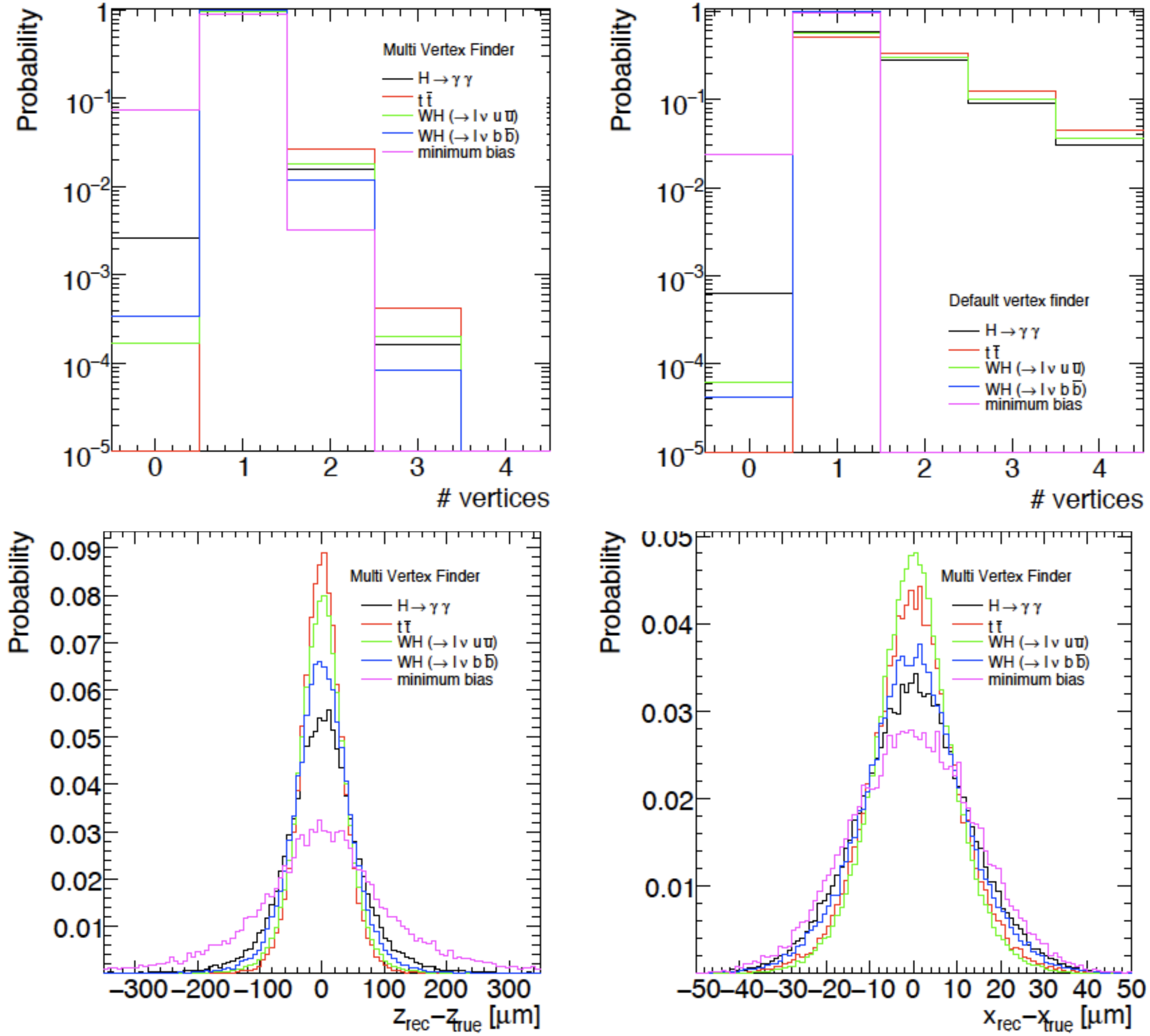


# Finder-Fitter @ ATLAS

| Name | Vertex finder | Vertex fitter | Deals with pile-up |
|---|---|---|---|
| Default vertex finder | Default vertex finder | Billoir vertex fitter | yes |
| Sequential vertex finder | Default vertex finder | Kalman vertex fitter | yes |
| Adaptive vertex finder | Adaptive vertex finder | Adaptive vertex fitter | no |
| Adaptive multi-vertex finder | Adaptive multi-vertex finder | Adaptive multi-vertex fitter | yes |

To isolate signal vertex among all found primary vertices:
- trans mom of the associated Trks
- number of associated Trks
- for APVF discriminator based on SUM $pT^2$, NN, etc..

# Plots ( MC no pile-up)



# Vertex posit. 900 GeV Data

Further studies are ongoing
Sequential vertex finder used
Good vtx efficiency if Ntrck>4