

Update on muon momentum resolution

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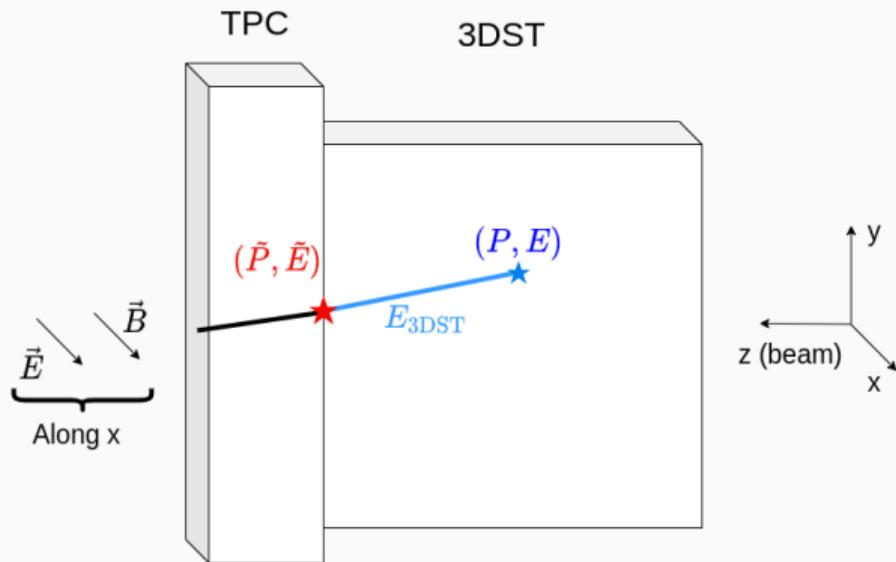
February 23, 2021



Irfu - CEA Saclay



Estimating P resolution



- P and E are the initial momentum and energy of the particle
- \tilde{P} and \tilde{E} are the momentum and energy of the particle when entering TPC
- $\tilde{P}_T = \sqrt{\tilde{P}_y^2 + \tilde{P}_z^2}$ measured in the TPC
- E_{3DST} is the energy deposited in the 3DST

Additional Effects

- MS in 3DST modifies particle direction
- Energy deposition in 3DST modifies particle energy

Resolution effects taken into account

- Error on sagitta measurement : $\left. \frac{\sigma_{p_T}}{p_T} \right|_{\text{Measure}}$ taken from theoretical formula
- Multiple scattering in the TPC : $\left. \frac{\sigma_{p_T}}{p_T} \right|_{\text{MS}} = 0.045 \frac{1}{B\sqrt{LX_0}} \sim 0.9\%$
in our case
($X_0 = 90$ m for CF_4)
- Error on the measurement of the energy deposit inside 3DST
 $E_{3\text{DST}}: \frac{\sigma_{E_{3\text{DST}}}}{E_{3\text{DST}}} = 2\%$
- Change on P_T due to MS in 3DST + materials between 3DST and TPC
- 3DST angular resolution

P_T resolution

P resolution

P_T resolution - Inputs from simulation

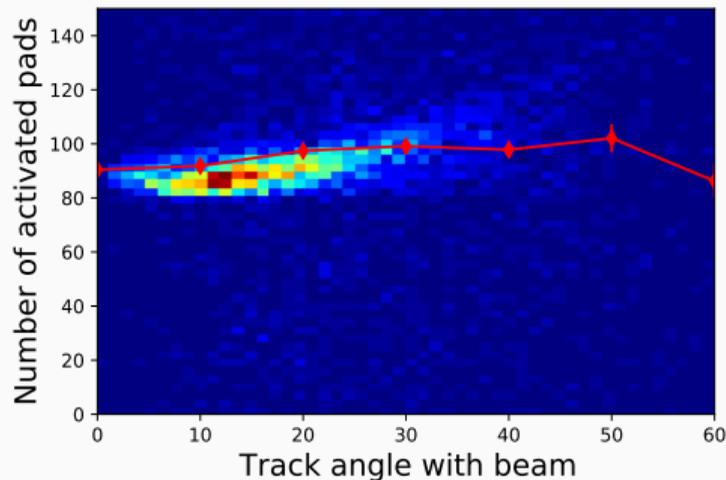
TPC resolution on P_T is estimated with:

$$\frac{\sigma_{P_T}}{P_T} = \frac{P_T}{0.3BL^2} \sqrt{\frac{720}{N+4}} \cdot \sigma_{r\phi}$$

Inputs

- $B = 0.6$ T
- P_T muon transverse momentum *
- L individual track length *
- N number of leading pads for track *
- $\sigma_{r,\phi}$ resolution taken from prototype data (cosmics and test beam)
- ~~Additional effects (non-uniformities, mis-alignment,...) calibrated by comparing to real neutrino data of T2K~~

* From track-by-track simulation

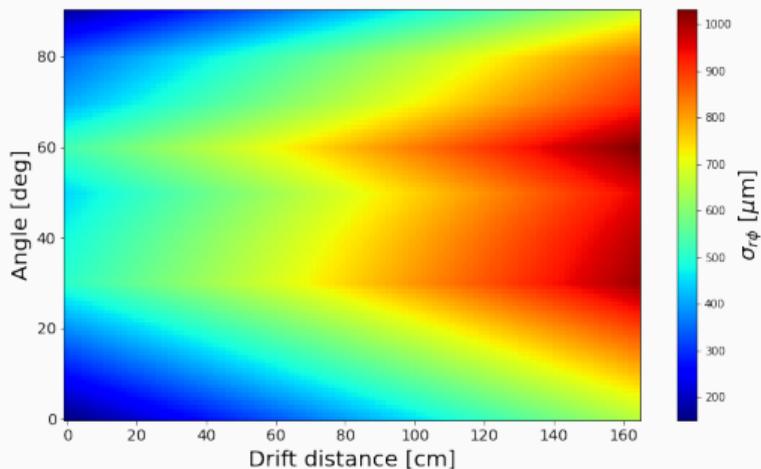


Simulation

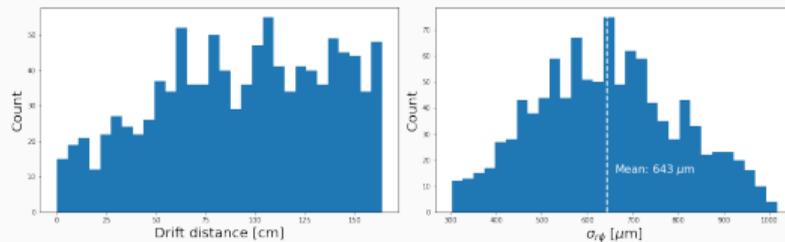
Prototype data are used to estimate $\sigma_{r\phi}$

Resistive Micromegas prototype testing

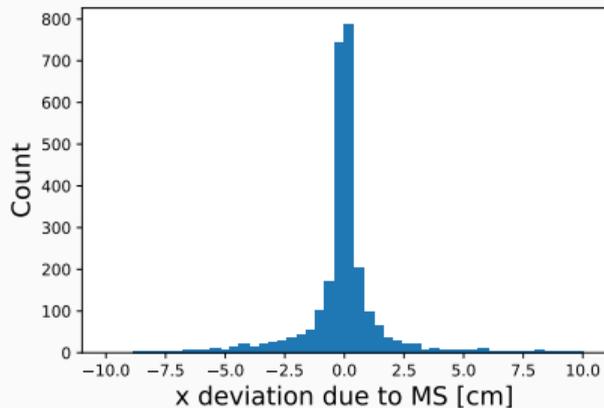
- 2018 test beam at CERN ; 2019 at DESY with magnetic field
- Cosmic data taking at Saclay



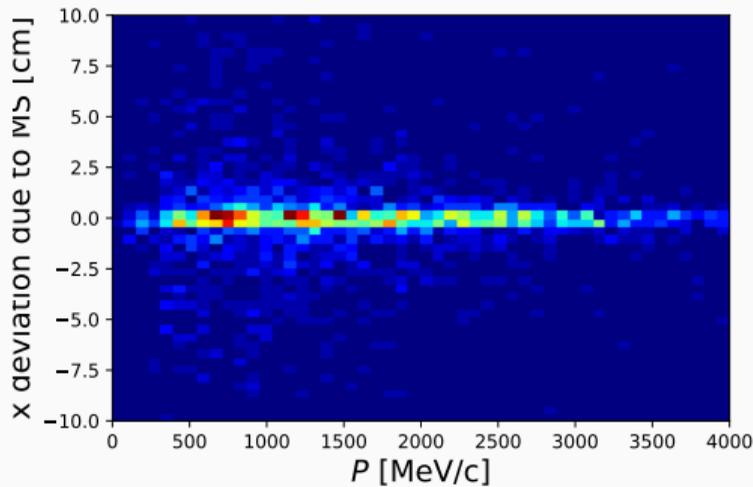
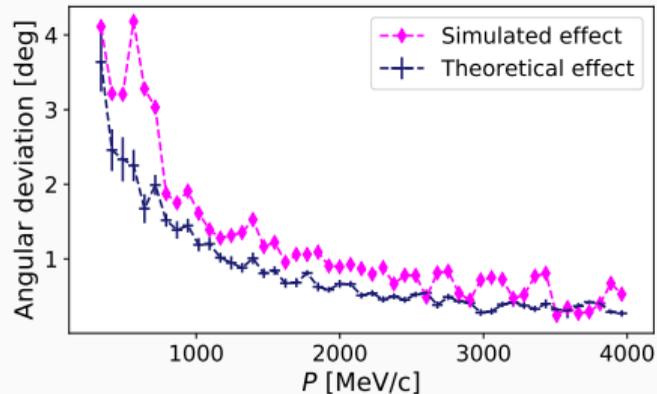
- Dependence of spatial resolution with drift distance and track angle.



Effect of MS on P_T



Effect of MS in 3DST

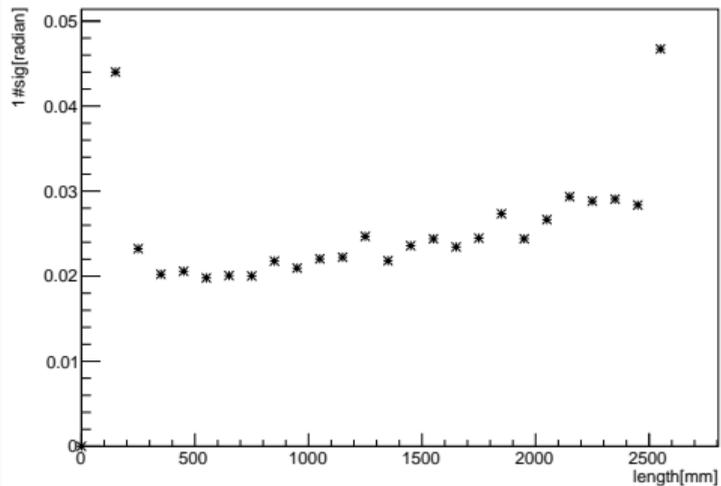


- The effect of MS of P_T is evaluated track by track from the simulation
- Theoretical formula

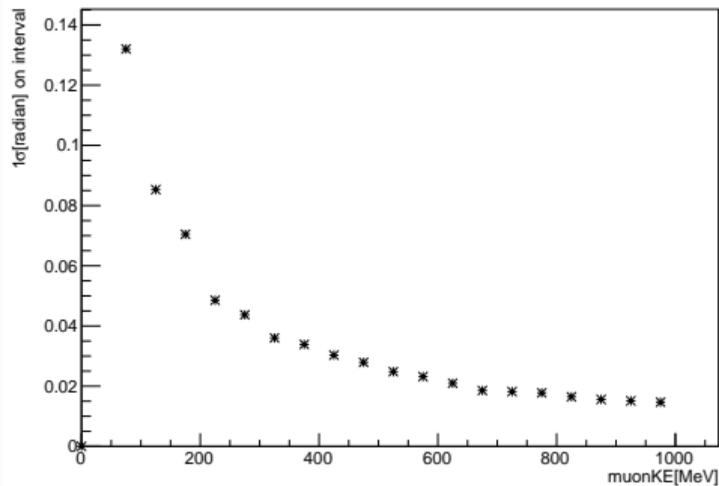
$$\theta_0 = \frac{13.6 \text{ MeV}}{\beta_{cp}} Z \sqrt{\frac{x}{X_0}} \left(1 + 0.038 \ln \frac{x}{X_0} \right) \quad 6$$

3DST angular resolution (Ki-Young results)

Angle resolution

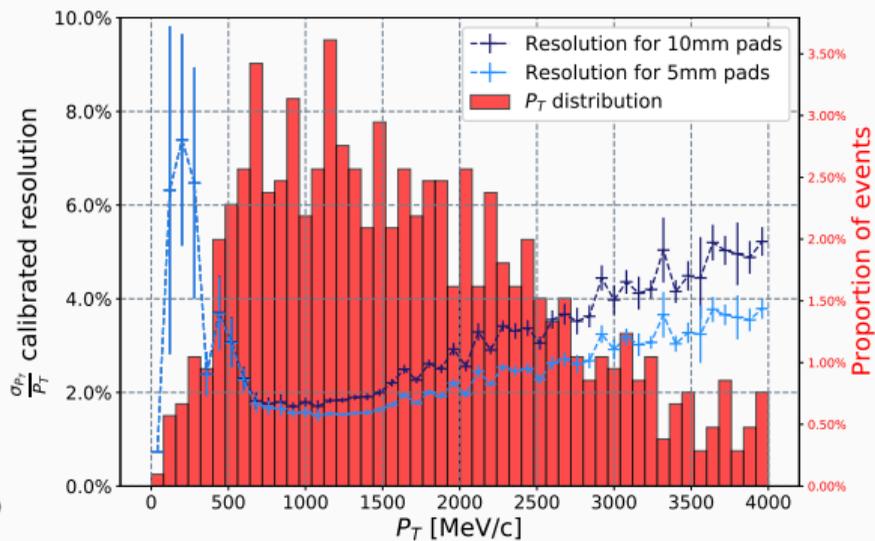
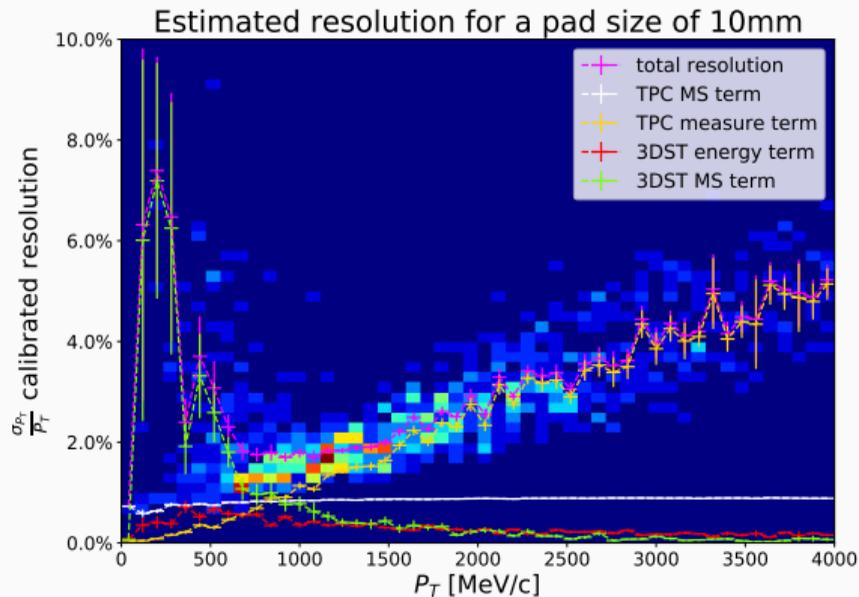


Avg Angle resolution



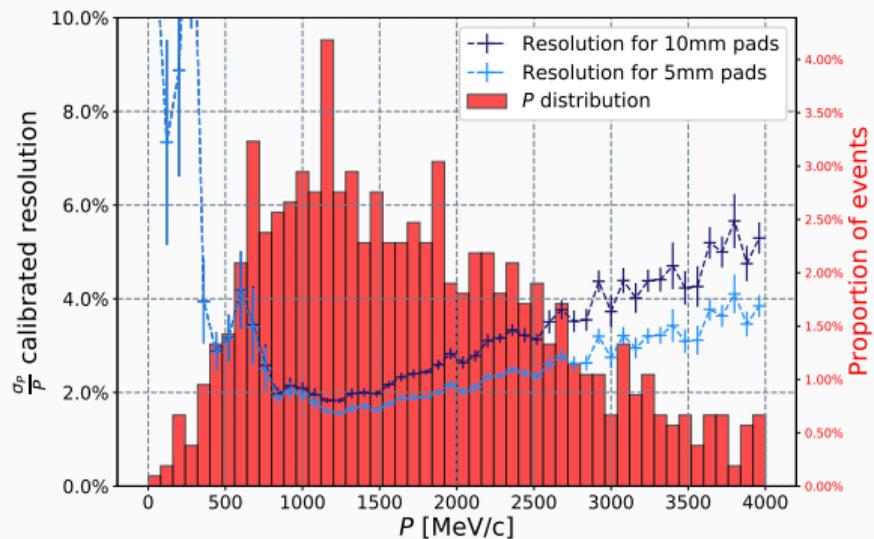
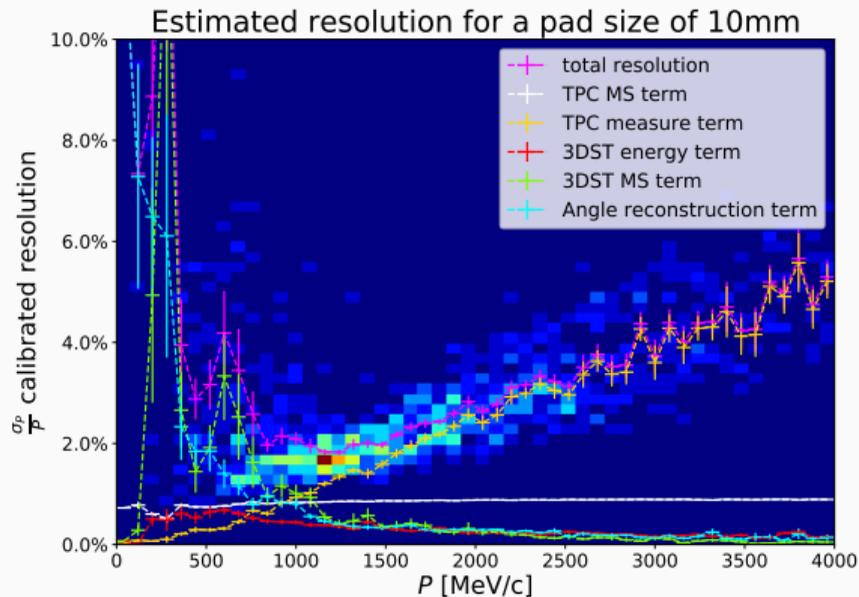
- The resolution on Ψ is computed from simulated tracks reconstruction in 3DST
- The dependance of the resolution depends mainly on the muon energy.

P_T resolution - DOWNSTREAM



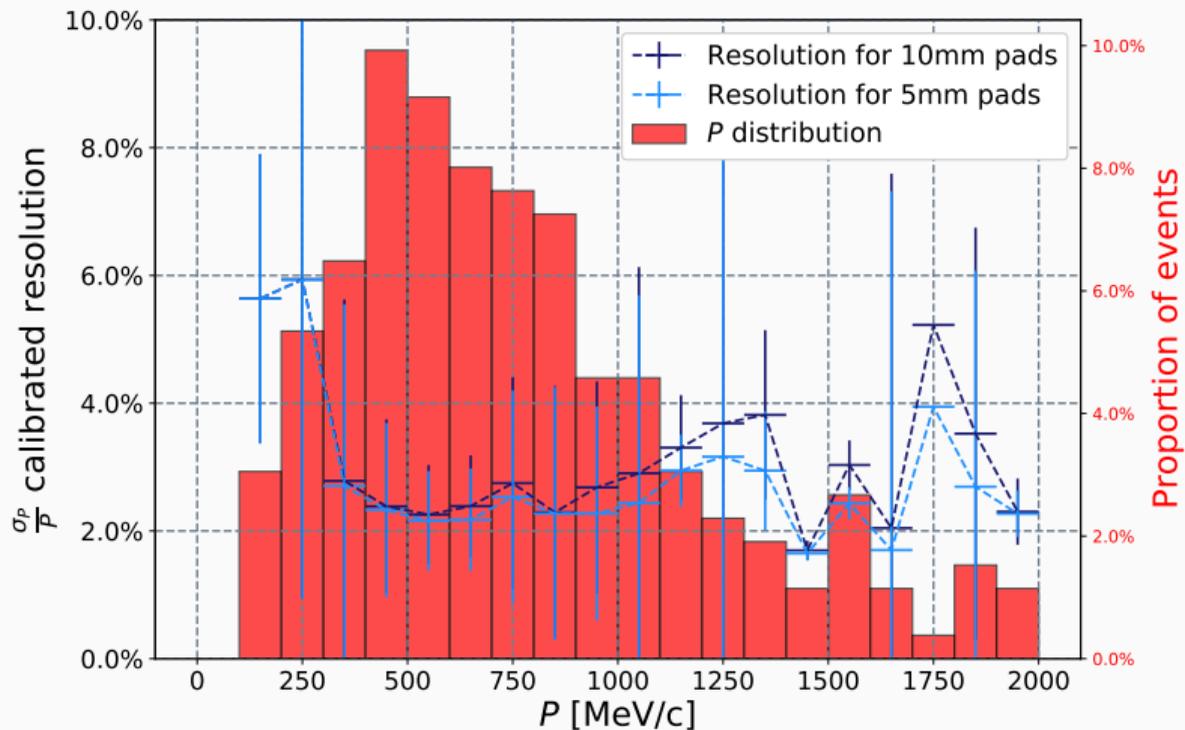
- Resolution of around 2% around 1 GeV
- Peak around 4% at lower momenta because of MS

P resolution - DOWNSTREAM



- Resolution of around 2% around 1 GeV
- Peak around 4% at lower momenta because of MS

P resolution - TOP & BOTTOM



Backup slides

Uncertainties

Computing factors

$$\begin{aligned} P &= \sqrt{E_{3\text{DST}}^2 + 2E_{3\text{DST}}\sqrt{m^2 + \tilde{p}^2} + \tilde{p}^2} \\ &= \sqrt{E_{3\text{DST}}^2 + 2E_{3\text{DST}}\sqrt{m^2 + \frac{\tilde{P}_T^2}{\sin^2 \tilde{\Psi}} + \frac{\tilde{P}_T^2}{\sin^2 \tilde{\Psi}}} \end{aligned}$$

$$\frac{\partial P}{\partial E_{3\text{DST}}} = \frac{E}{P}$$

$$\frac{\partial P}{\partial \tilde{P}_T} = \frac{\tilde{P}}{P \sin \tilde{\Psi}} \frac{E}{E - E_{3\text{DST}}}$$

$$\frac{\partial P}{\partial \tilde{\Psi}} = -\frac{\tilde{p}^2}{P \tan \tilde{\Psi}} \frac{E}{E - E_{3\text{DST}}}$$

This supposes no input from 3DST concerning the momentum.

Uncertainty composition

Values measured at the entrance of the TPC are denoted with a tilde \sim .

$$\begin{aligned} \left(\frac{\sigma_P}{P}\right)^2 &= \left(\frac{EE_{3\text{DST}}}{P^2}\right)^2 \left(\frac{\sigma_{E_{3\text{DST}}}}{E_{3\text{DST}}}\right)^2 && \text{3DST energy term} \\ &+ \left(\frac{\tilde{P}}{P \sin \Psi} \frac{E}{E - E_{3\text{DST}}}\right)^2 \left(\frac{\sigma_{\tilde{P}_T}}{\tilde{P}_T}\right)^2 && \text{TPC transverse momentum term} \\ &+ \left(\frac{\tilde{P}^2}{P^2} \frac{E}{E - E_{3\text{DST}}} \cotan \Psi\right)^2 (\Delta\Psi)^2 && \text{3DST multiple scattering term} \end{aligned}$$

with

$$\left(\frac{\sigma_{\tilde{P}_T}}{\tilde{P}_T}\right)^2 = \left(\frac{\sigma_{\tilde{P}_T} \Big|_{\text{Measure}}}{\tilde{P}_T}\right)^2 + \left(\frac{\sigma_{\tilde{P}_T} \Big|_{\text{MS}}}{\tilde{P}_T}\right)^2$$