Monte Carlo Study of TPC Performance

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(GLD/TPC collaboration)

Contents

Why we study TPC performance using Monte Carlo simulation?

Before construction of the prototype, need to
(1) determine the expected performance of the production-type
(2) optimize the design parameters
(3) evaluate the influence of BG and the materials, etc…

Requirement from Physics

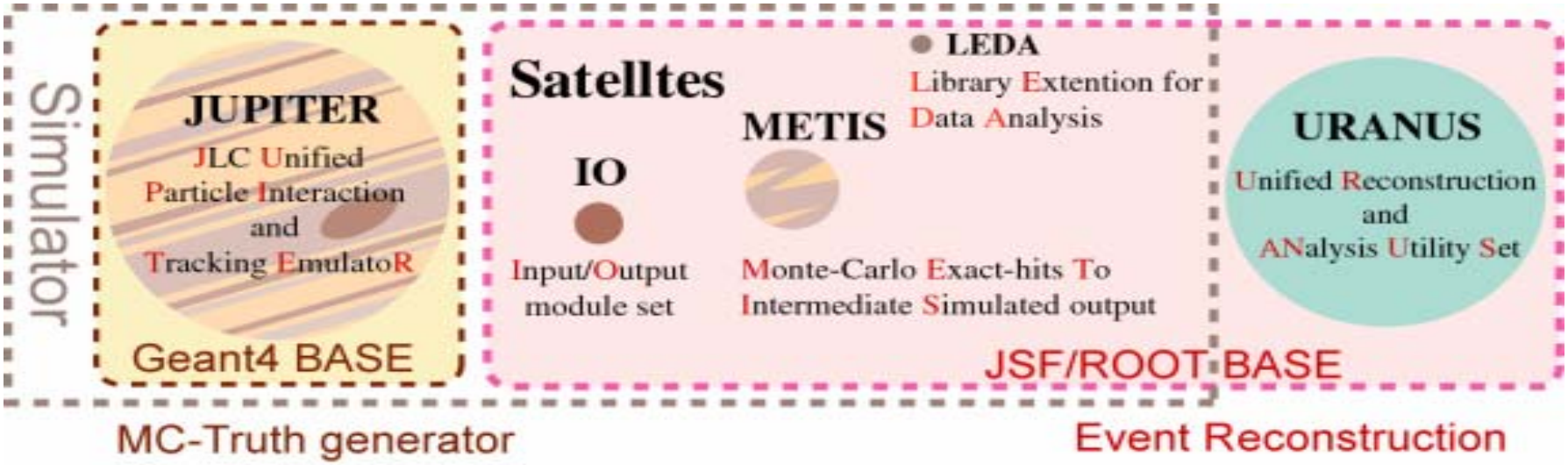
-- momentum resolution $\sigma_{p_{\ell^\pm}}/p_{\ell^\pm} \leq 0.4\%@p_{\ell^\pm} = 50\,GeV$

-- unambiguous track-cluster matching for PFA (particle flow algorithm)
momentum resolution: $\sigma_{PT} < 1\times10^{-4}\,P_T$ **(GeV)**

-- Particle ID, etc…

Monte Carlo simulation is a good tool for this purpose!!

Monte Carlo Simulation tool



TPC detector simulation

✧ **JUPITER** --- Geant4 based full detector simulator

✧ **Satelltes, URANUS** --- event reconstruction module

- exact hit to smeared hit
- track fitting by kalman fitter (not including energy loss)

Status of the Study

Target of momentum resolution

$\sigma P_T < 1 \times 10^{-5} P_T$ (TPC+IT+VTX)

Working hypotheses for GLD/TPC 3T geometry

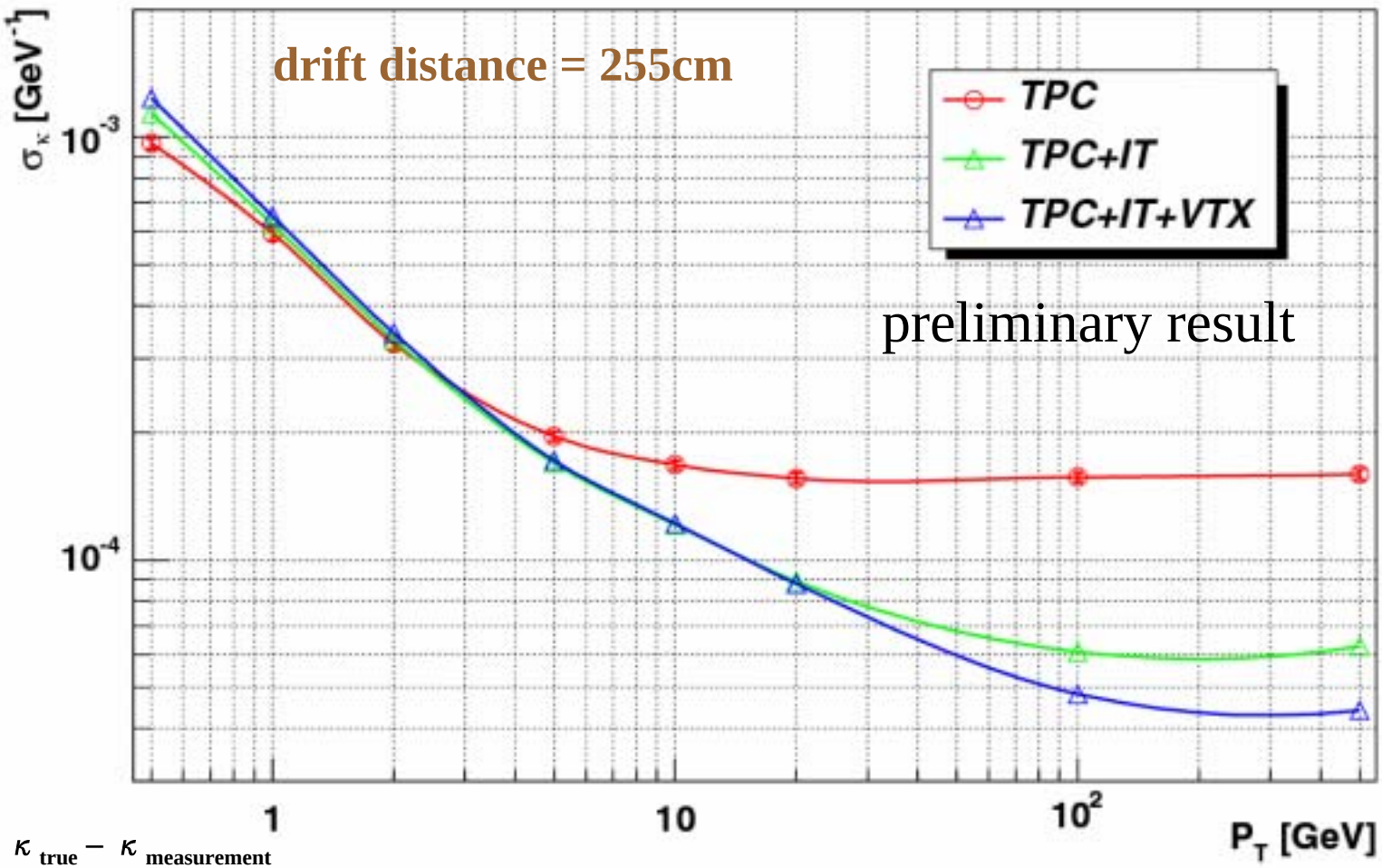
(based on analytic resolution formula assuming drift distance independent spatial resolution)

- ✓ $R_{out} - R_{in}$ = 154cm, Length = 255×2 (cm)
- ✓ Diffusion of gas ($\sigma_{xy}^2 = \sigma_0^2 + C_d^2/(Ne \times \alpha) \times Z_{drift}$)
  -- TDR gas: σ_0=70 μ m, C_d=80 μ m/$\sqrt{}$ cm, Ne=63, α =1 , σ_z = 400 μ m
- ✓ B= 3T
- ✓ N_{sample} = 200
- ✓ V_{drift} = 5 cm/μ sec

estimate

- momentum resolution for single track
- cos θ dependence of momentum resolution

Momentum resolution for single track



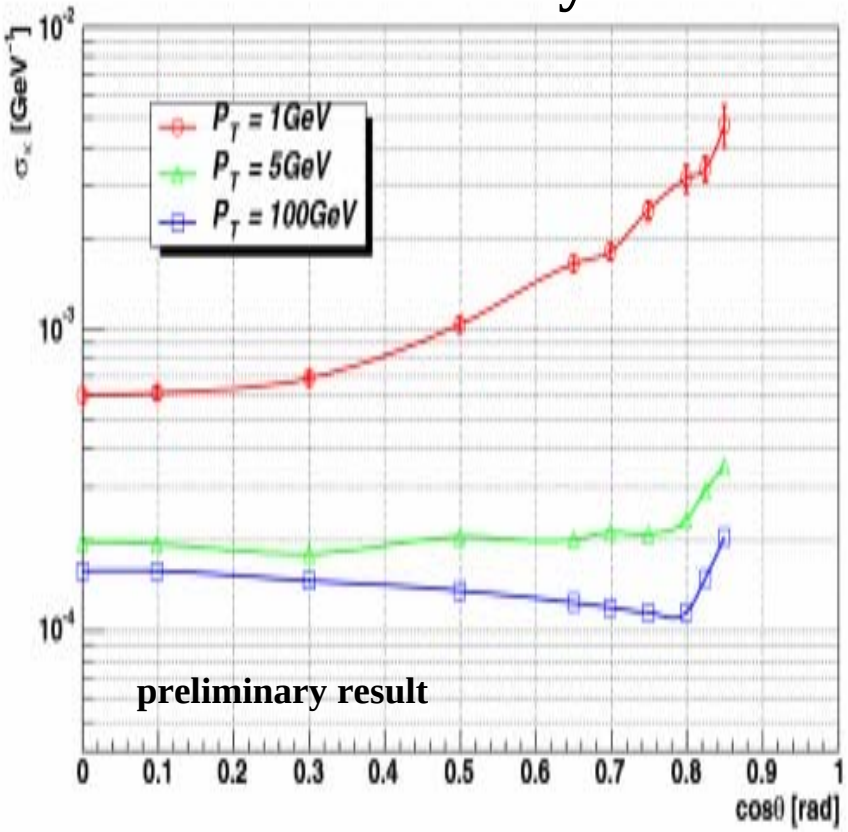
$\sigma\ \kappa = \kappa_{\text{true}} - \kappa_{\text{measurement}}$

$\kappa = Q / P_T$

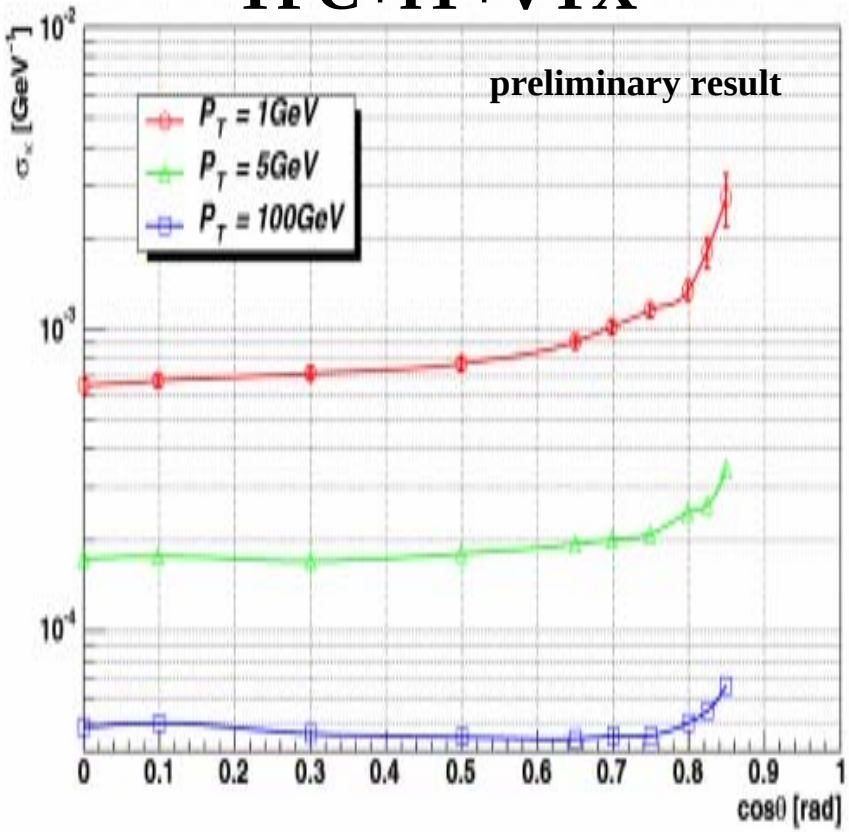
Momentum resolution for single track

--- *cos θ dependence* ---

TPC only

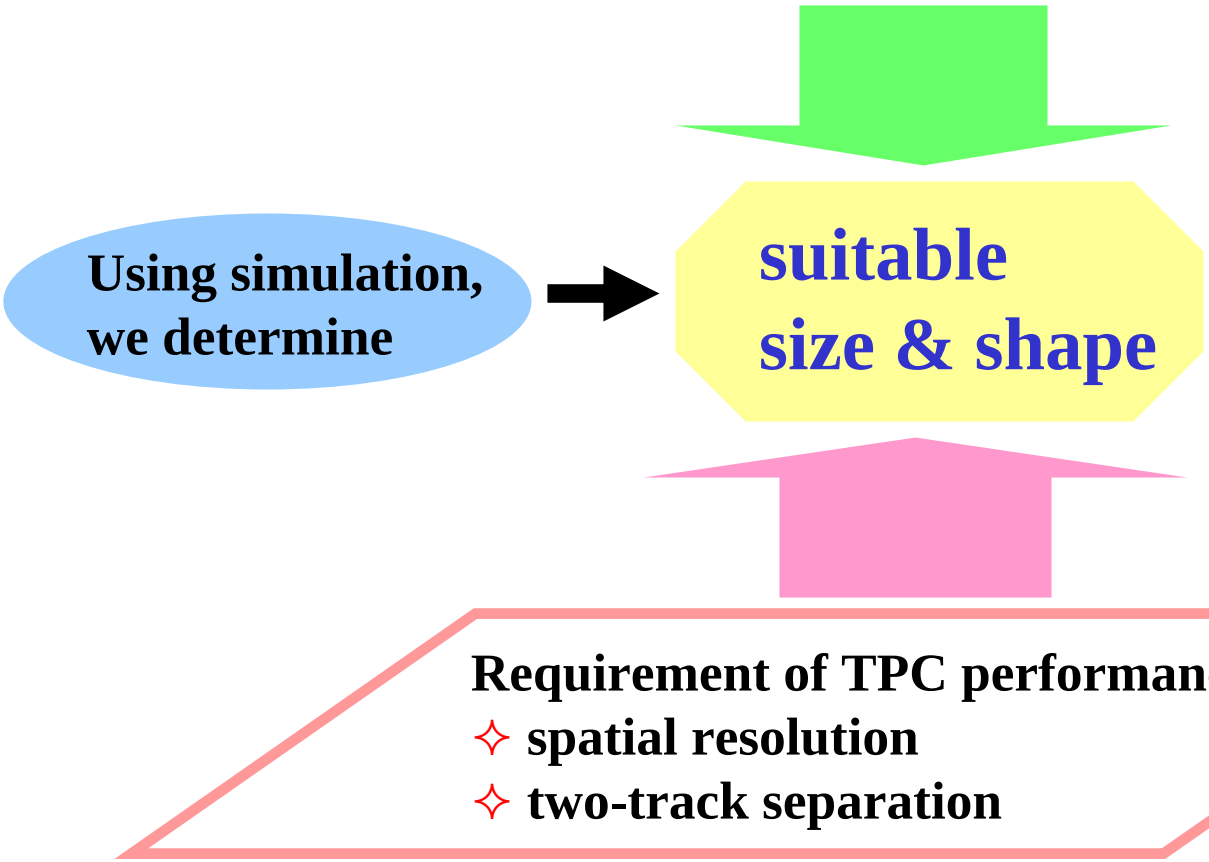


TPC+IT+VTX

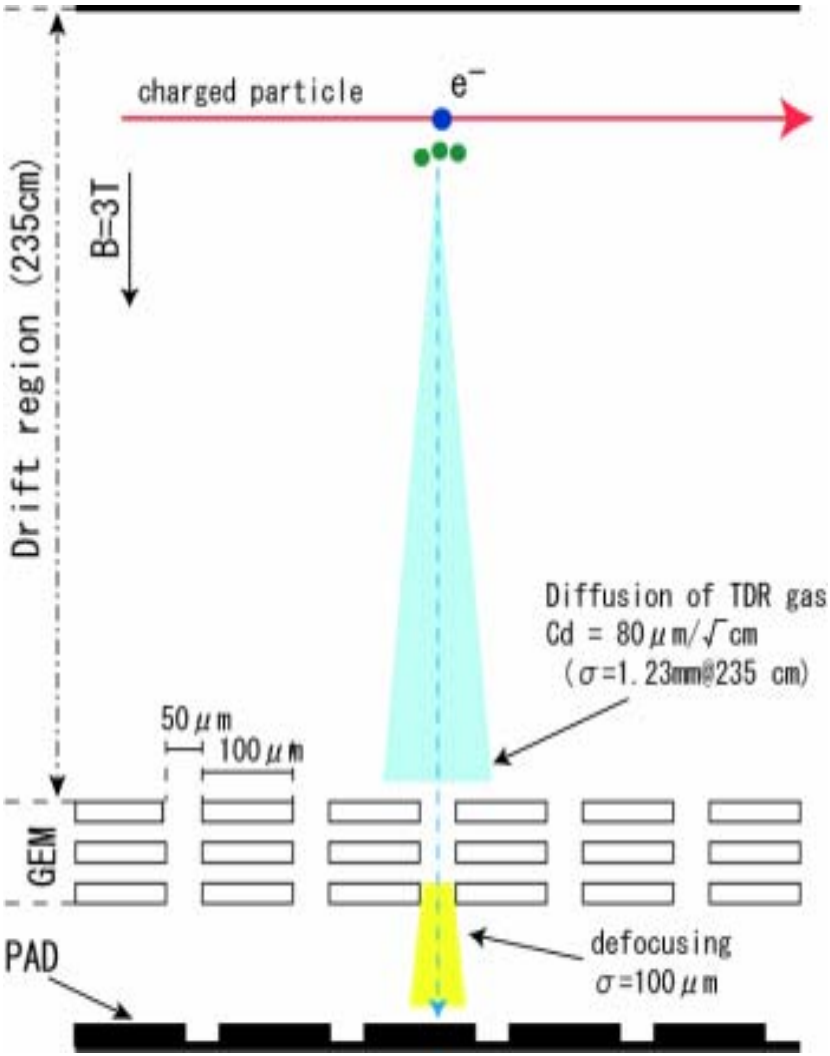


What determine the PAD shape?

- # of channel (48M channel @ 500×500 μ m^2 PAD)
- Read out method (analog or digital etc.)



Simple PAD simulation



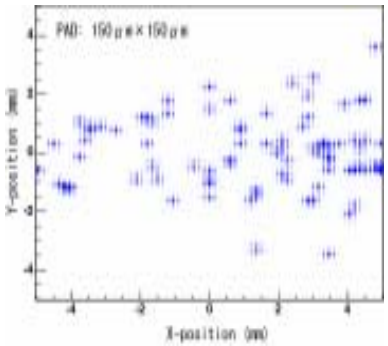
Assumption for PAD simulation

- **B=3T**
- **Max. drift distance = 235cm**
- **Using TDR gas**
  - **-- Cd = 80 μ m/$\sqrt{}$ cm@3T**
    Gauss distribution
  - **-- # primary e = 30/cm**
    Poisson distribution
  - **-- # secondary e**
    Landau distribution (NIM A(301)202)
- **GEM (one layer)**
  - **-- hole: ϕ 50 μ m, 100 μ m pitch**
  - **-- gain: 10^3**
- **Defocusing: σ = 100 μ m**
  Gauss distribution

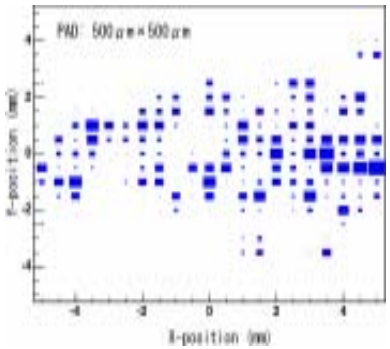
PAD response for single track

Drift distance 235 cm

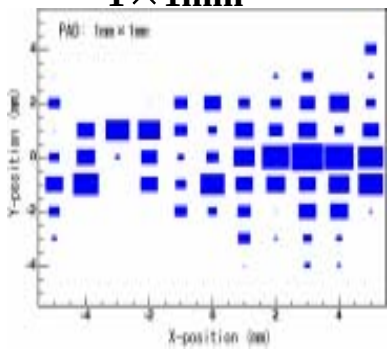
150×150 μ m^2



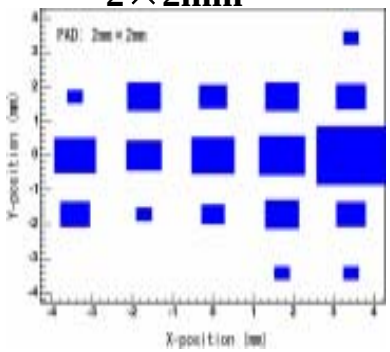
500×500 μ m^2



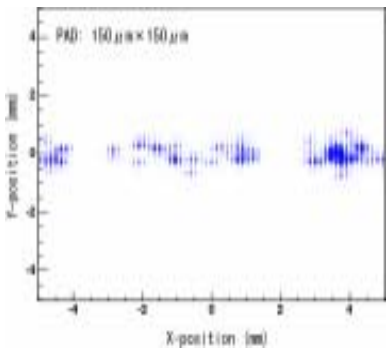
1×1mm^2

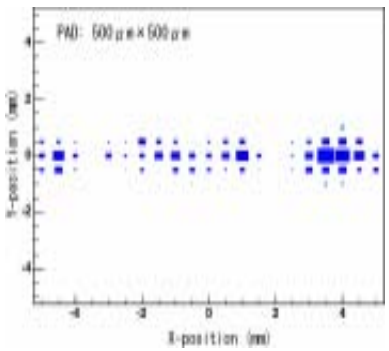


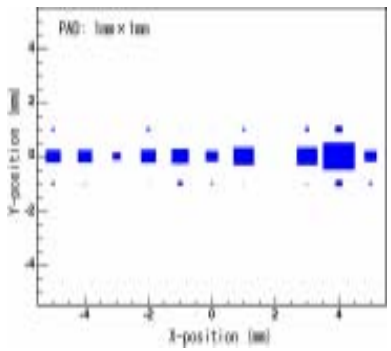
2×2mm^2

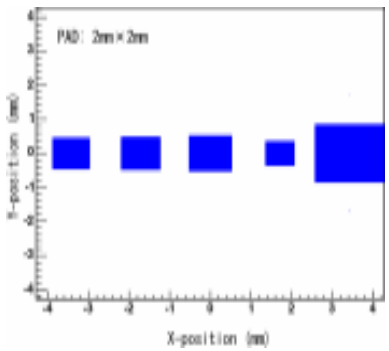


Drift distance 10 cm







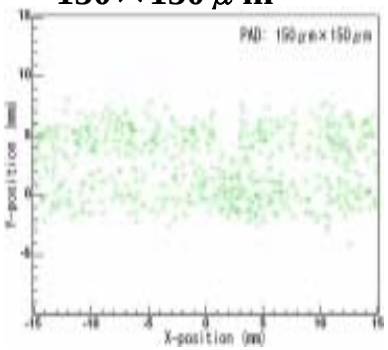


PAD response for two-track

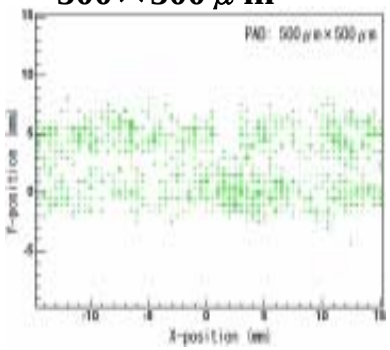
--- drift distance: 235cm ---

space of two-track: 5mm

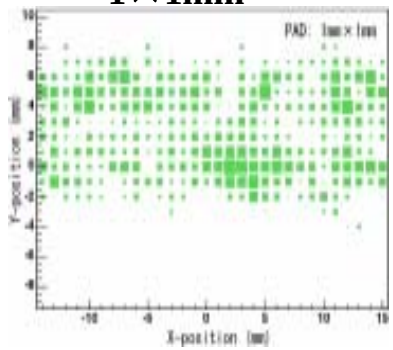
150×150 μ m^2



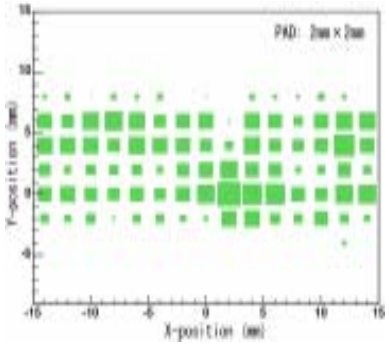
500×500 μ m^2



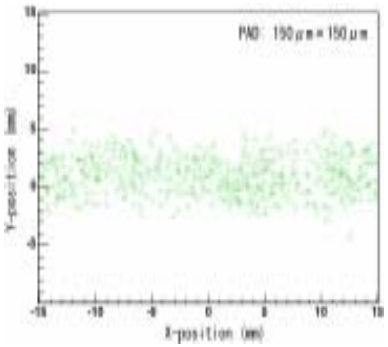
1×1mm^2

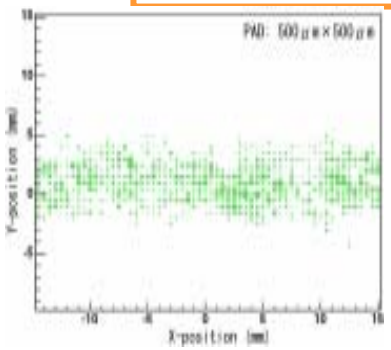


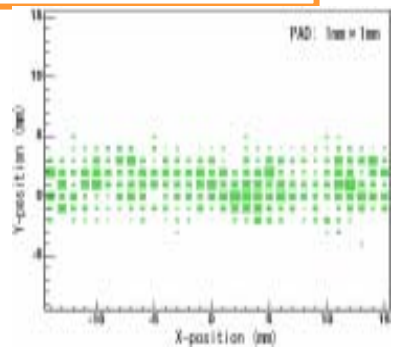
2×2mm^2

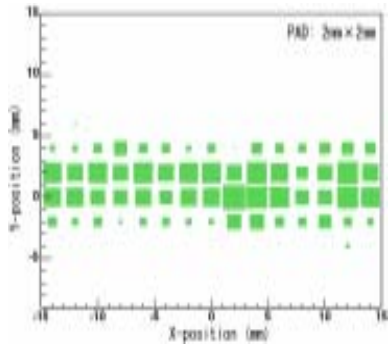


space of two-track: 2mm

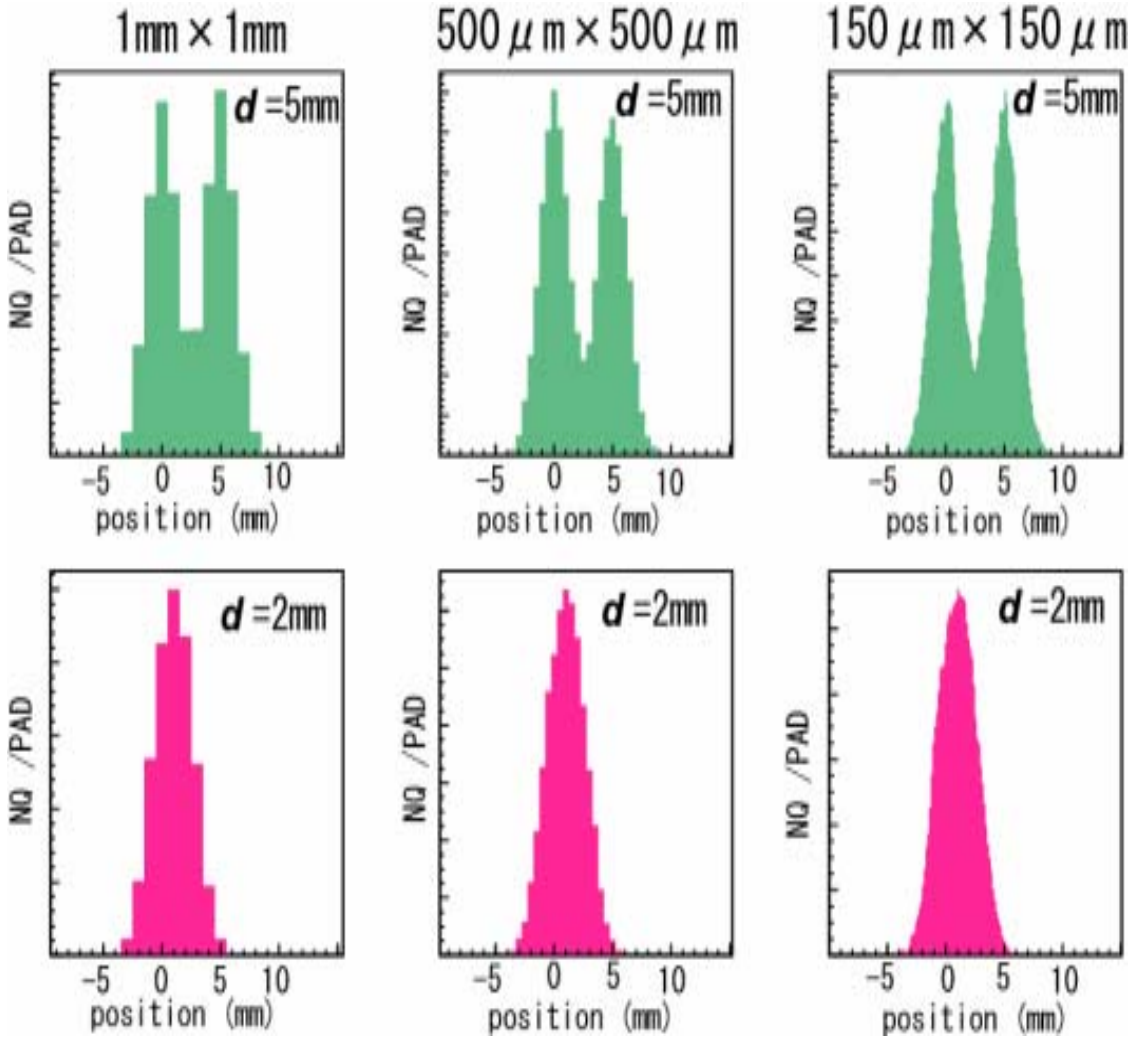




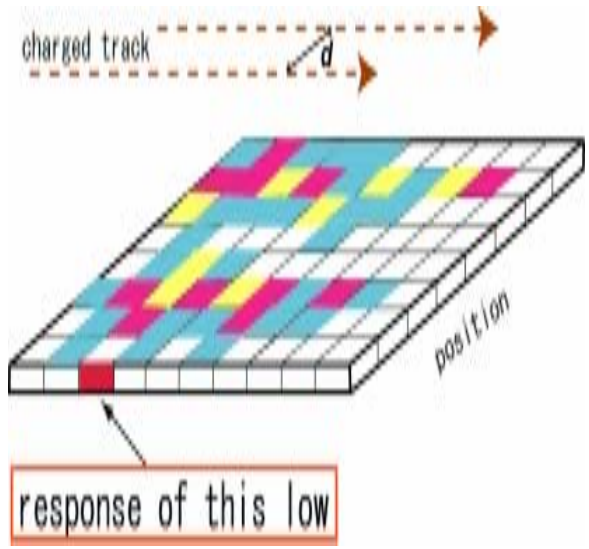




PAD response for two-track (1000 events)



PAD of 1×1mm^2 can separate two tracks with 5mm space



Summary

- **We start to estimate the performance of TPC by our Monte Carlo simulator, JUPITER, Satelltes and URANUS.**
  - --- momentum resolution (TPC only and TPC+IT+VTX)
  - --- θ dependence for momentum resolution
- **The future plan**
  - --- track fitting including the energy loss
  - --- estimate the two-track separation
  - --- estimate the ability of TPC using realistic track finding
  - --- estimate the performance of all trackers (TPC+IT+VTX)
- **We just start PAD optimization study by simple simulation.**
  - --- separation of two-track with 2mm space is difficult by the diffusion of TDR gas
  - --- proceed to the more realistic simulation for the optimization