# Time-of-Flight System in SpdRoot

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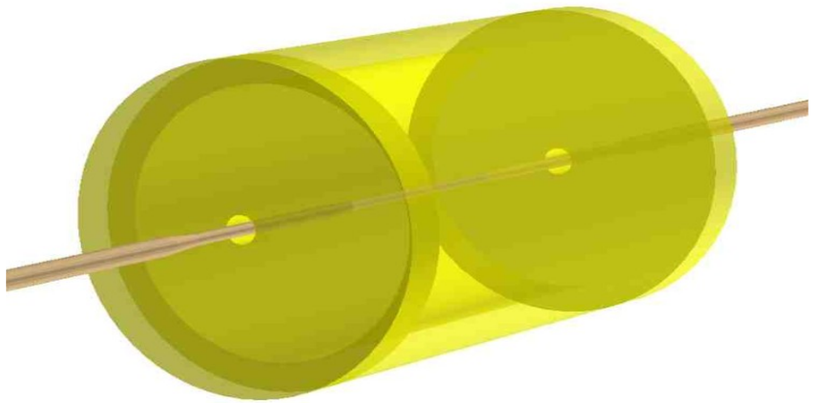
SPD S&C meeting
21.09.2021

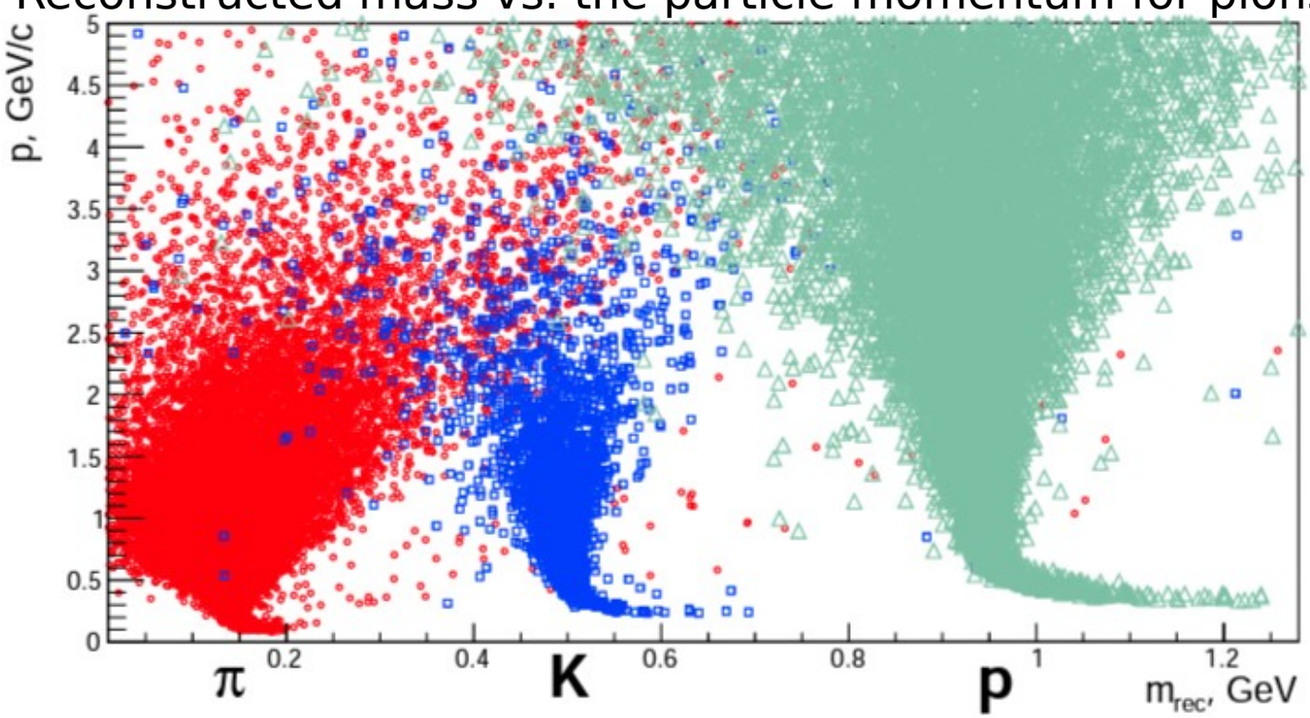
# The purpose of the report

- To check out the TOF detector added by Arthur in SpdRoot
  (git clone -b artur_dev https://git.jinr.ru/nica/spdroot.git)



- To check behaviour of distributions at low momenta

Reconstructed mass vs. the particle momentum for pions, kaons, and protons




**SPD CDR**
http://spd.jinr.ru/2102-00442/
page 135

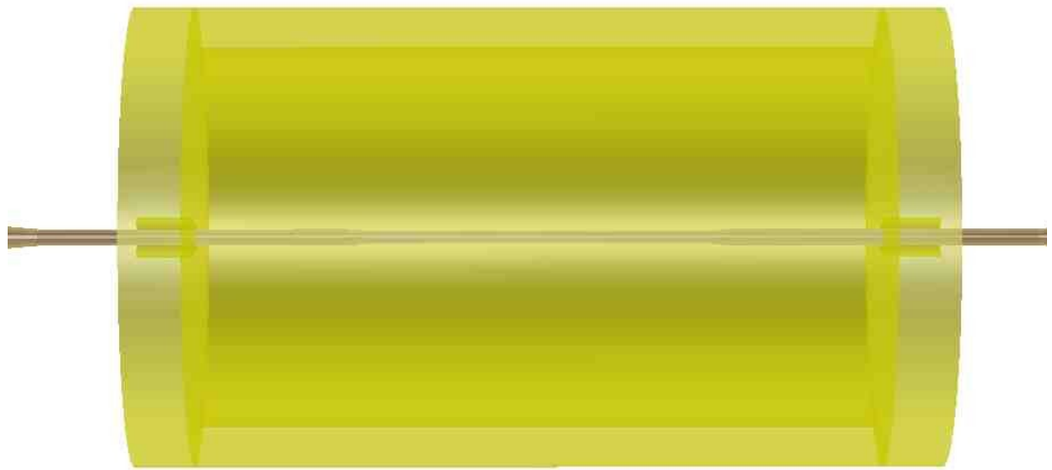
# TOF in SpdRoot

Thanks Artur for desciption TOF in SpdRoot
(git clone -b artur_dev https://git.jinr.ru/nica/spdroot.git)

Endcap

**Shape**: cylinder
**Material**: air
**Thickness**: 30 *cm*
**R_min**: 10 *cm*
**R_max**: 115 *cm*
***Distance from the center of set-up to endcap`s wall along the Z axis***: 171.6 *cm*

Barrel



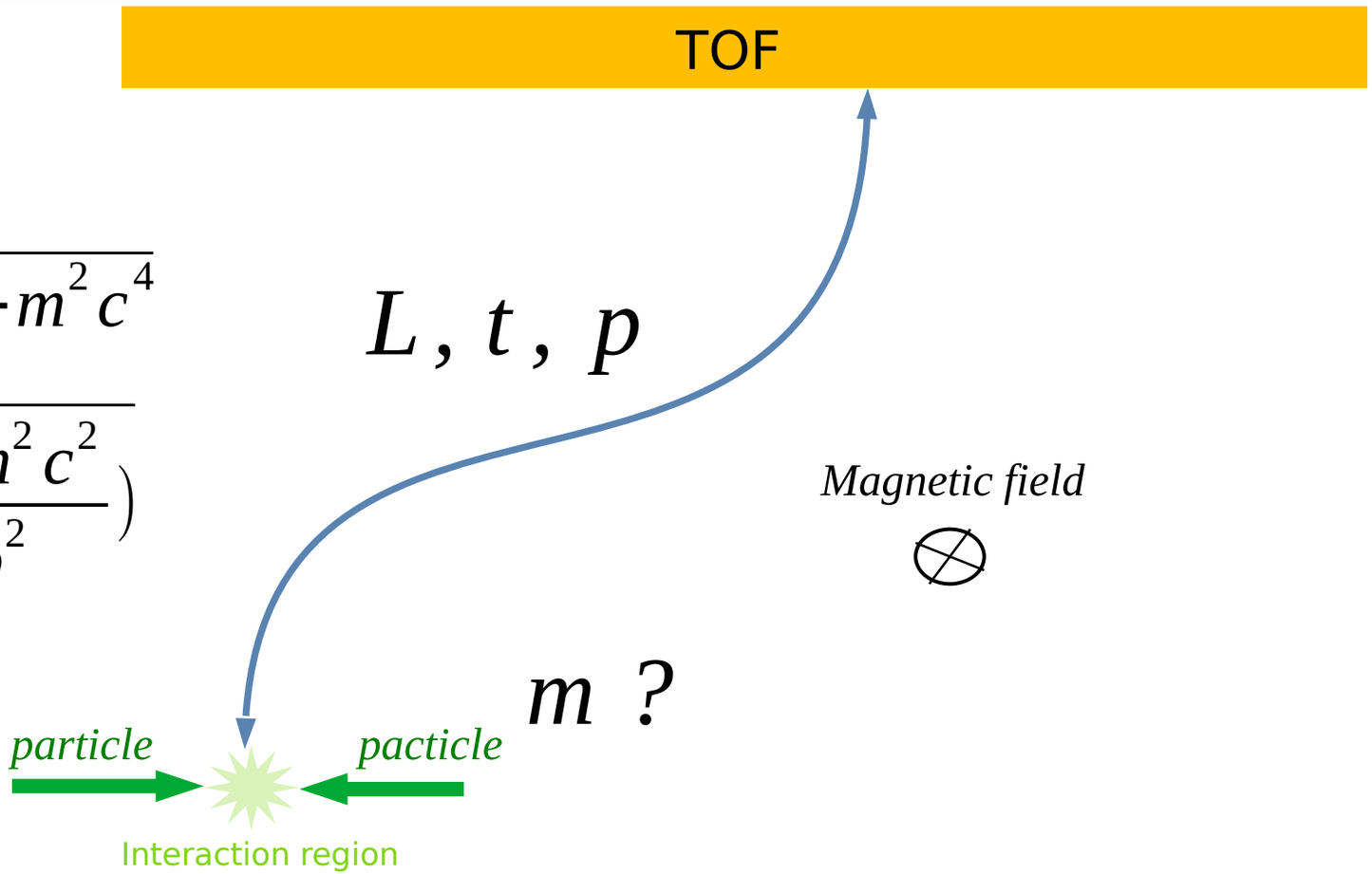
**Shape**: cylinder
**Material**: air
**Length**: 343.2 *cm*
**Thickness**: 20 *cm*
**R_min**: 95 *cm*
**R_max**: 115 *cm*

# The particle identification (PID) analysis with TOF

Time-of-flight measurement

$$t=\frac{L}{v}=\frac{L}{\beta c}=\frac{L\,E}{pc^2};\quad E=\sqrt{p^2c^2+m^2c^4}$$

$$t=L\frac{\sqrt{p^2c^2+m^2c^4}}{pc^2}=\frac{L}{c}\sqrt{\left(1+\frac{m^2c^2}{p^2}\right)}$$



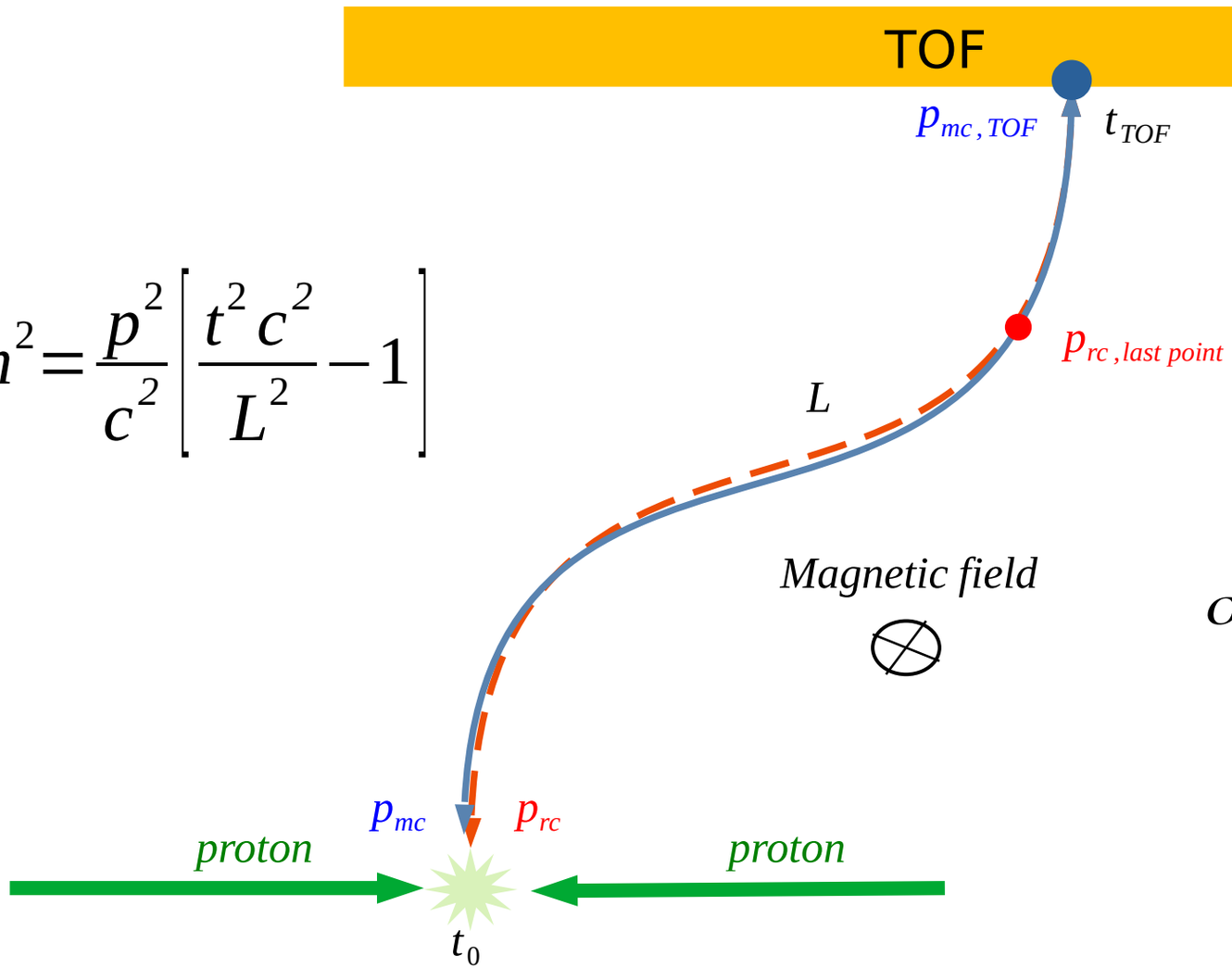

Mass of particle

$$m^2=\frac{p^2}{c^2}\left[\frac{t^2c^2}{L^2}-1\right]$$

$$\sigma^2_{m^2}=4m^4\left(\frac{\sigma_p}{p}\right)^2+4E^4\left(\frac{\sigma_t}{t}\right)^2+4E^4\left(\frac{\sigma_L}{L}\right)^2$$

# PID analysis with TOF in SpdRoot

$$m^2 = \frac{p^2}{c^2}\left[\frac{t^2 c^2}{L^2} - 1\right]$$




**Track Selection**:
- Track from PV
- Hit in TOF

$$\sigma^2_{m^2} = 4m^4\left(\frac{\sigma_p}{p}\right)^2 + 4E^4\left(\frac{\sigma_t}{t}\right)^2 + 4E^4\left(\frac{\sigma_L}{L}\right)^2$$

from reconstruction

$$\sigma = \sqrt{\sigma^2_{t_0} + \sigma^2_{TOF}}$$

fixed

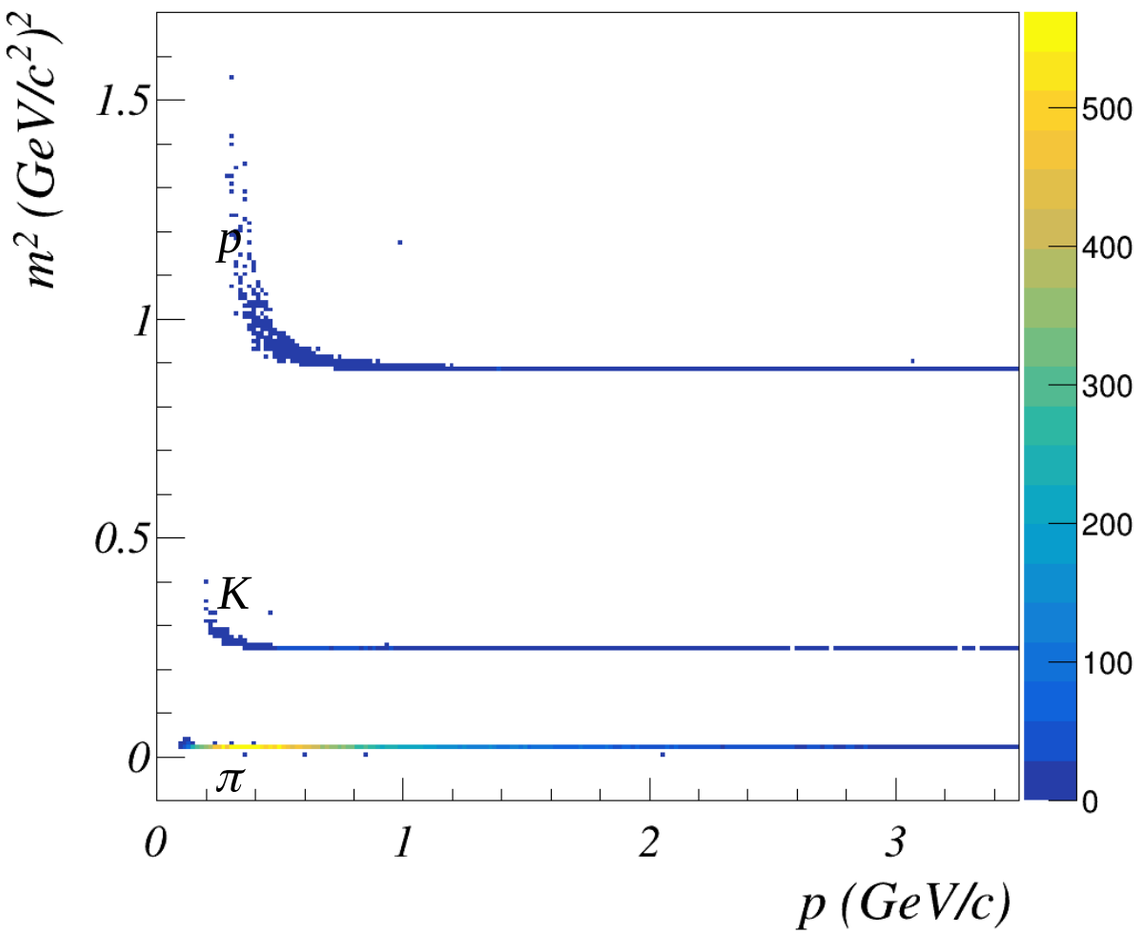
Minimum bias *pp* 27 *GeV* events were generated (SimuQslPy8.C)

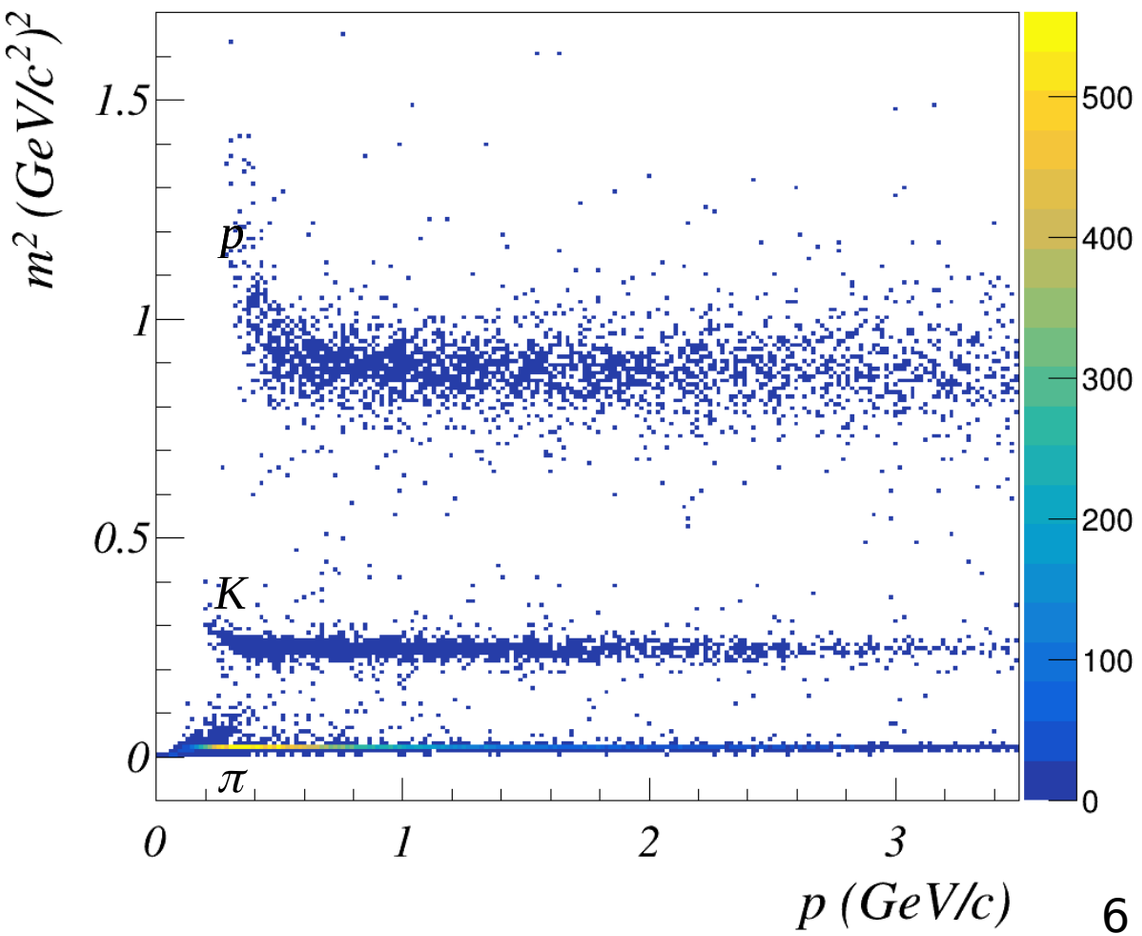
# Analysis without time smearing

$t_{TOF}$ – without smearing
$t_0$ – without smearing

$$m^2 = \frac{p_{mc}^2}{c^2}\left[\frac{t_{TOF}^2 c^2}{L^2} - 1\right]$$

$$m^2 = \frac{p_{rc}^2}{c^2}\left[\frac{t_{TOF}^2 c^2}{L^2} - 1\right]$$



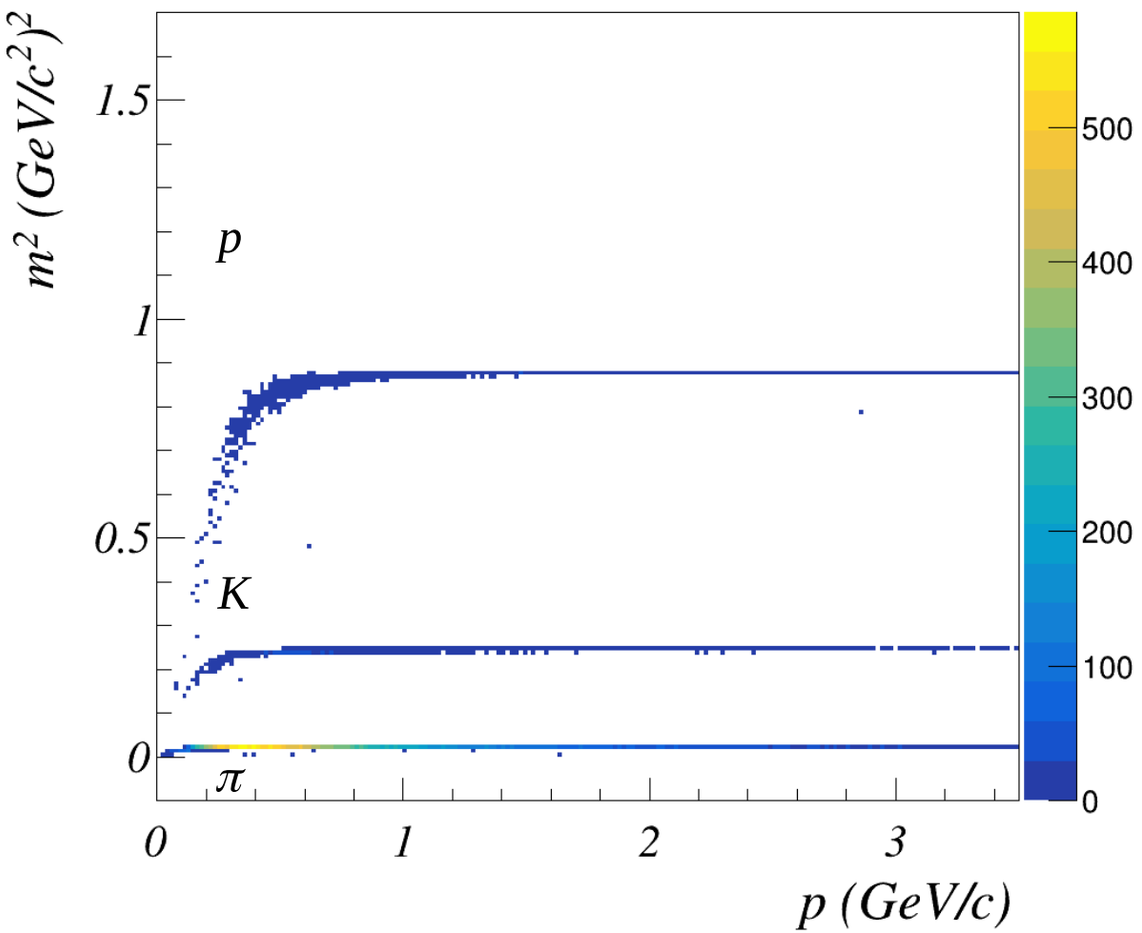



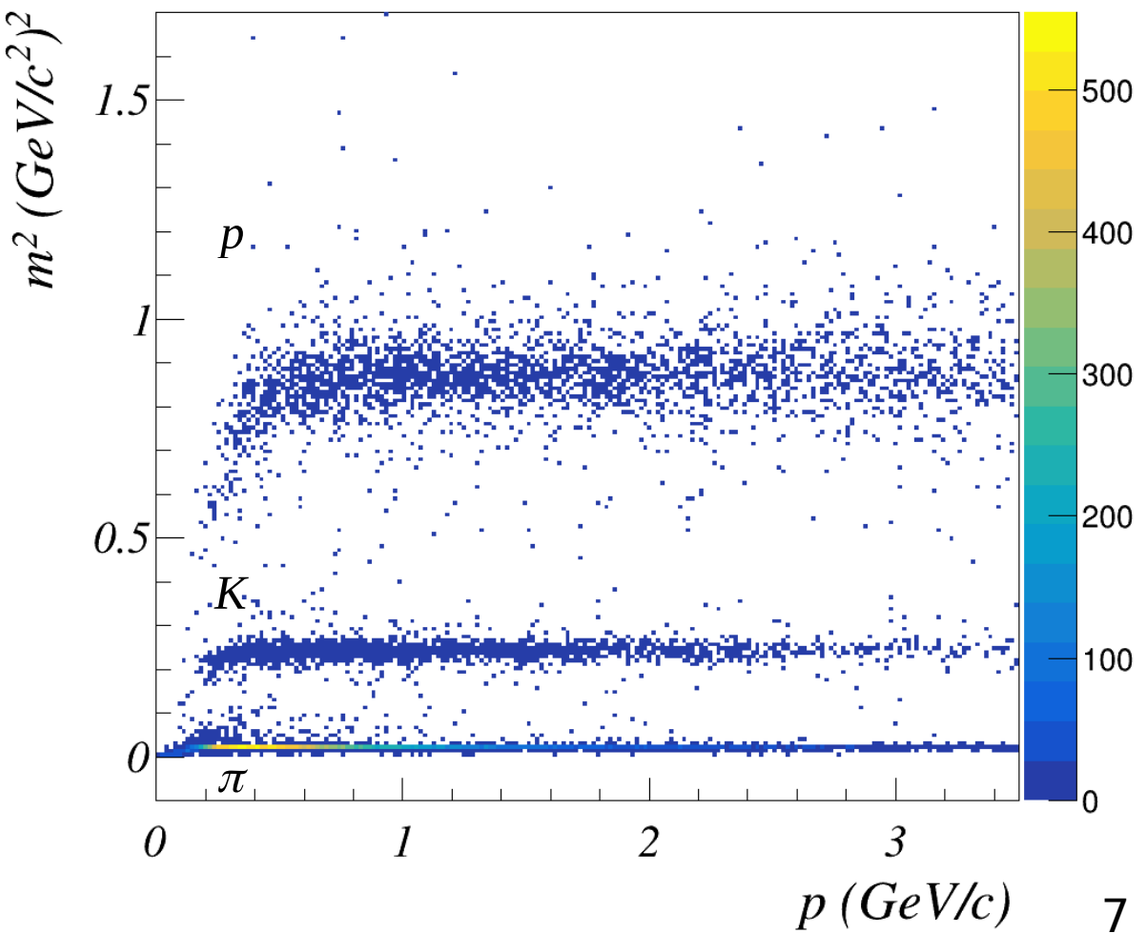
# Analysis without time smearing

$t_{TOF}$ – without smearing
$t_0$ – without smearing

$$m^2 = \frac{p^2_{mc,TOF}}{c^2}\left[\frac{t^2_{TOF}c^2}{L^2} - 1\right]$$

$$m^2 = \frac{p^2_{rc,last\ point}}{c^2}\left[\frac{t^2_{TOF}c^2}{L^2} - 1\right]$$



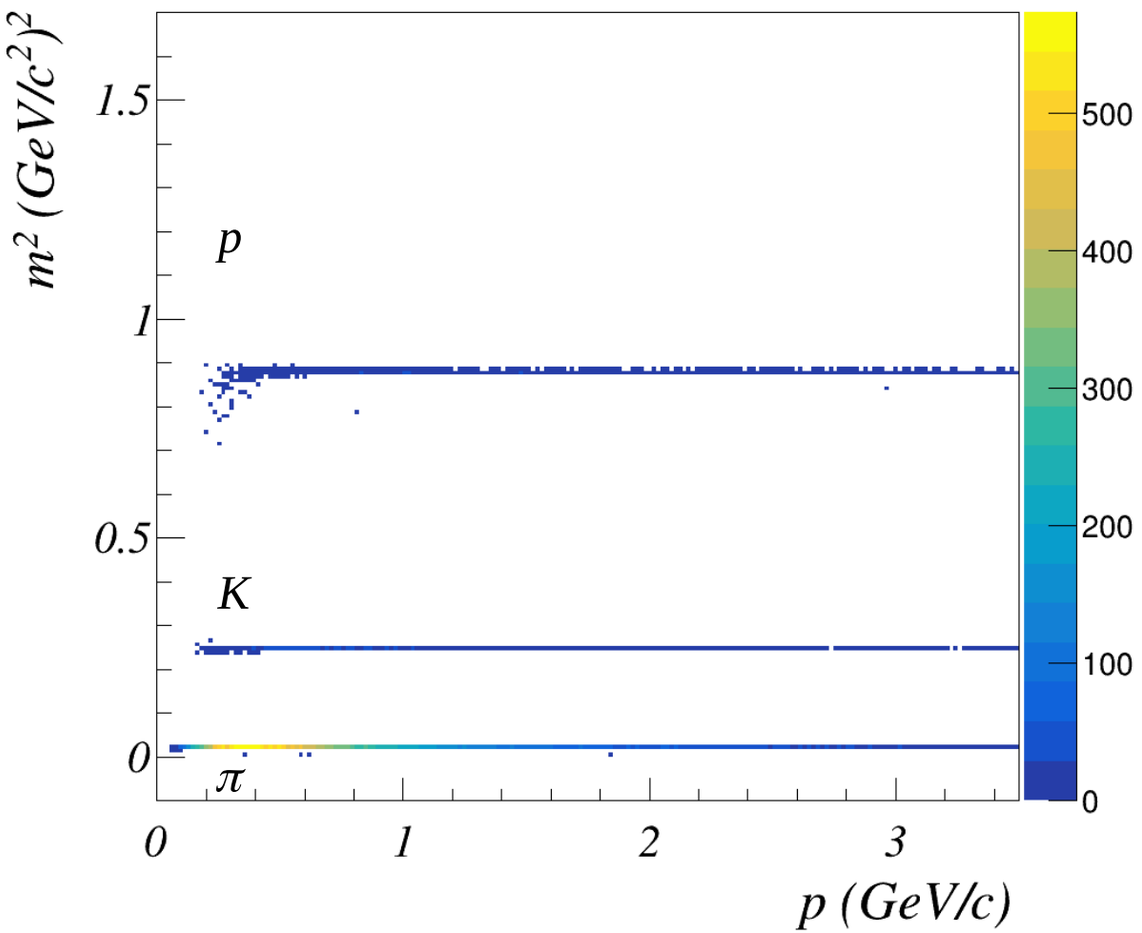



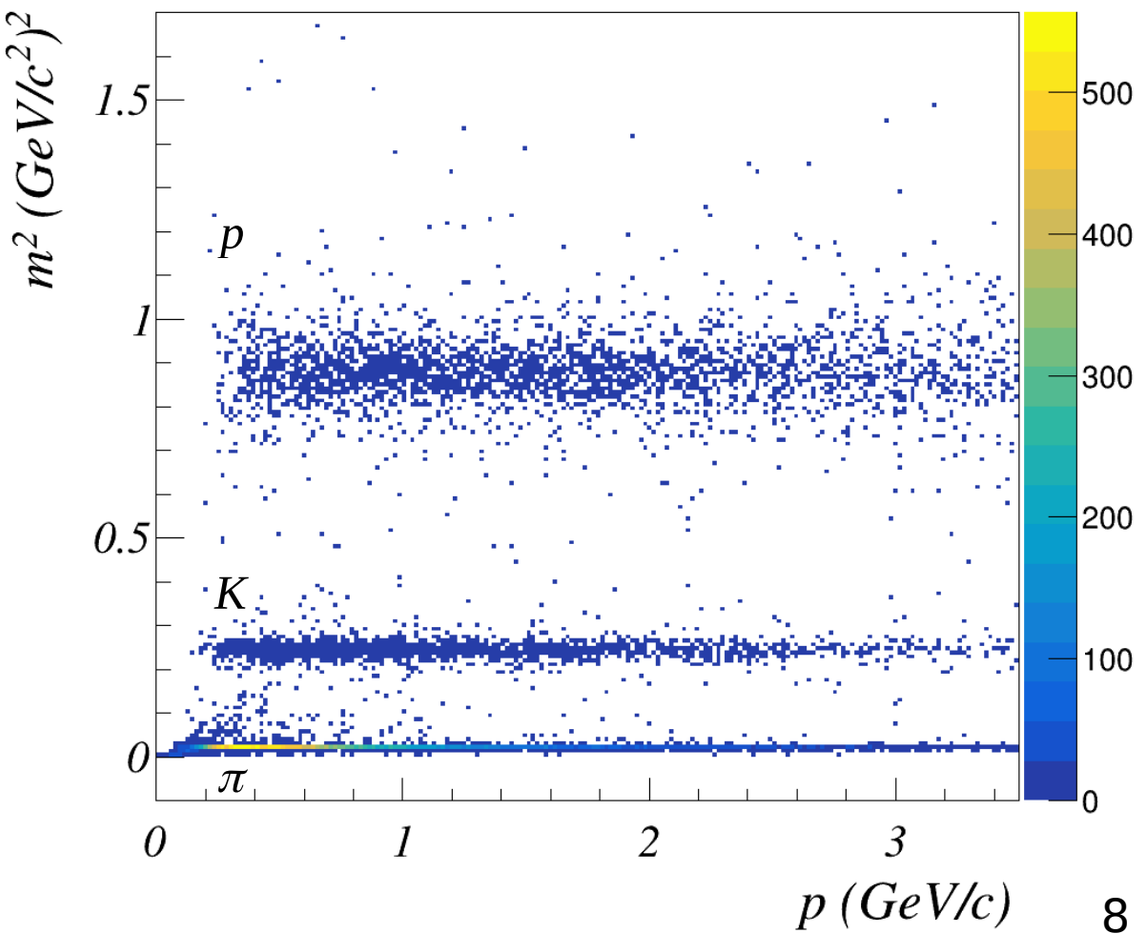
# Analysis without time smearing

$t_{TOF}$ – without smearing
$t_0$ – without smearing

$$m^2 = \frac{\left\{\frac{p_{mc,TOF} + p_{mc}}{2}\right\}^2}{c^2}\left[\frac{t_{TOF}^2 c^2}{L^2} - 1\right]$$

$$m^2 = \frac{\left\{\frac{p_{rc,last\ point} + p_{rc}}{2}\right\}^2}{c^2}\left[\frac{t_{TOF}^2 c^2}{L^2} - 1\right]$$



# Analysis with time smearing

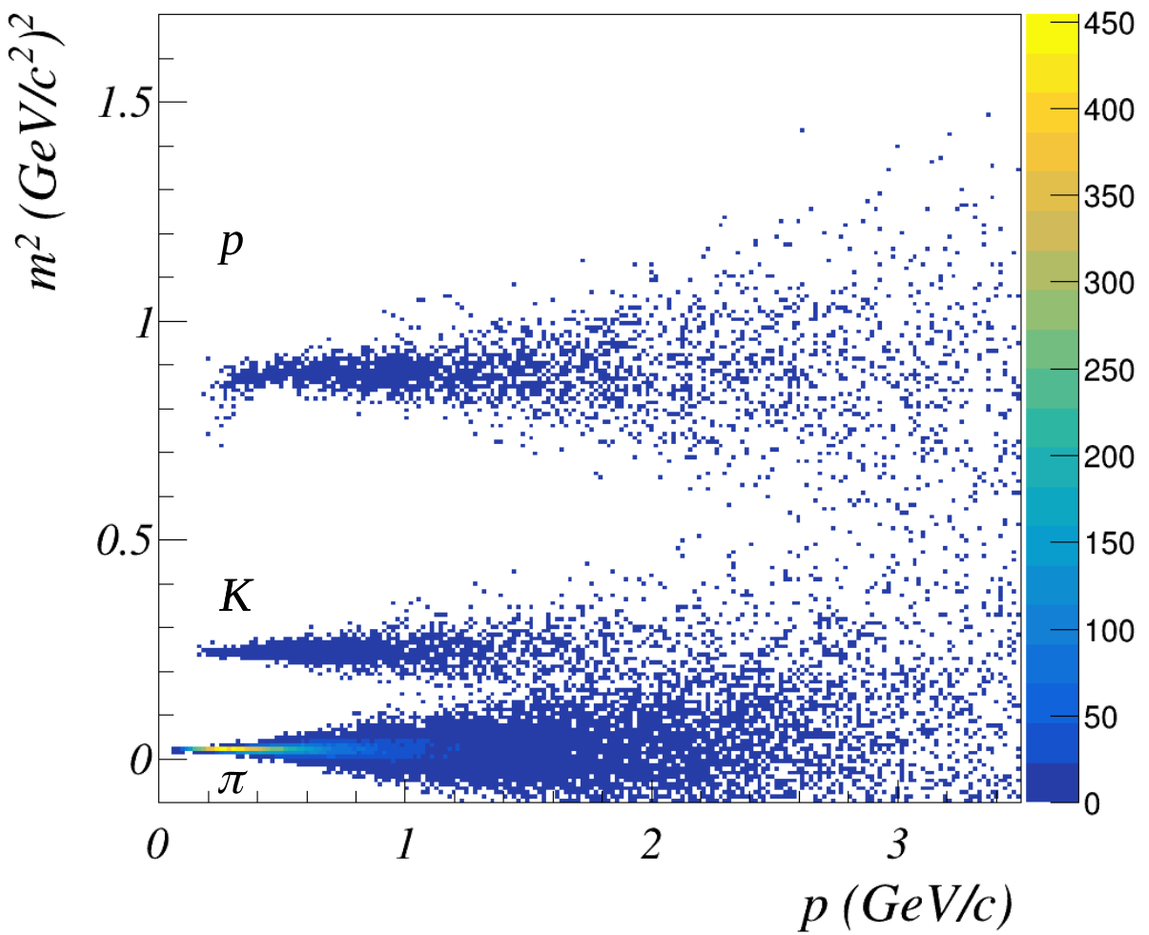
$t_0 - without\ smearing$

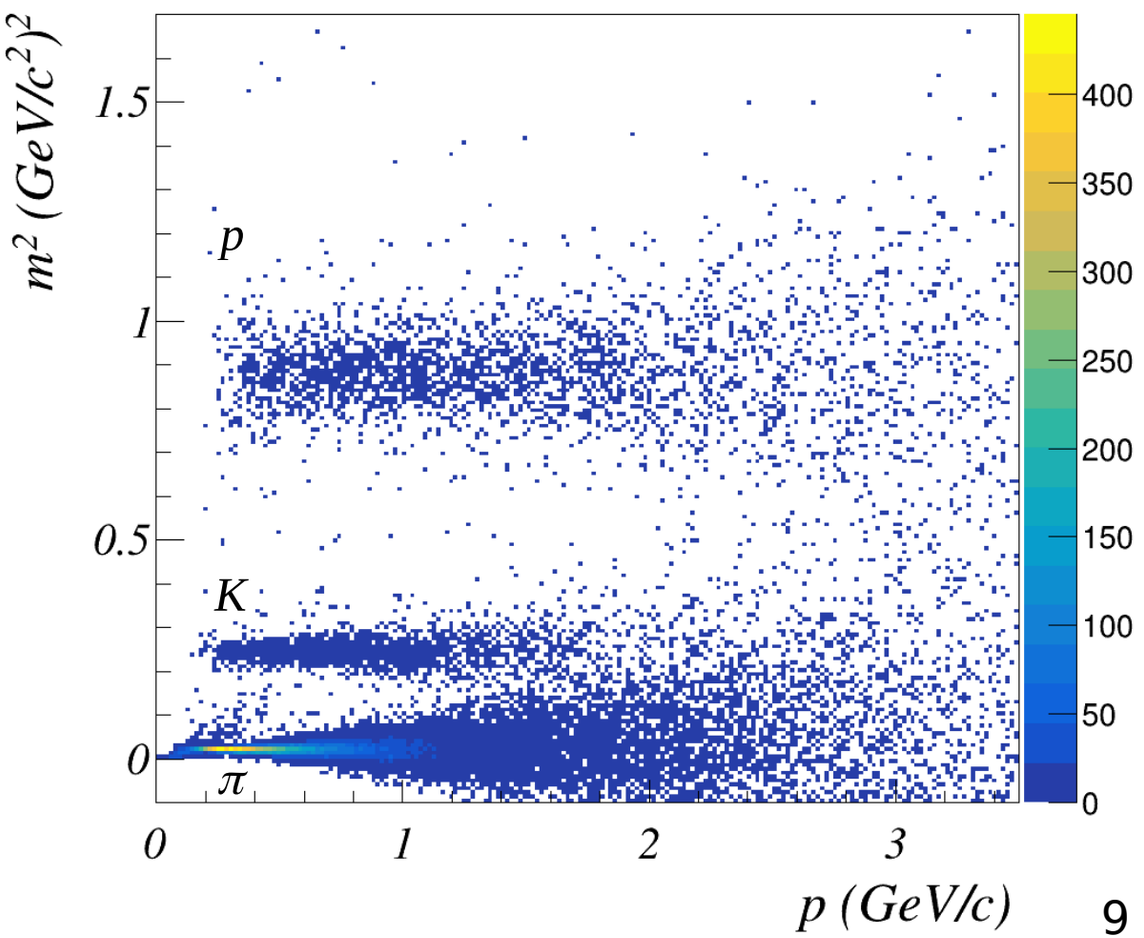
$\sigma_{TOF} = 60$

$$t = gaus\left(t_{TOF}, \sigma_{TOF}\right)$$

$$m^2 = \frac{\left\{\frac{p_{mc,TOF} + p_{mc}}{2}\right\}^2}{c^2}\left[\frac{t^2 c^2}{L^2} - 1\right]$$

$$m^2 = \frac{\left\{\frac{p_{rc,last\ point} + p_{rc}}{2}\right\}^2}{c^2}\left[\frac{t^2 c^2}{L^2} - 1\right]$$

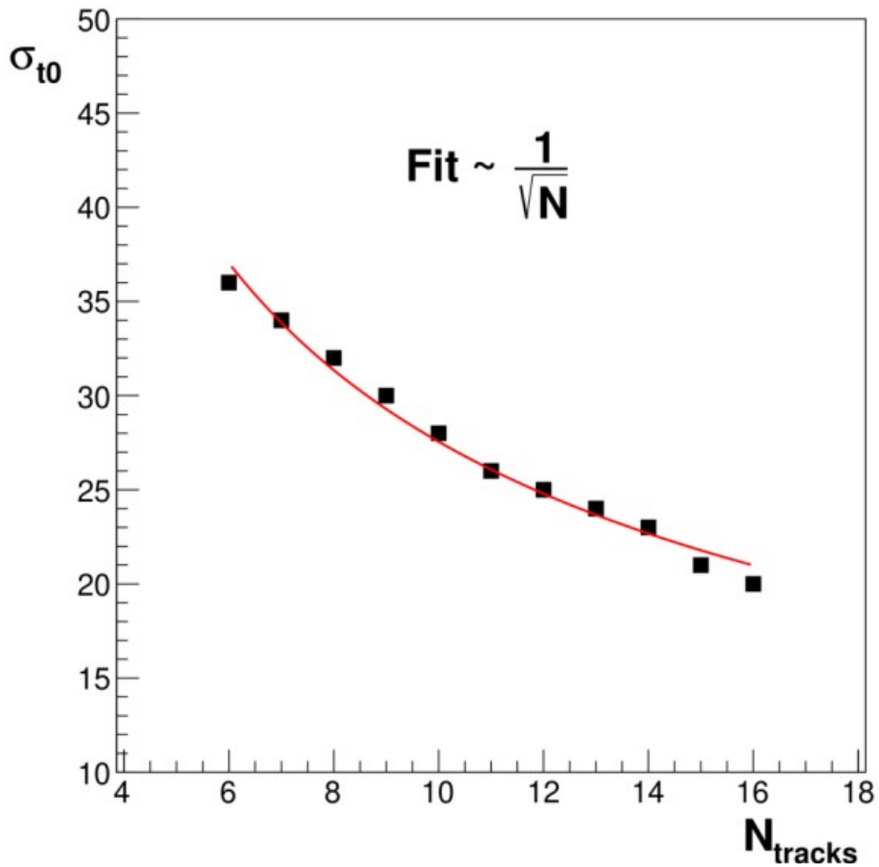


# Time uncertainty in the primary vertex

From talk Mitrofanov Evgenii (March 31 , 2021) «Status of t0 reconstruction»

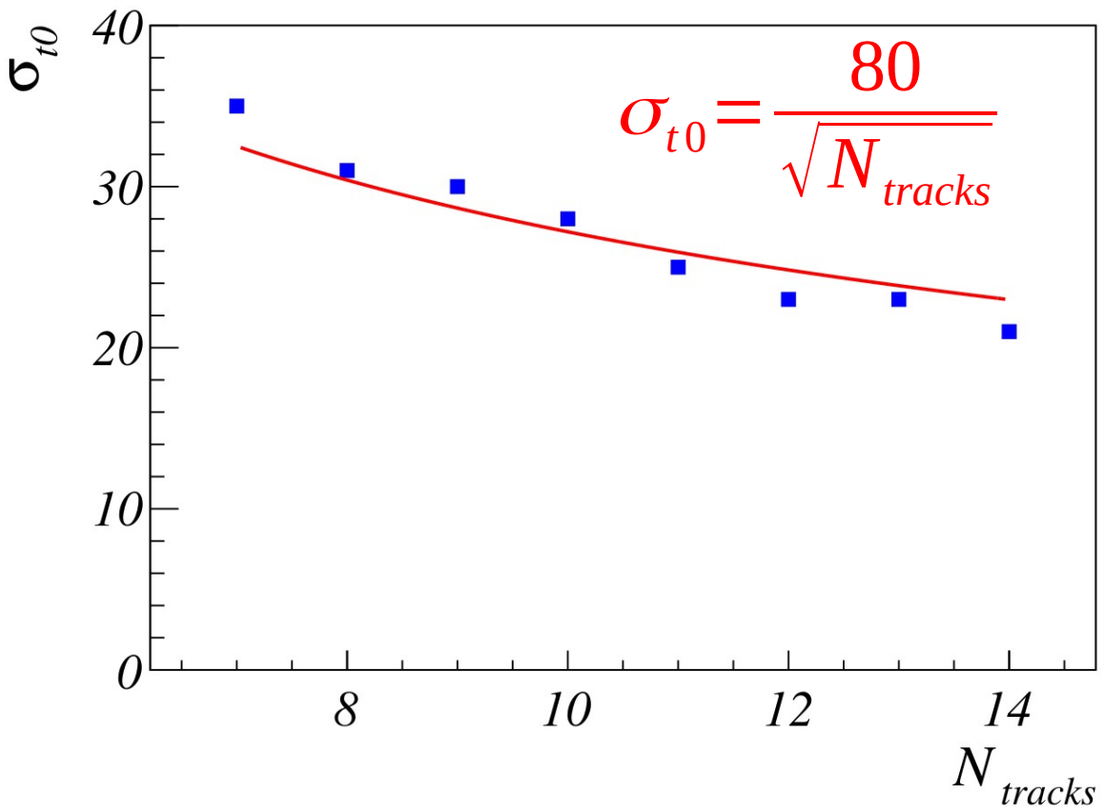
(https://indico.jinr.ru/event/2054/contributions/12244/attachments/9691/15555/Mitrofanov_31032021.pdf)

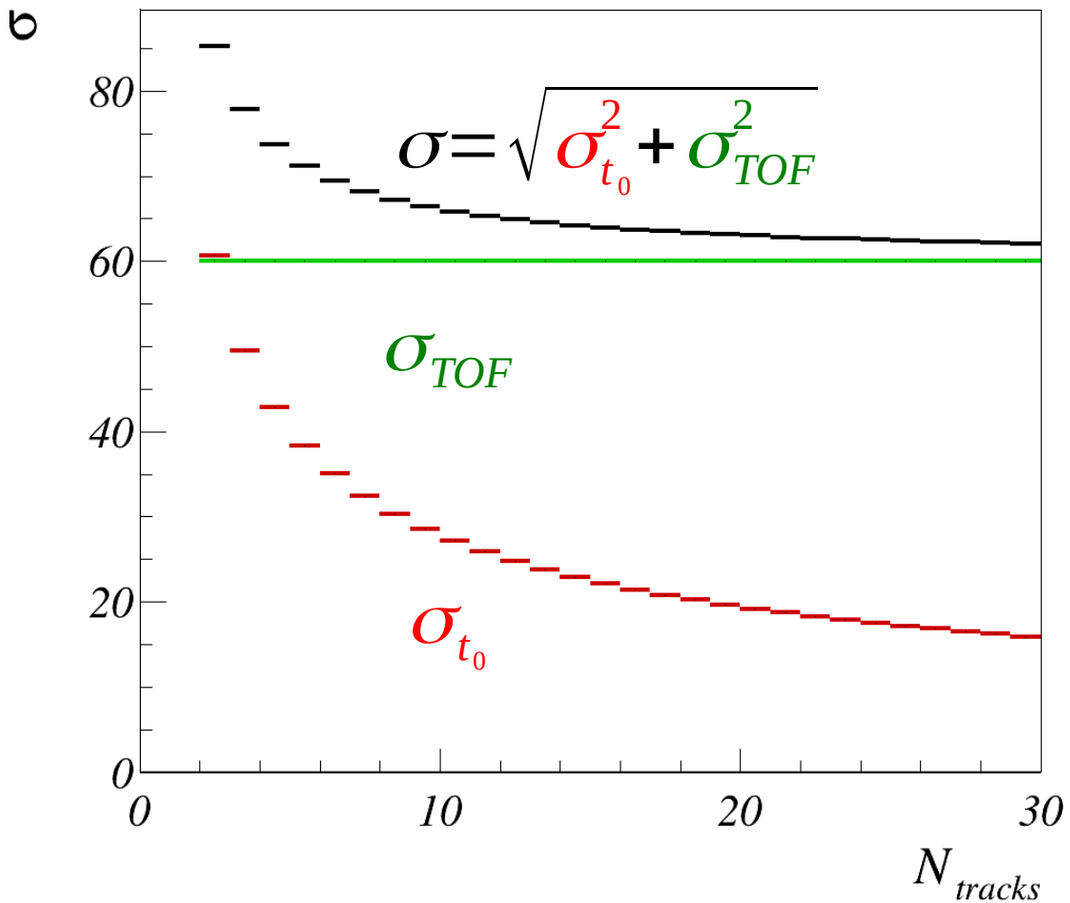



| Number of tracks | Running time, s | Accuracy of t0 reconstruction, ps |
|---|---|---|
| 14 | 25 | 21 |
| 13 | 9 | 23 |
| 12 | 2 | 23 |
| 11 | 0.7 | 25 |
| 10 | 0.22 | 28 |
| 9 | 0.07 | 30 |
| 8 | 0.04 | 31 |
| 7 | 0.04 | 35 |
| 6 | 0.04 | 70 |

More than 2 minutes needed to reconstruct t0 with 16 tracks in the event

# Time uncertainty in the primary vertex



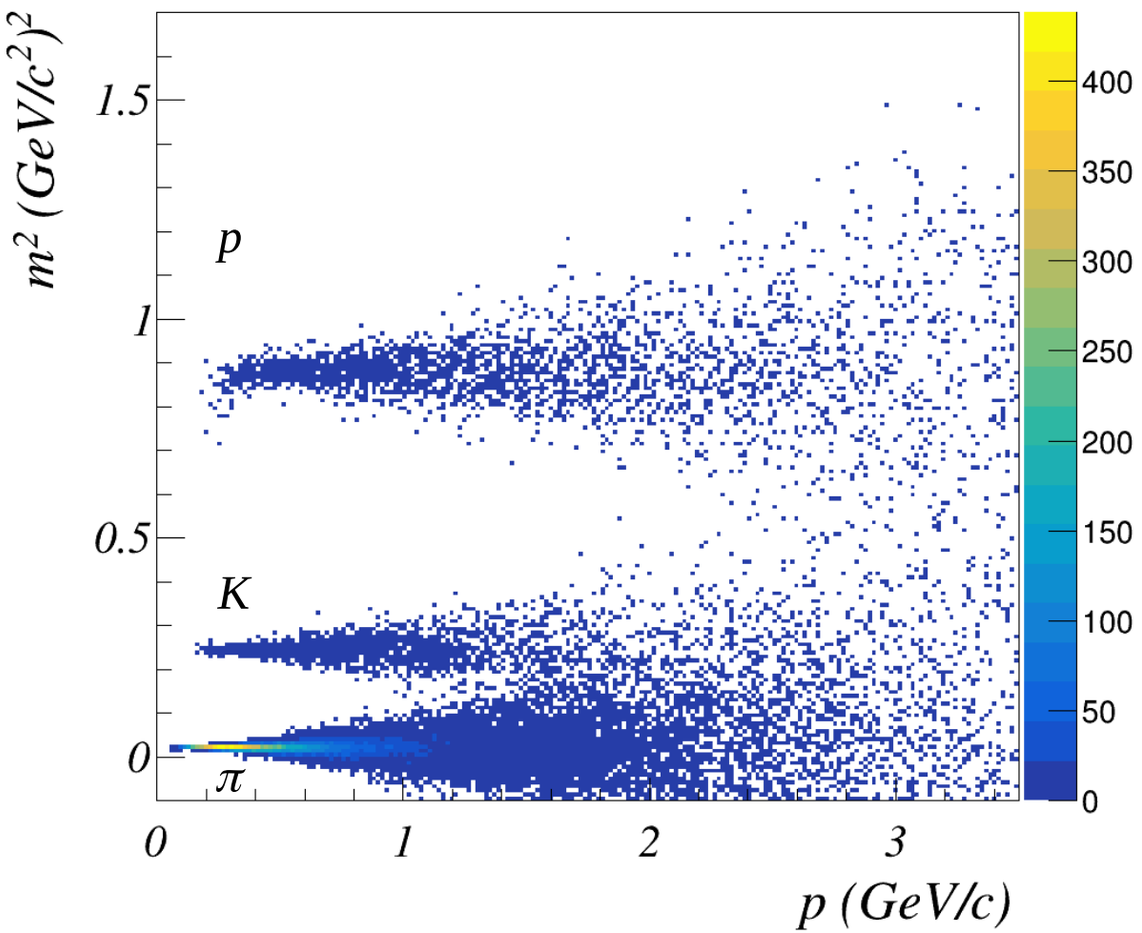
# Analysis with time smearing

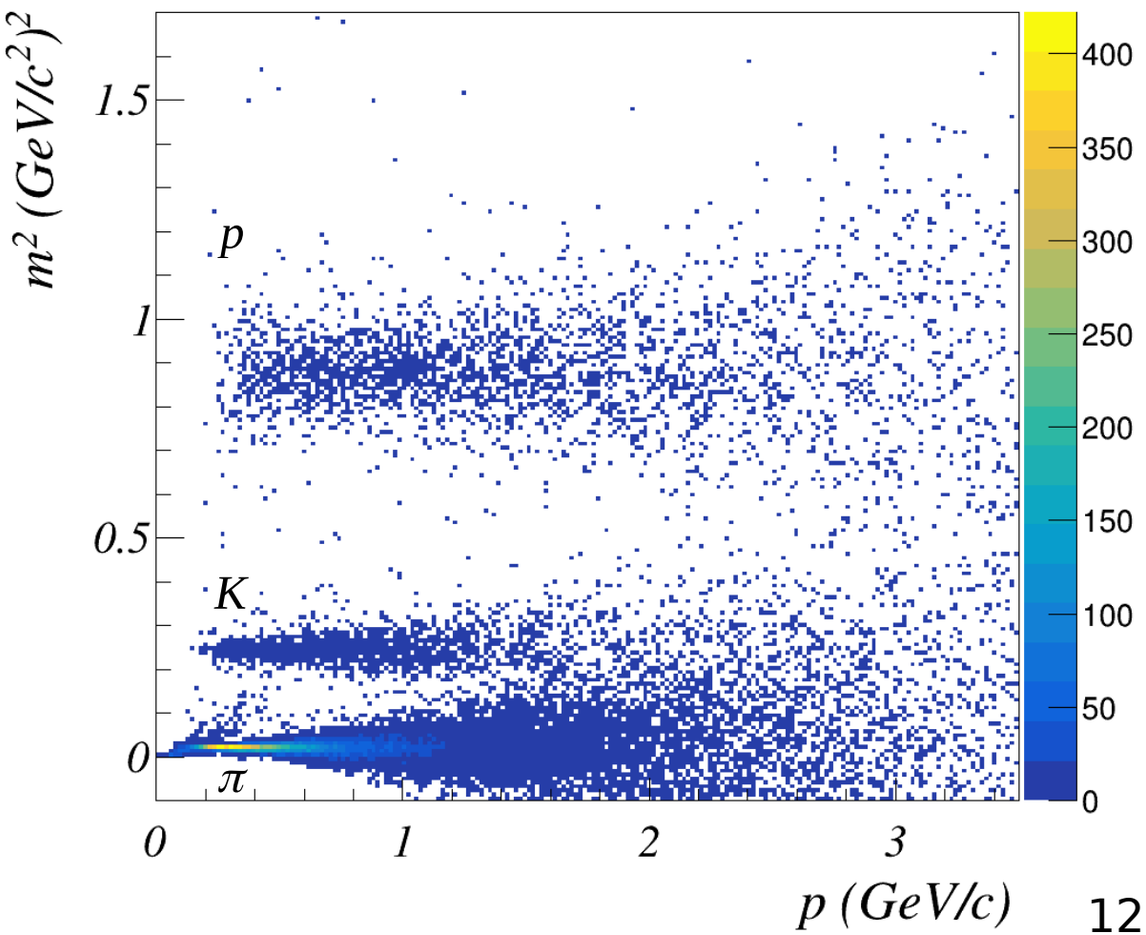
$$\sigma=\sqrt{\sigma_{t_0}^2+\sigma_{TOF}^2} \qquad \sigma_{t0}=\frac{80}{\sqrt{N_{tracks}}} \qquad \sigma_{TOF}=60$$

$$t=gaus\left(t_{TOF},\sigma\right)$$

$$m^2=\frac{\left\{\frac{p_{mc,TOF}+p_{mc}}{2}\right\}^2}{c^2}\left[\frac{t^2c^2}{L^2}-1\right]$$

$$m^2=\frac{\left\{\frac{p_{rc,last\ point}+p_{rc}}{2}\right\}^2}{c^2}\left[\frac{t^2c^2}{L^2}-1\right]$$

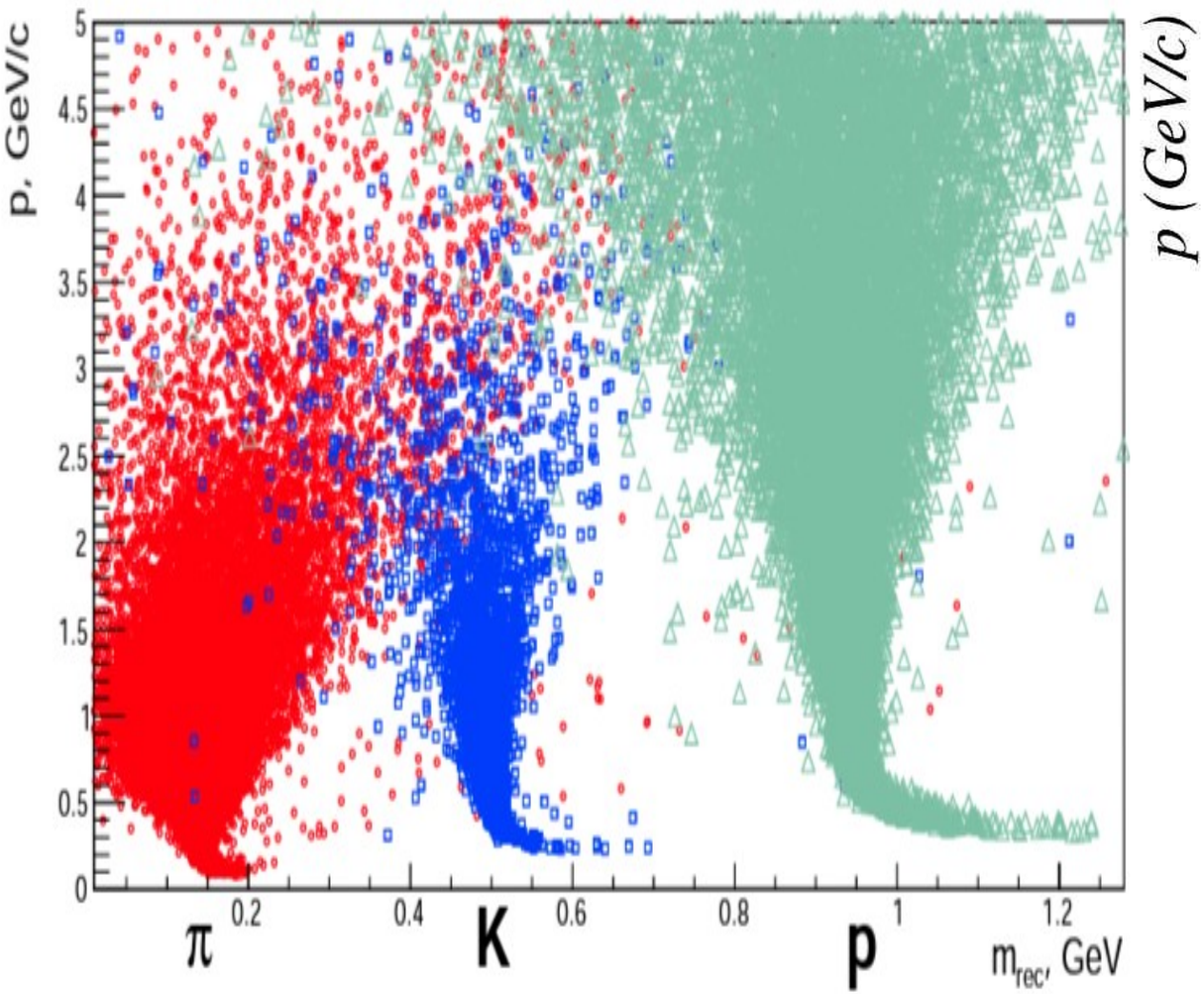


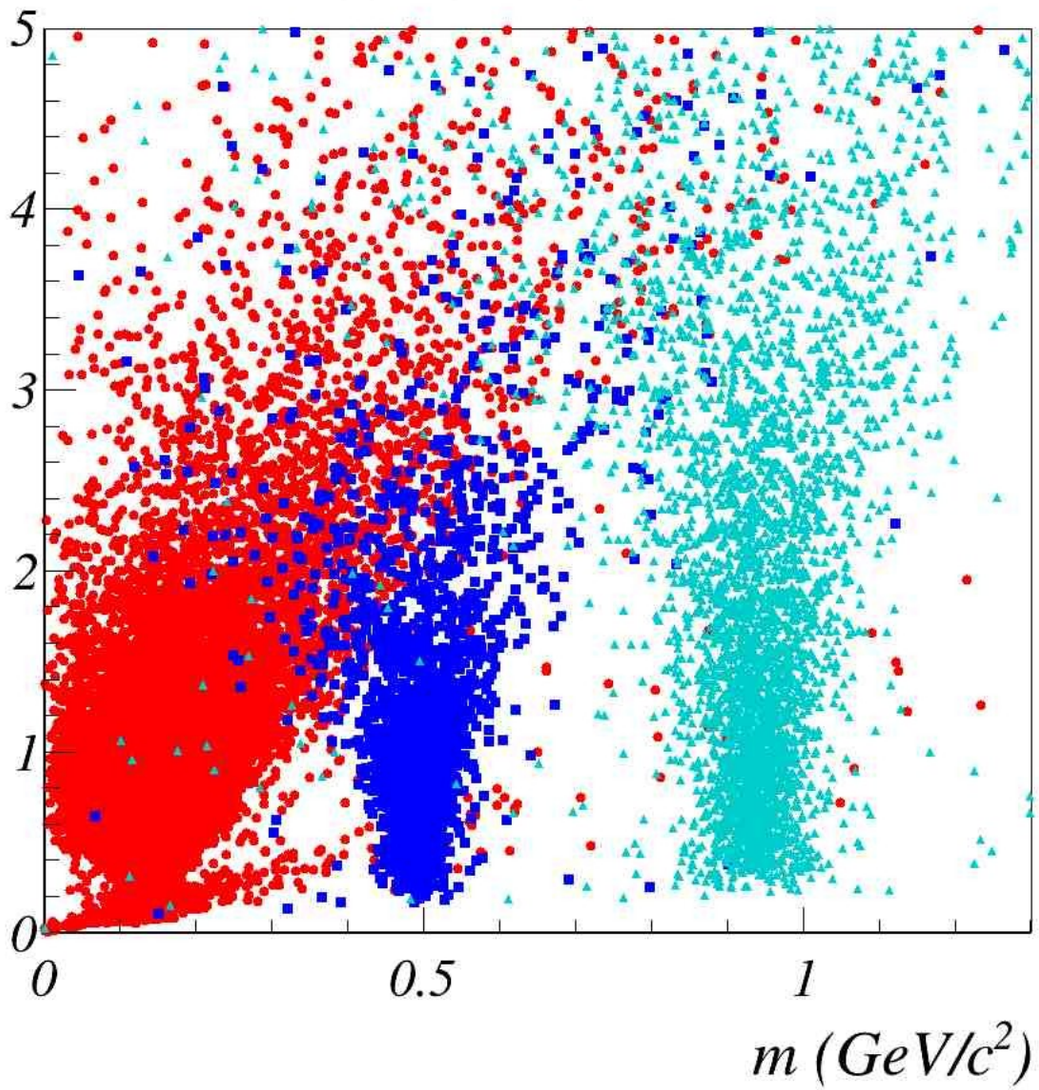
# Comparison results

Reconstructed mass vs. the particle momentum for pions, kaons, and protons

SPD CDR




current talk



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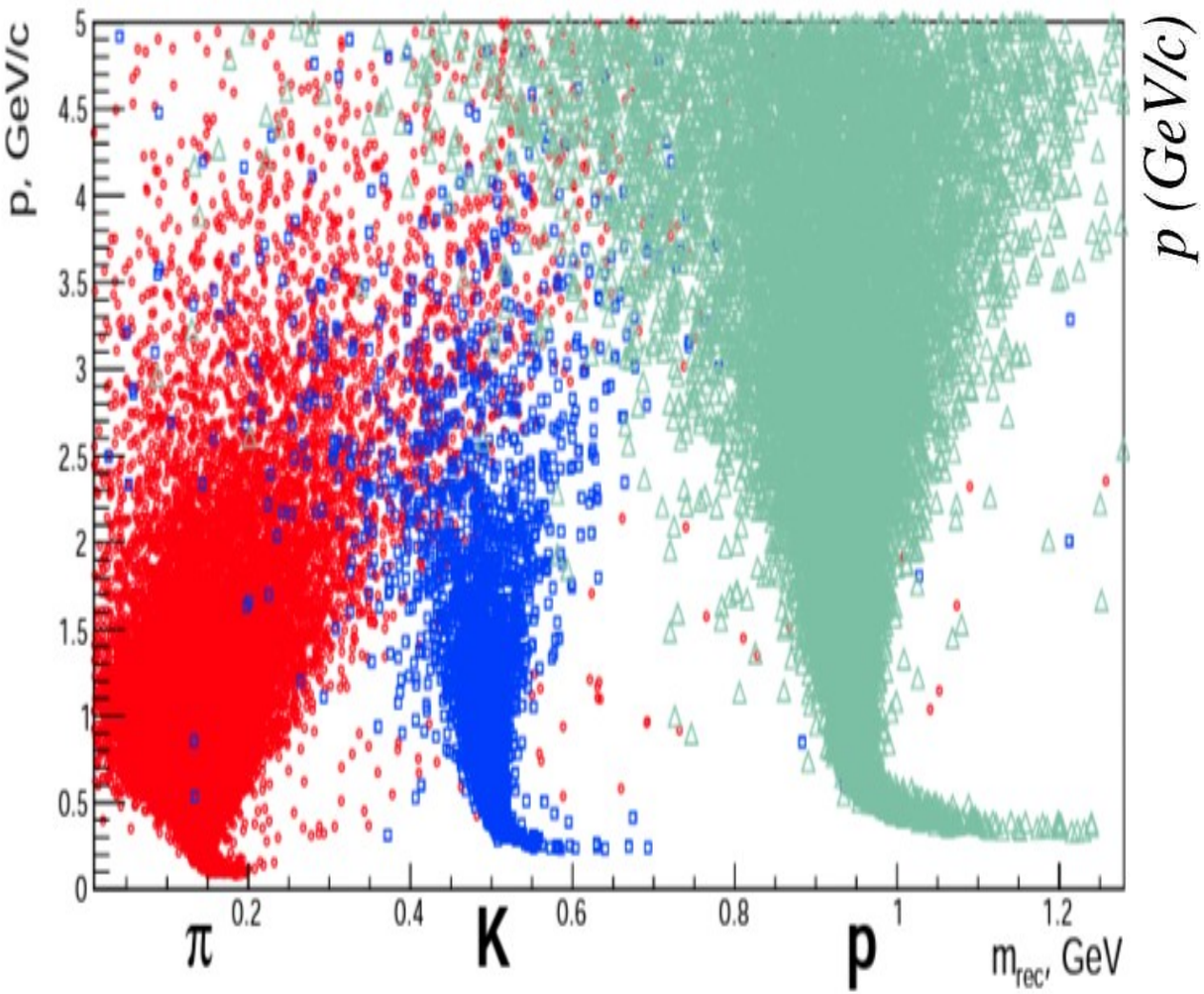


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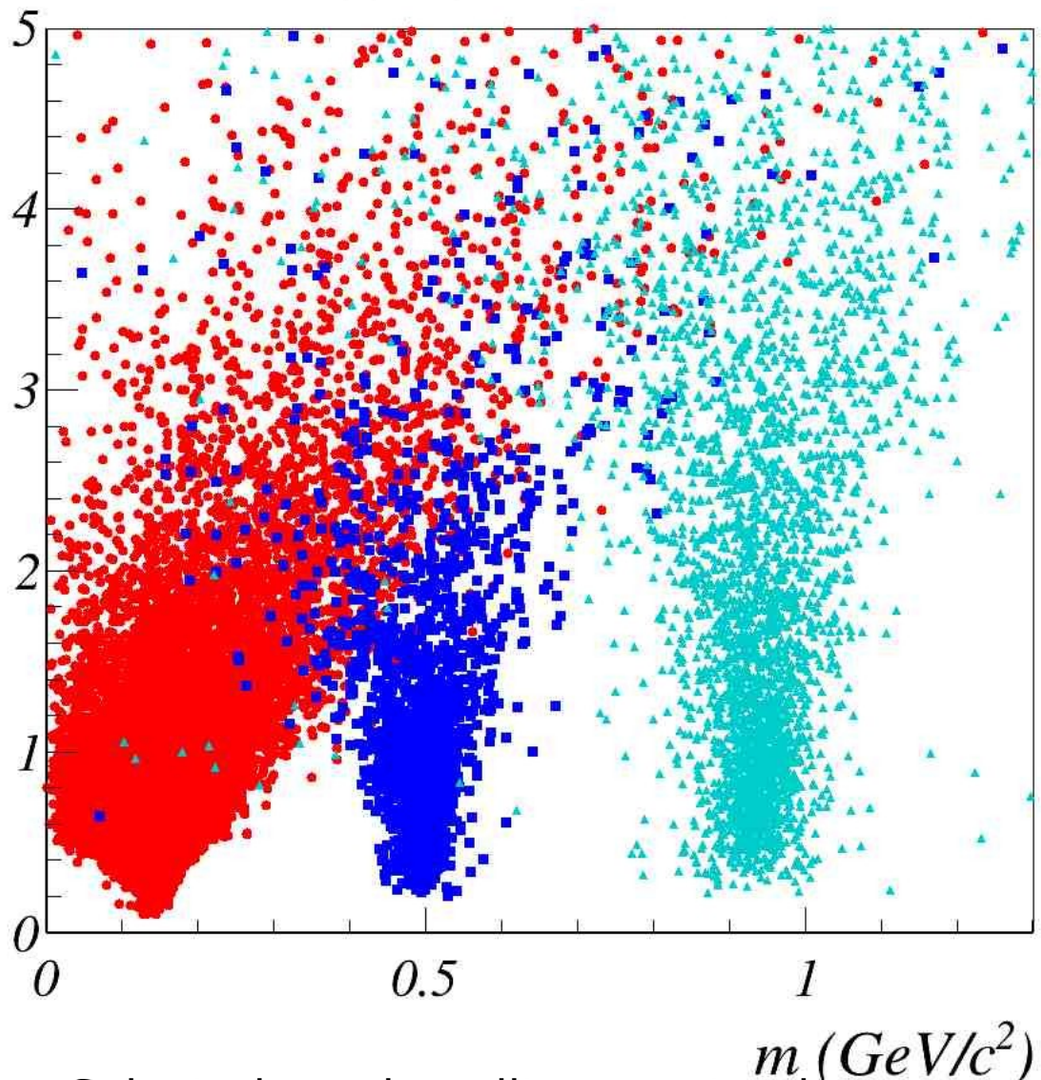


Selected good quality reco. tracks

(fitpars→GetIsGood()) [class SpdTrackFitPar]

# Conclusion

- Arthur's code works correctly;
- The distortions of mass at low momentum is the result of energy loss by the particles;
- At momentum < 1 GeV the uncertainty associated with momentum dominates;
- At momentum > 1 GeV the uncertainty associated with time.