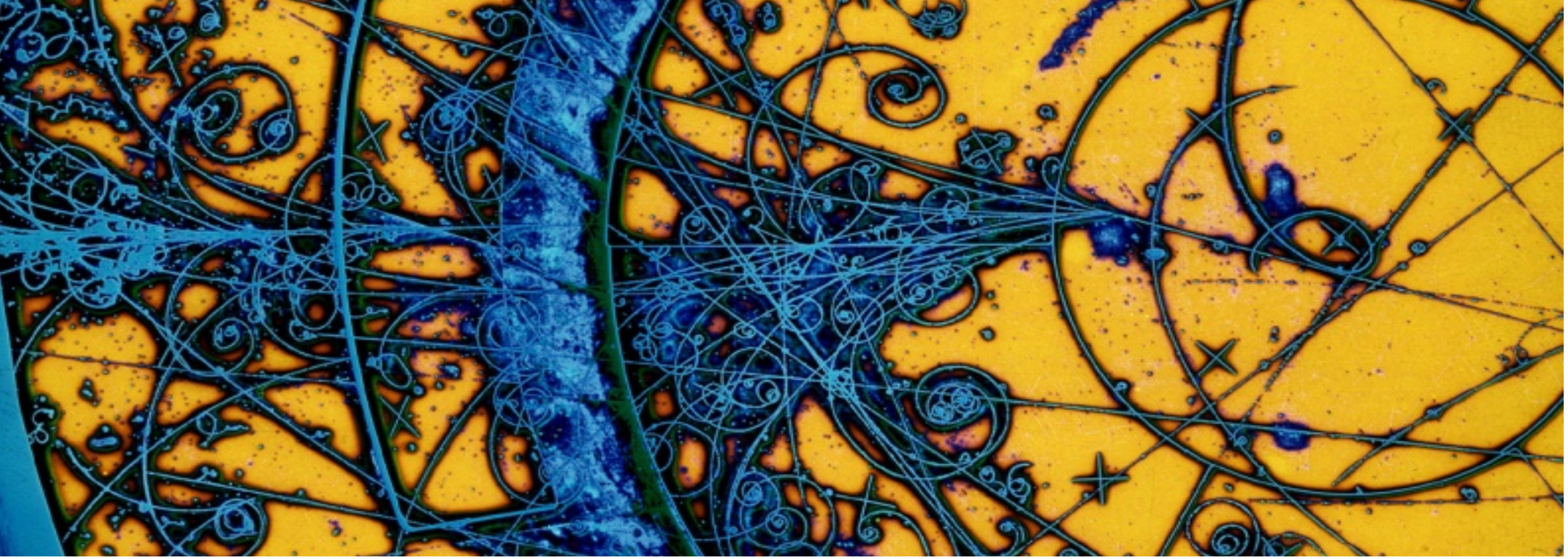

LHCspin spectrometer & ~~simulations~~ calculations

some thoughts for an IR4 setup

Marco Santimaria

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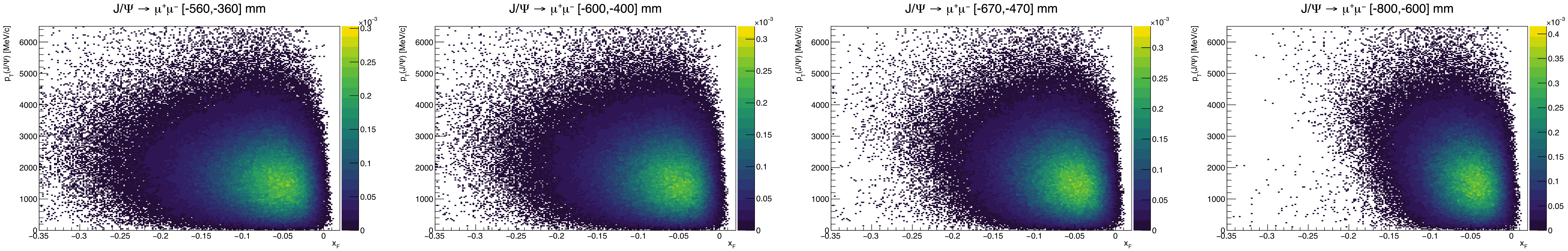
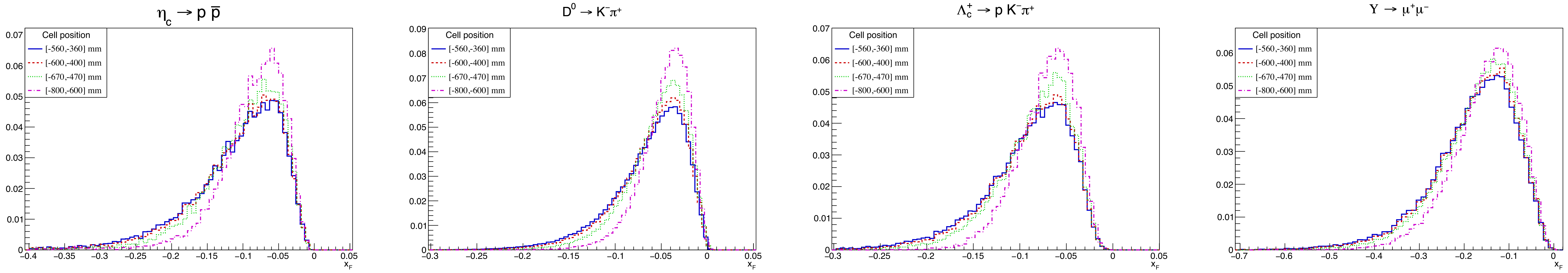
marco.santimaria@lnf.infn.it

Kinematic coverage at LHCb

- Full simulations with LHCb Upgrade I detector ($\eta = [2,5]$) were produced to investigate the kinematic coverage and efficiencies vs the distance between the cell and the vertex detector (VELO)
- The kinematic coverage depends on the cell position → p_T slightly affected, x range shrinks when moving upstream
- The goal of this WP to produce something similar for the IR4 setup, informed by the physics reach



- x_F spectra for some channels:

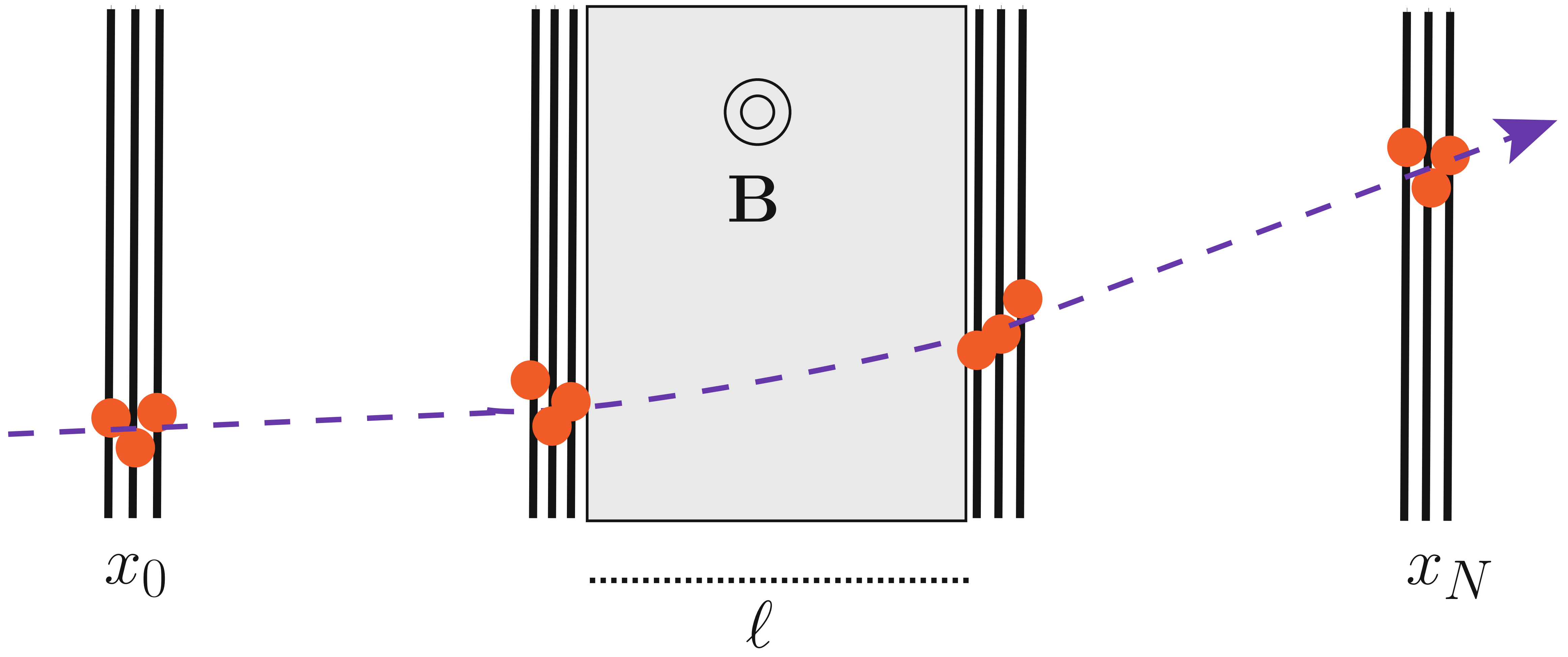


Spectrometer

- The IR4 setup will be in-between an R&D setup and an actual detector
- We need a GEANT simulation of a possible spectrometer layout, possibly using [DD4HEP] geometry description
- Ahead of that, here I just make simple considerations from formulas

- Momentum resolution: Gluckstern formula for equally spaced trackers in B
- For the configuration on the right side it can be shown that:

$$\frac{\delta p}{p} = \frac{8\sigma}{\sqrt{N+1}} \frac{1}{0.3z \cdot Bl \cdot L} p$$



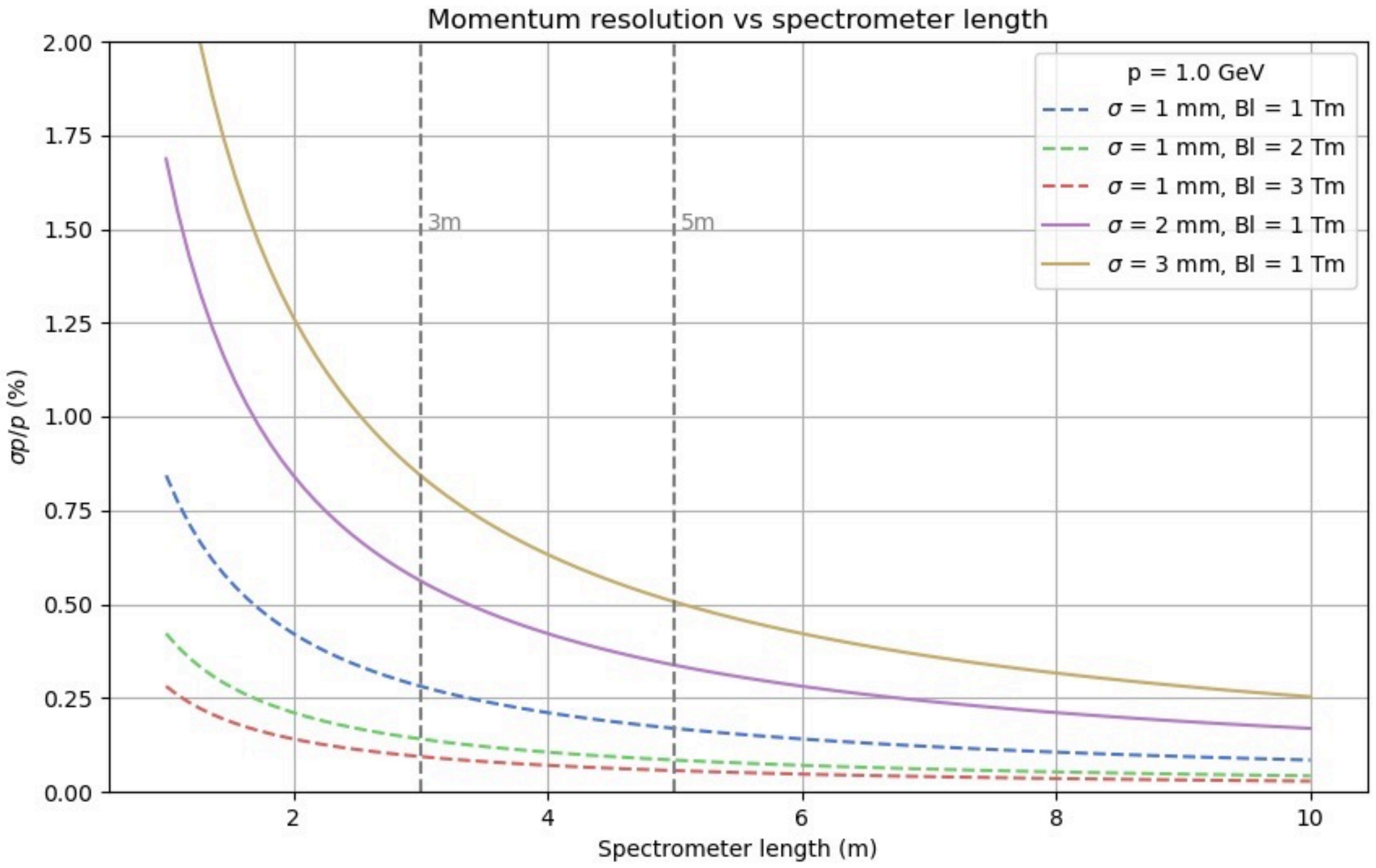
[L. Bianchini 2018]

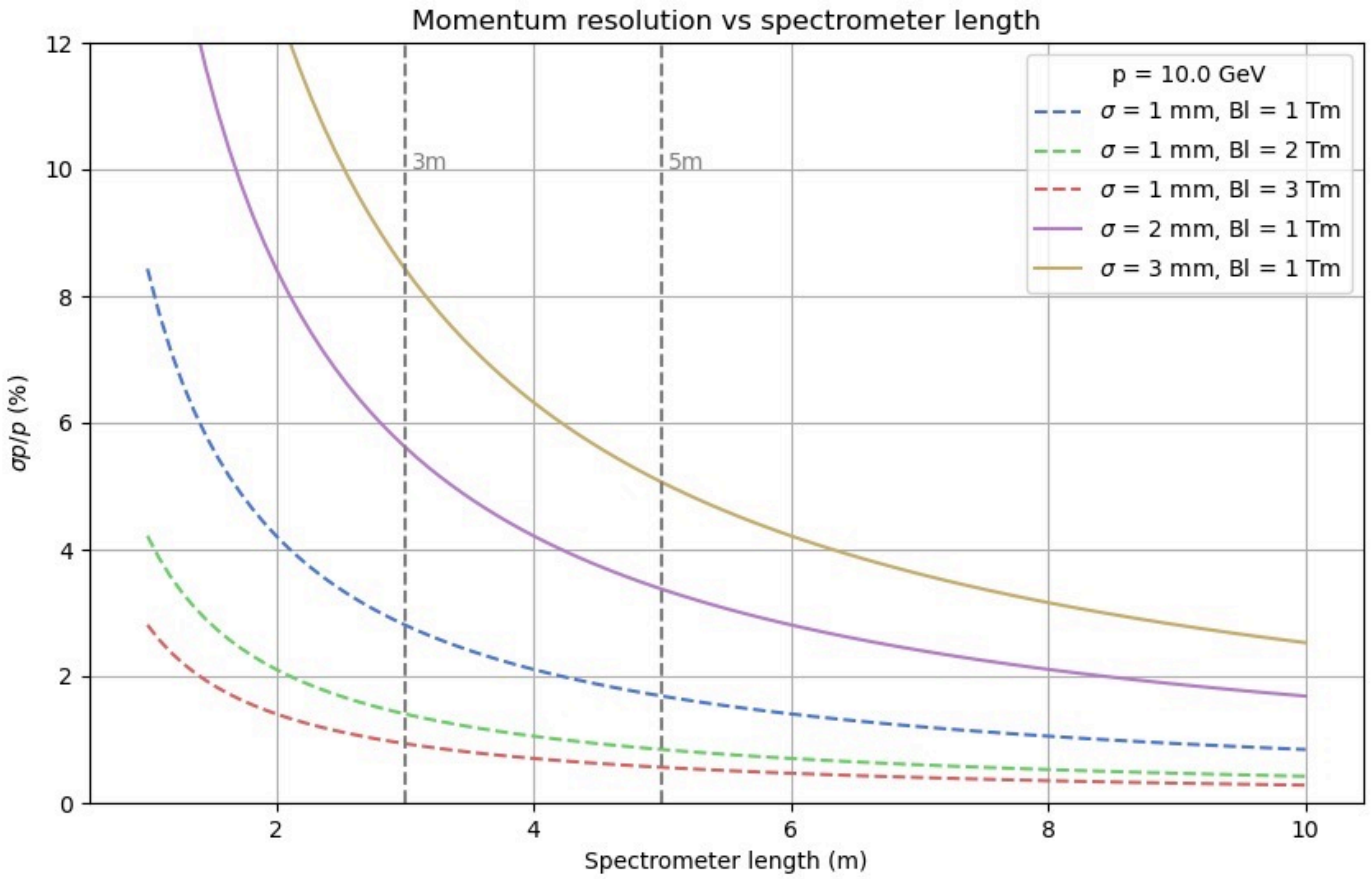
- Assuming:
  - Sagitta error $\delta s \approx \sigma$
  - $N \gtrsim 10$ hit measurements with resolution σ
  - Small bending angle (e.g. a few degrees)
  - No MS contribution. (or can be assumed to be equal to the spatial resolution)

$$\frac{\delta p}{p}\Big|_{MS} = \frac{0.0136}{0.3B\beta}\sqrt{\frac{1}{LX_0}}$$

Momentum resolution vs lever arm

- The lever arm will be driven by the available space
- Showing three easily achievable hit resolutions: σ = 1,2,3 mm (*)
- with reasonable bending powers: Bl = 1,2,3 Tm
- and N = 10 hit measurements





→ can achieve < 1 % resolution within a few meters for momenta up to a few GeV

(*) the single hit resolution of the prototype sciFi modules installed at IR4 is around $150\ \mu$m

Mass resolution

- An interesting performance figure for physics is the dimuon invariant mass resolution around $m = 3$ GeV
- If p > GeV and with small opening angle, as shown on the right, then:

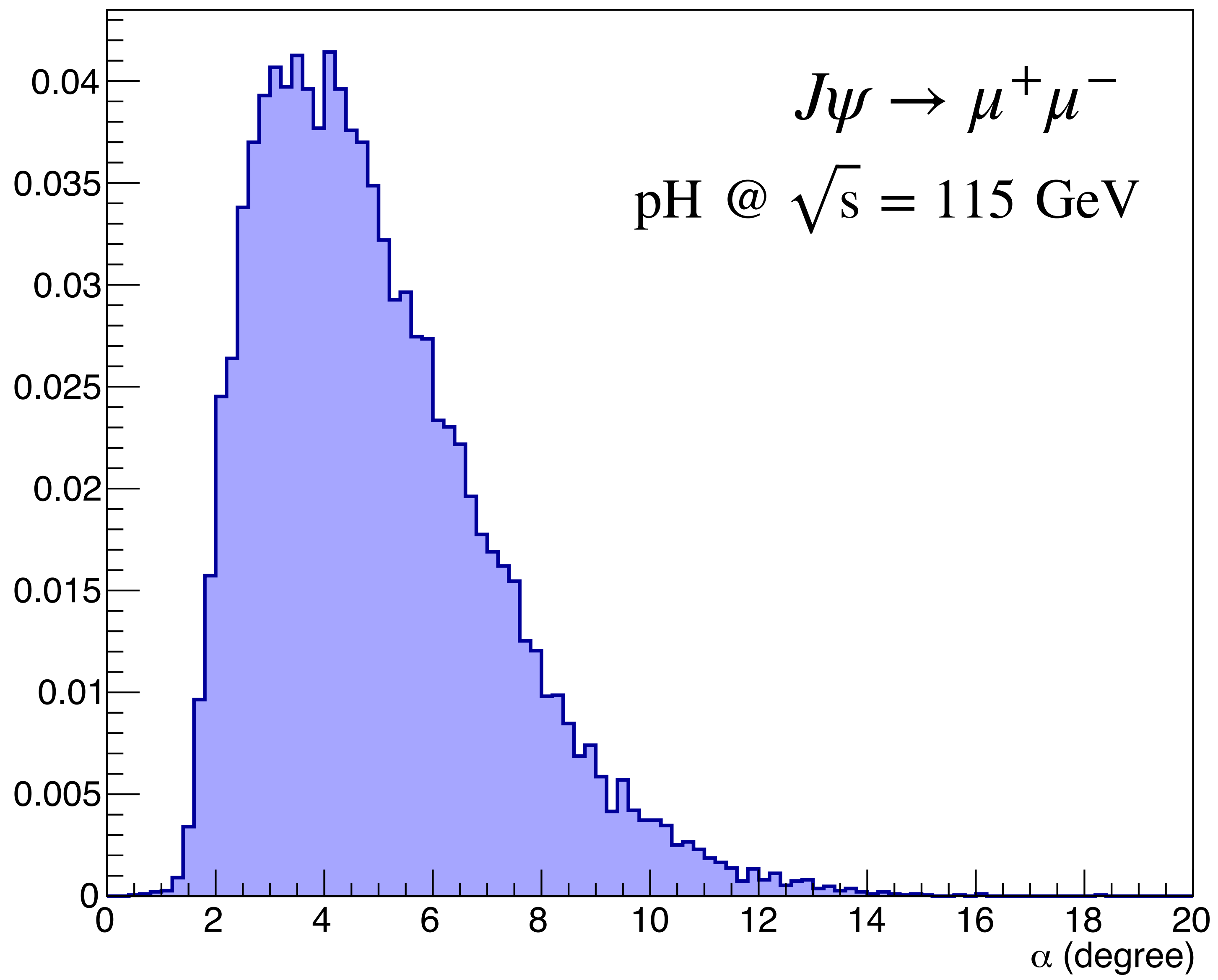
$$m \approx 2p\sin(\alpha/2)$$

$$\left(\frac{\delta m}{m}\right)^2 = \left(\frac{\delta p}{p}\right)^2 + \left(\frac{\delta\alpha}{2\tan\alpha/2}\right)^2 \approx \left(\frac{\delta p}{p}\right)^2 + \left(\frac{\delta\alpha}{\alpha}\right)^2$$

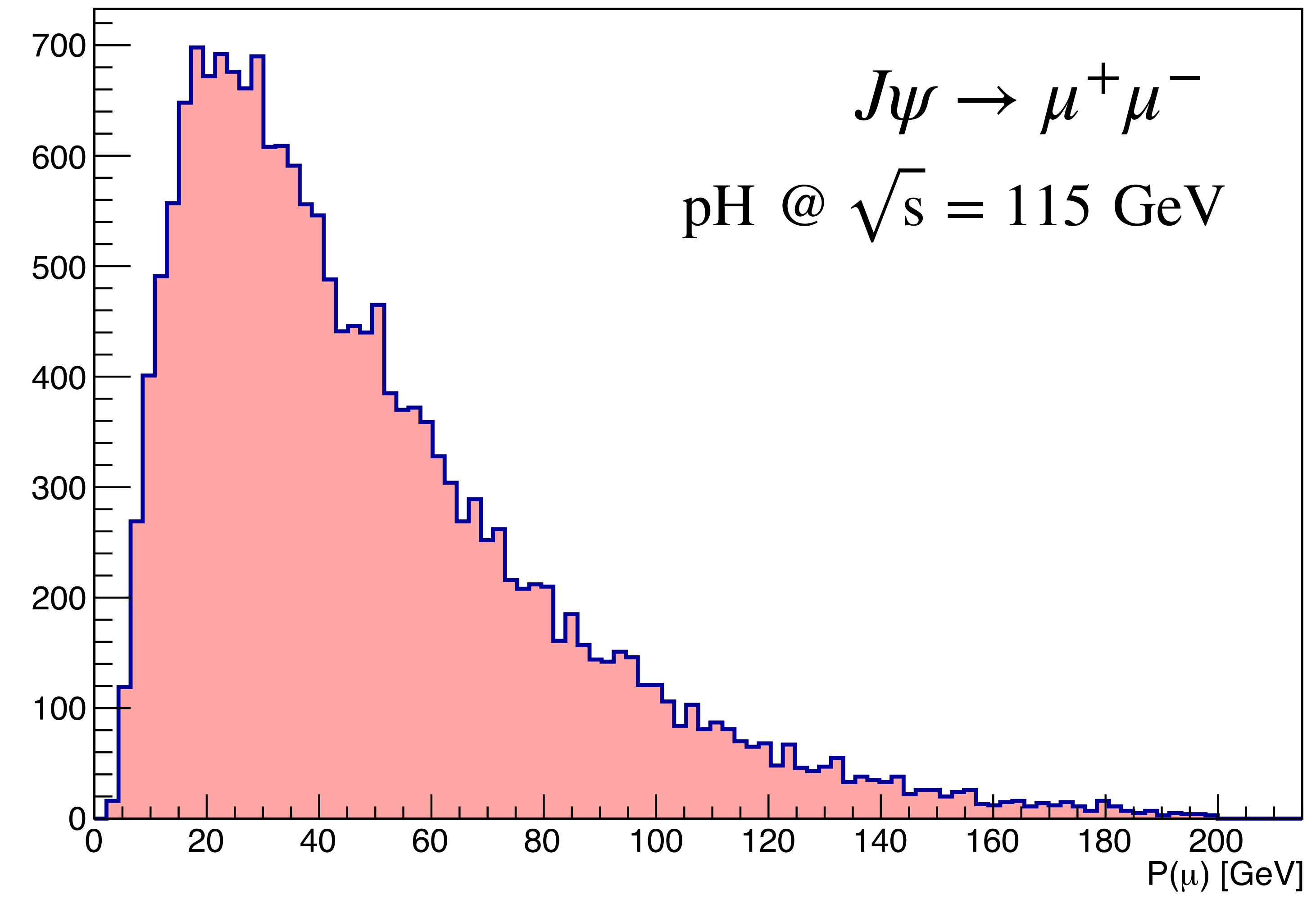
- Assuming B and detector alignment error are negligible then in the above we have ~ similar contributions, which means a mass resolution of ~ $\sqrt{2}$ X the p resolution

→ if we achieve $\delta p/p = 1\,\%$ that makes $\delta m \approx 40$ MeV at the J/ψ mass (compared to ~ 13 MeV at LHCb)

opening angle



momentum

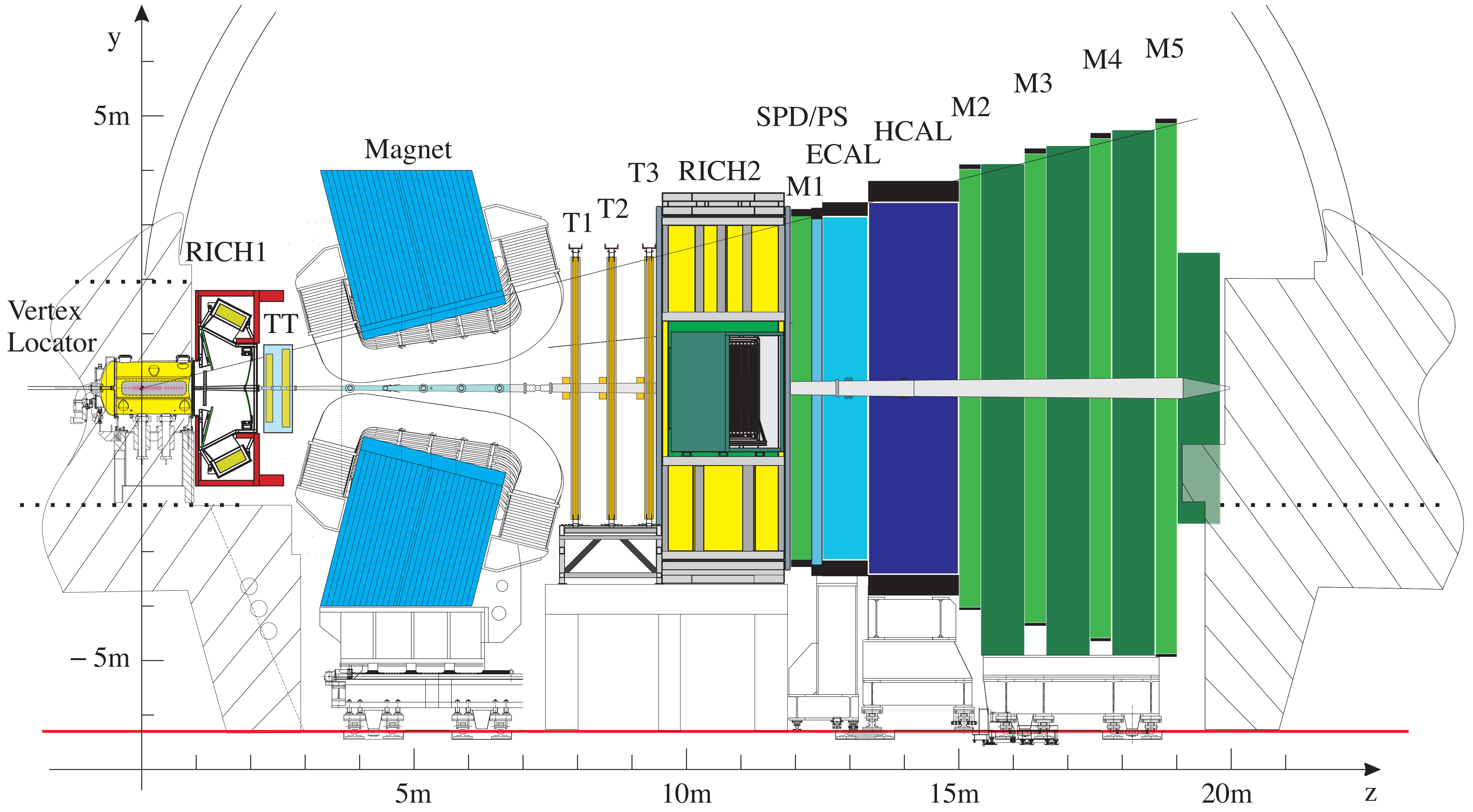


Muon identification

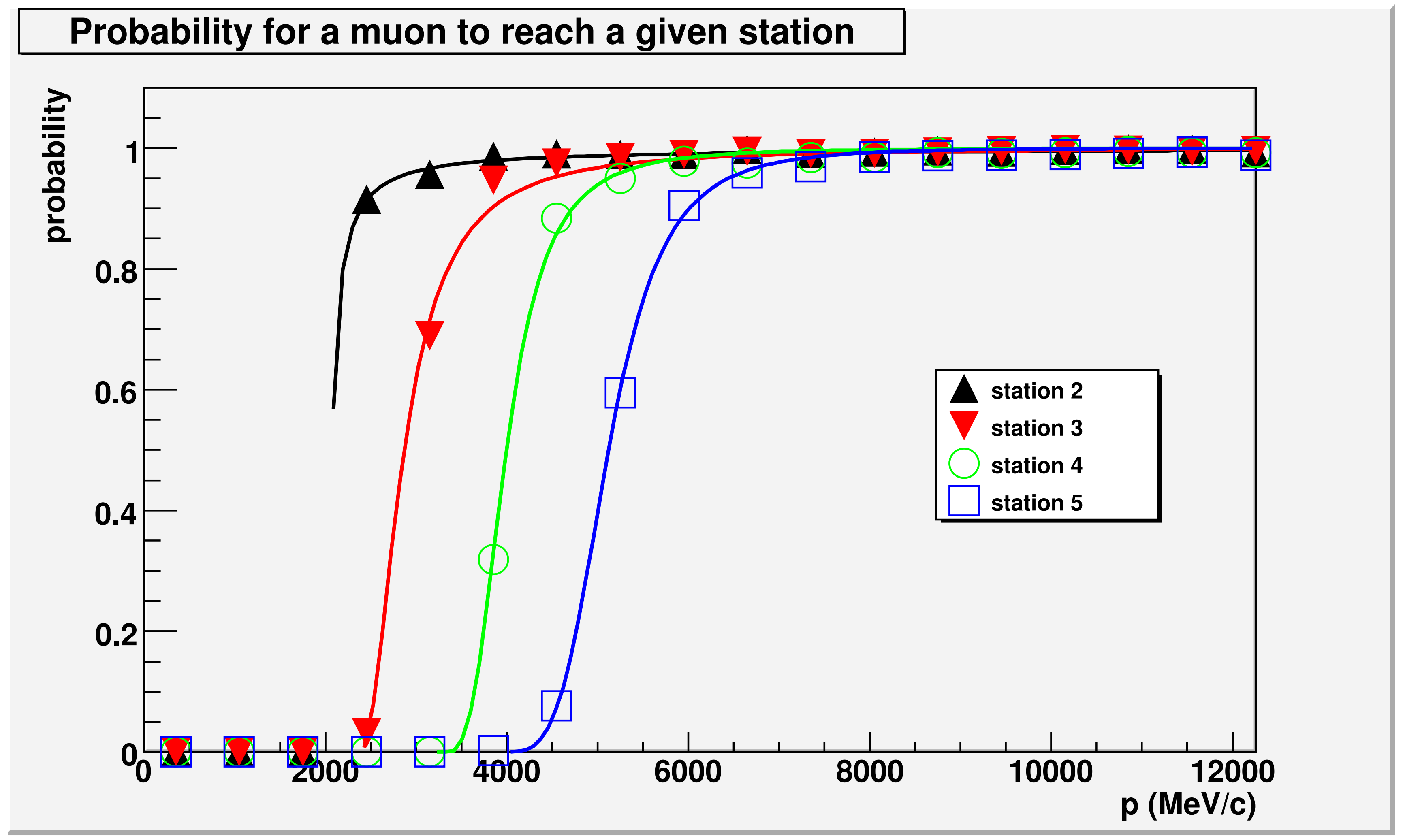
- MuonID can be done with some layers of gas chambers and iron walls. e.g. from M1 removal (2018) at LHCb:
  - GEMs with pad size 1 x 2.5 cm
  - MWPCs with pad size 2 x 5 cm

    → might be reused?

    → an occasion to test muRwells planned for LHCb U2?



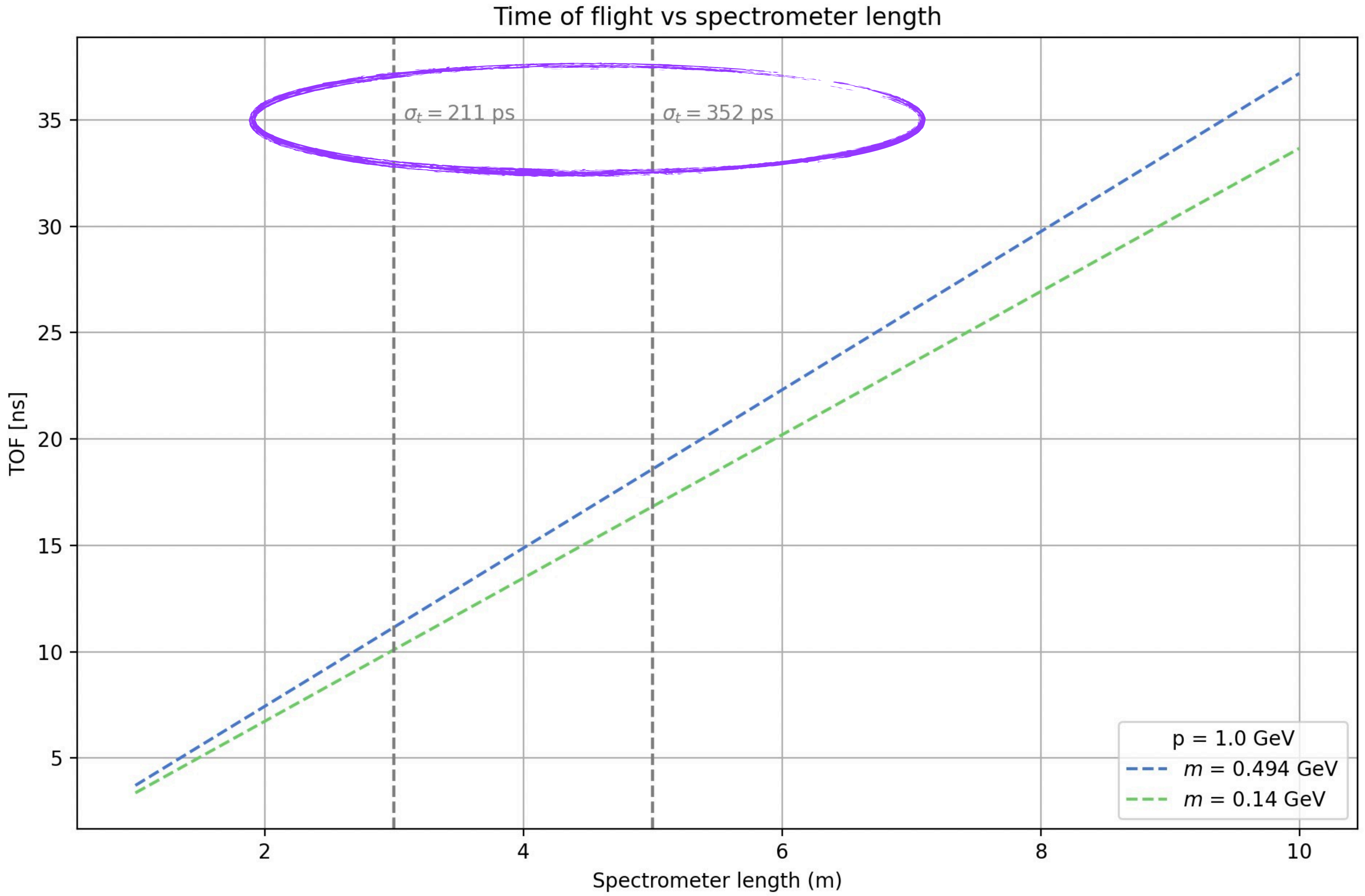
- Can think of 3-5 layers of gas chambers w iron walls to filter muons
- Right plot: 80 cm of iron btw each station
- Can tune absorbers length and number of stations to achieve a desired muonID-misID working point
- This depends on the momentum i.e. on the physics channels

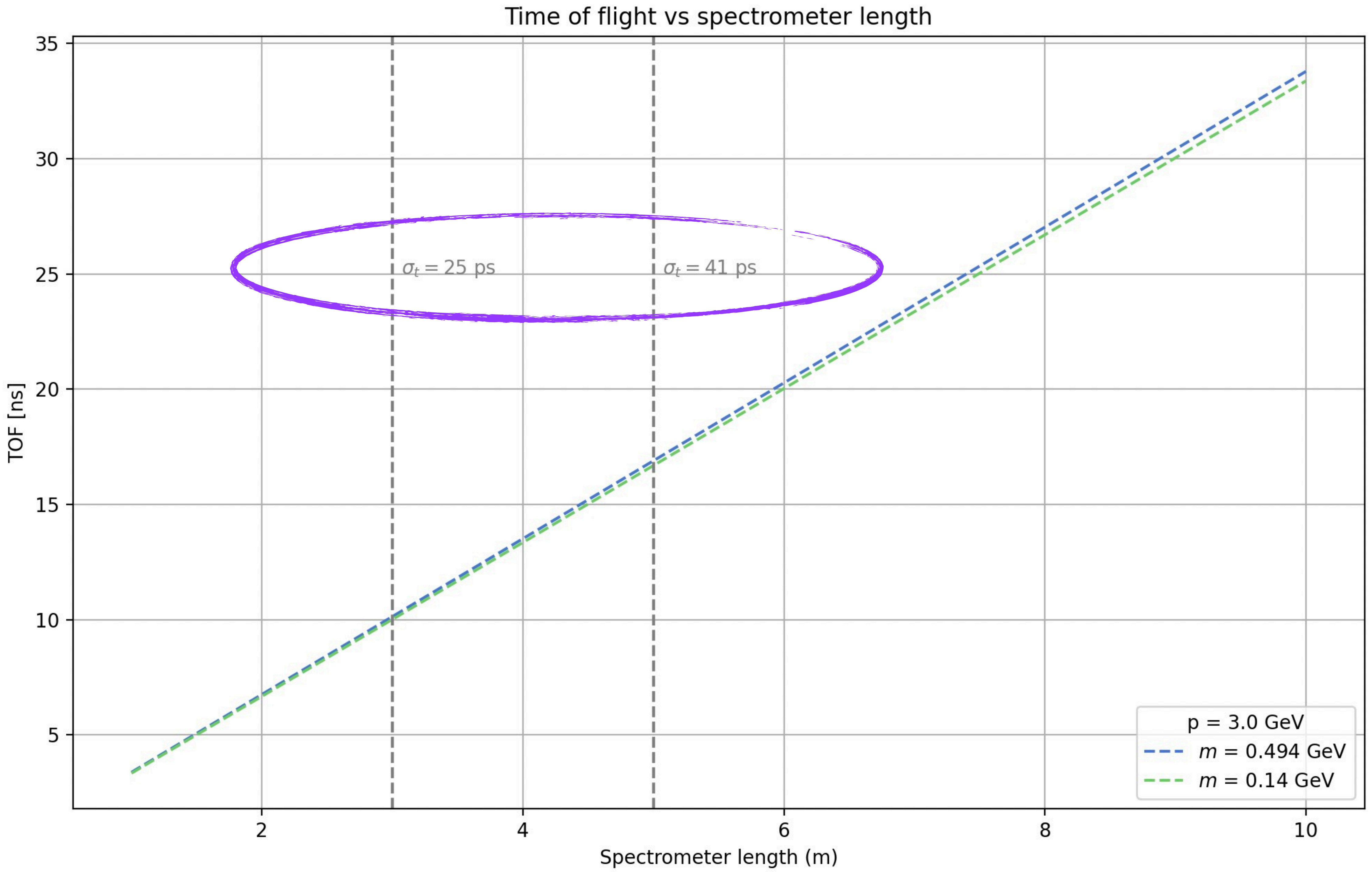


[LHCb-PUB-2009-013]

Time of flight

- A RICH detector is probably too much, what about scintillators for TOF?
- Time resolution needed to separate π and K by at least 5σ
  - $p \sim 1$ GeV $\rightarrow$ $\sigma_t = \mathcal{O}(100)$ ps (can)
  - $p \sim 3$ GeV $\rightarrow$ $\sigma_t = \mathcal{O}(10)$ ps (cannot)





Conclusions

- Not covered: a vertex detector? Maybe use spare VELO modules or exploit the setup to develop U2-like sensors in vacuum?
- Basic considerations given here to start the discussion
- A second step can be to check kinematic acceptance on generated quantities from LHCb FT simulations, knowing the spectrometer acceptance
- We need to develop a GEANT simulation from scratch to assess detector capabilities: needs people!