TRACKING SYSTEM FOR **UPGRADE 2**

Alessandro Scarabotto

Supervisors:
Lucia Grillo
Chris Parkes

Thanks to:
Irene Cortinovis

ABOUT ME

- Graduated from my Bachelor in Physics at the University of Ferrara (UNIFE) in July 2018

- Master student in a Double Degree Physics Program Paris Sud - Ferrara University

Università degli Studi di Ferrara

UNIVERSITÉ PARIS SUD

université PARIS-SACLAY

UPGRADE 2

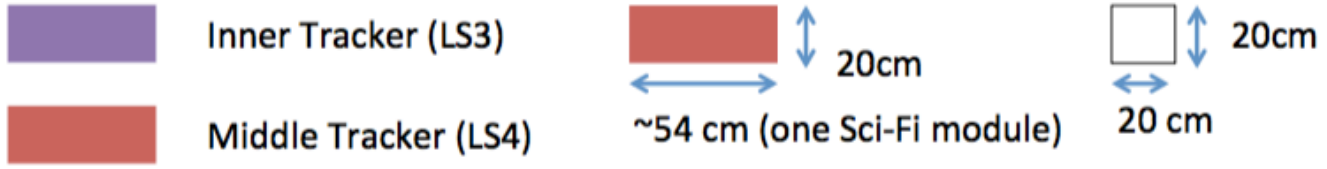
Upstream Tracker (UT)

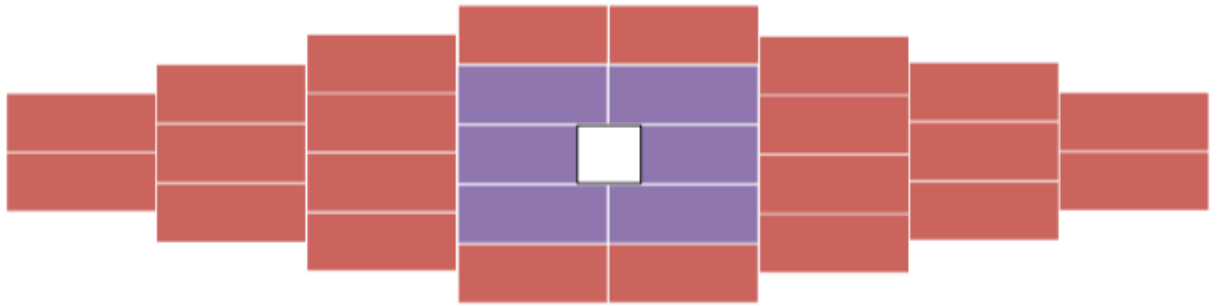
- Replacing strips with Silicon pixels

T-stations

Hybrid Detector (Mighty Tracker):

- Inner Silicon Detector made of pixels (**Inner Tracker** and **Middle Tracker**)
  - Outside Scintillating Detector similar to Upgrade 1 solution





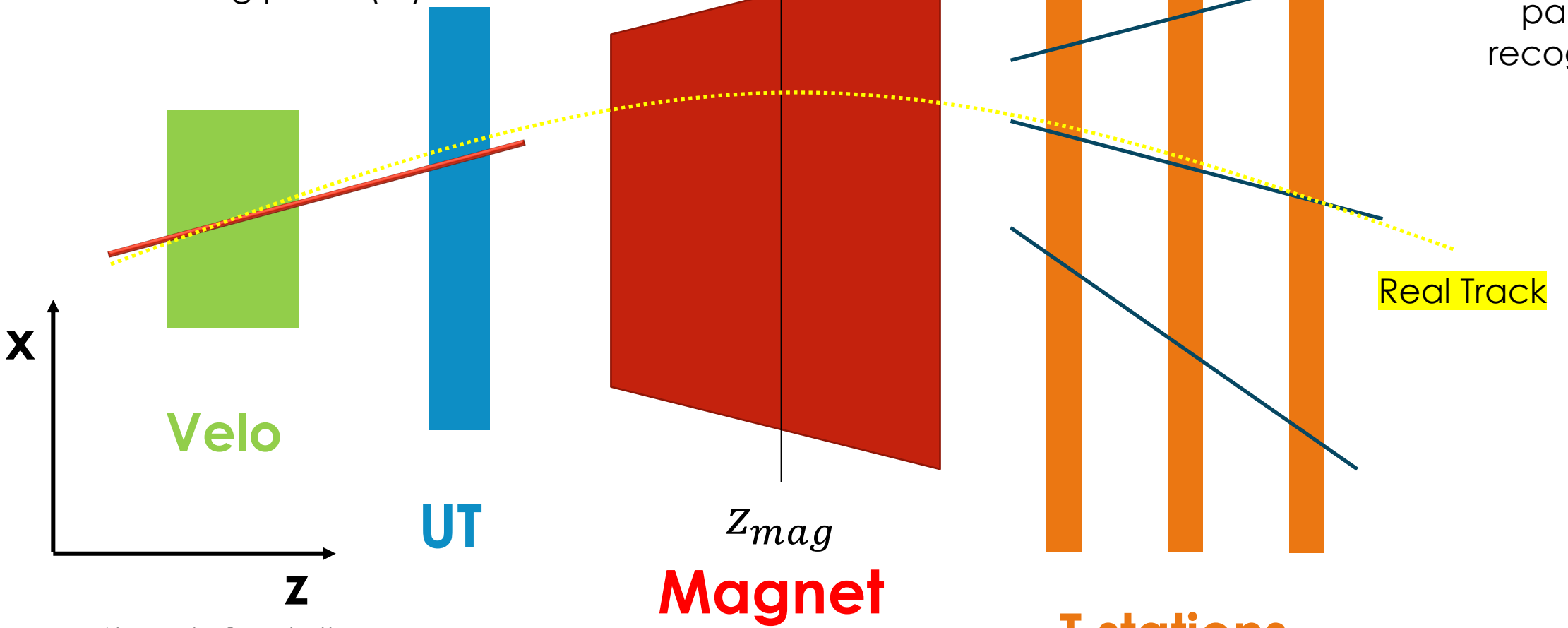
IT
Area per layer = 6 lots of 20x54 cm = 0.7 m^2 (minus beam hole)
Total Area = 6 layers of 0.7 m^2 = 3.9 m^2 (minus beam hole)

IT+MT
Area per layer = 28 lots of 20x54 cm = 3.0 m^2 (minus beam hole)
Total Area = 6 layers of 0.7 m^2 = 18.1 m^2 (minus beam hole)

TRACK MATCHING

Long tracks

Bending plane (xz)



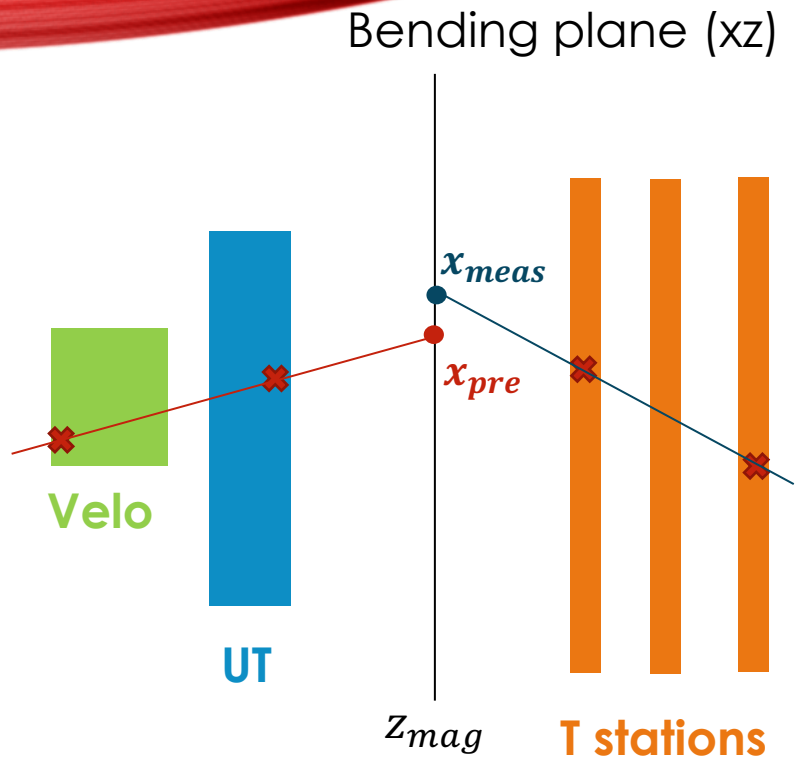
TRACK MATCHING IDEA

Let's build our χ^2

$$\chi^2 =$$

TRACK MATCHING IDEA

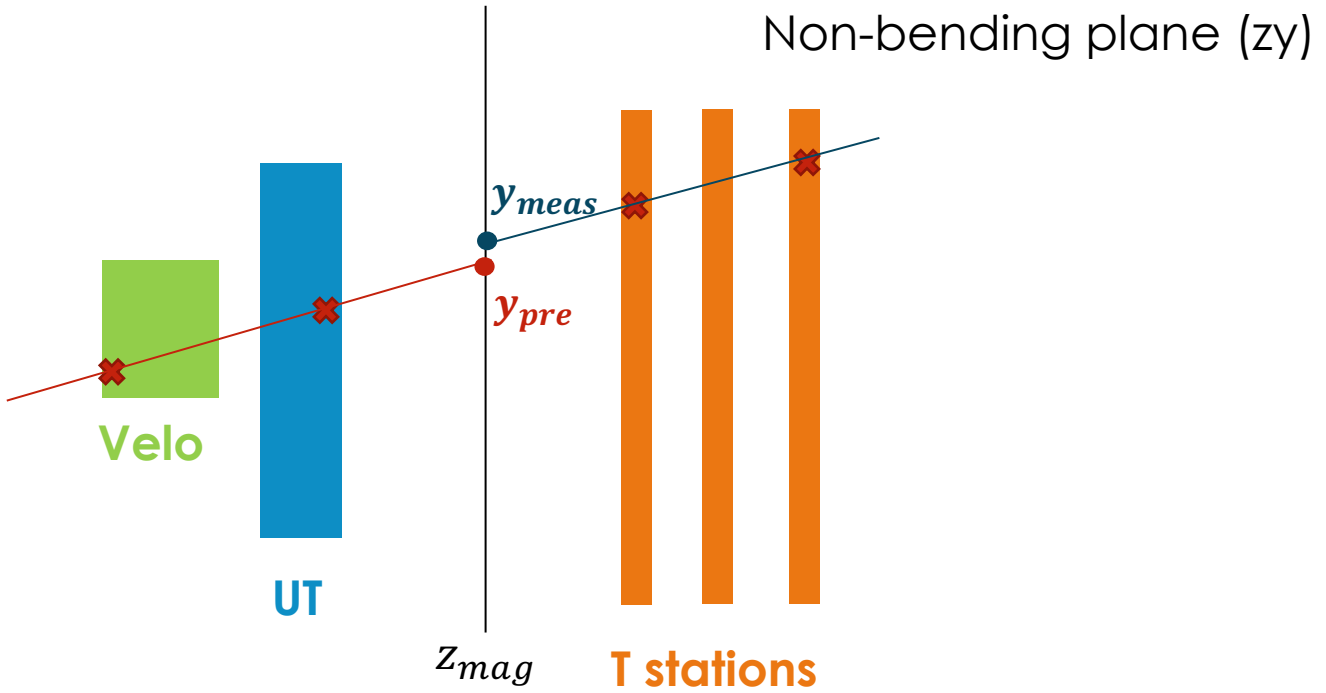
Let's build our χ^2



$$\chi^2 = \frac{(x_{pre} - x_{meas})^2}{(\sigma_x)^2}$$

TRACK MATCHING IDEA

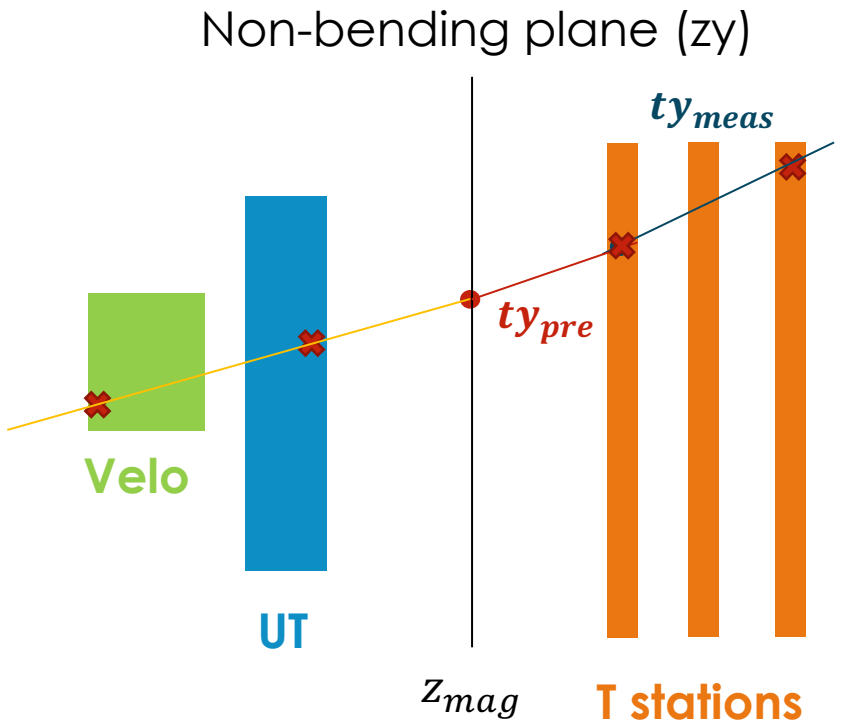
Let's build our χ^2



$$\chi^2 = + \frac{(y_{pre} - y_{meas})^2}{(\sigma_y)^2}$$

TRACK MATCHING IDEA

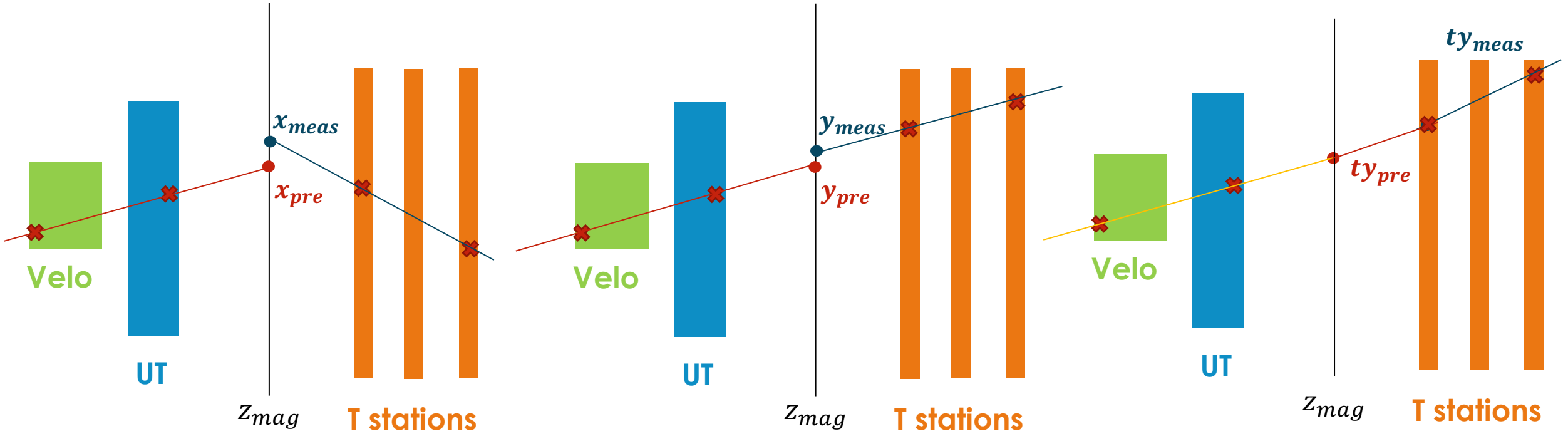
Let's build our χ^2



$$\chi^2 = + \frac{(ty_{pre} - ty_{meas})^2}{(\sigma_{ty})^2}$$

TRACK MATCHING IDEA

Let's build our χ^2



$$\chi^2 = \frac{(x_{pre} - x_{meas})^2}{(\sigma_x)^2} + \frac{(y_{pre} - y_{meas})^2}{(\sigma_y)^2} + \frac{(ty_{pre} - ty_{meas})^2}{(\sigma_{ty})^2}$$

EFFICIENCY AND GHOST RATE

Find the match with minimum χ^2 and check if it's real or fake

$$\textbf{Efficiency} = \frac{real\ match}{total\ long\ tracks}$$

$$\textbf{Ghost rate} = \frac{fake\ match}{all\ matched\ (real+fake)}$$

FIRST RESULTS

20 events for long tracks coming from MC sample of B decays

Luminosity = $2 \times 10^{33}\ cm^{-2}s^{-1}$

Upgrade 1

Efficiency

0.968 ± 0.005

Ghost Rate

0.127 ± 0.008

(Upgrade1 analysis valid only for long tracks with this algorithm conditions)

Luminosity = $1.5 \times 10^{34}\ cm^{-2}s^{-1}$

Upgrade 2

Efficiency

0.932 ± 0.003

Ghost Rate

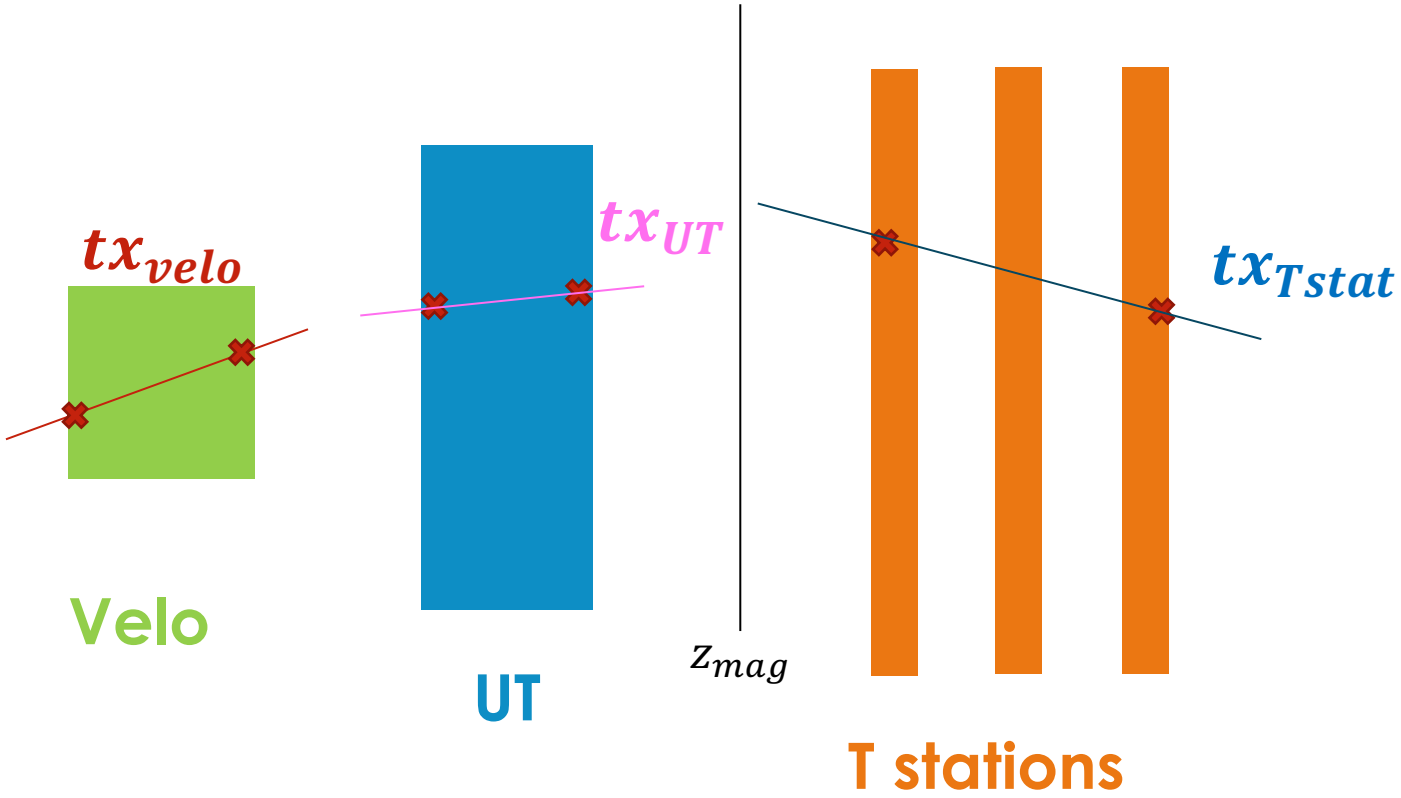
0.173 ± 0.004

Idea to reduce Ghost Rate:

Use a threshold to cut very large χ^2

ADDING MOMENTUM TERM

$$\chi^2 = \frac{(x_{pre}-x_{meas})^2}{(\sigma_x)^2} + \frac{(y_{pre}-y_{meas})^2}{(\sigma_y)^2} + \frac{(ty_{pre}-ty_{meas})^2}{(\sigma_{ty})^2} + \frac{(p_{pre}-p_{meas})^2}{(\sigma_p)^2}$$



- tx_{UT} - tx_{velo} → p_{pre}
  Expected momentum resolution: ~15%

- tx_{Tstat} - tx_{velo} → p_{meas}
  Expected momentum resolution: ~1%

MOMENTUM RESULTS

3-4 events for long tracks

Upgrade 2

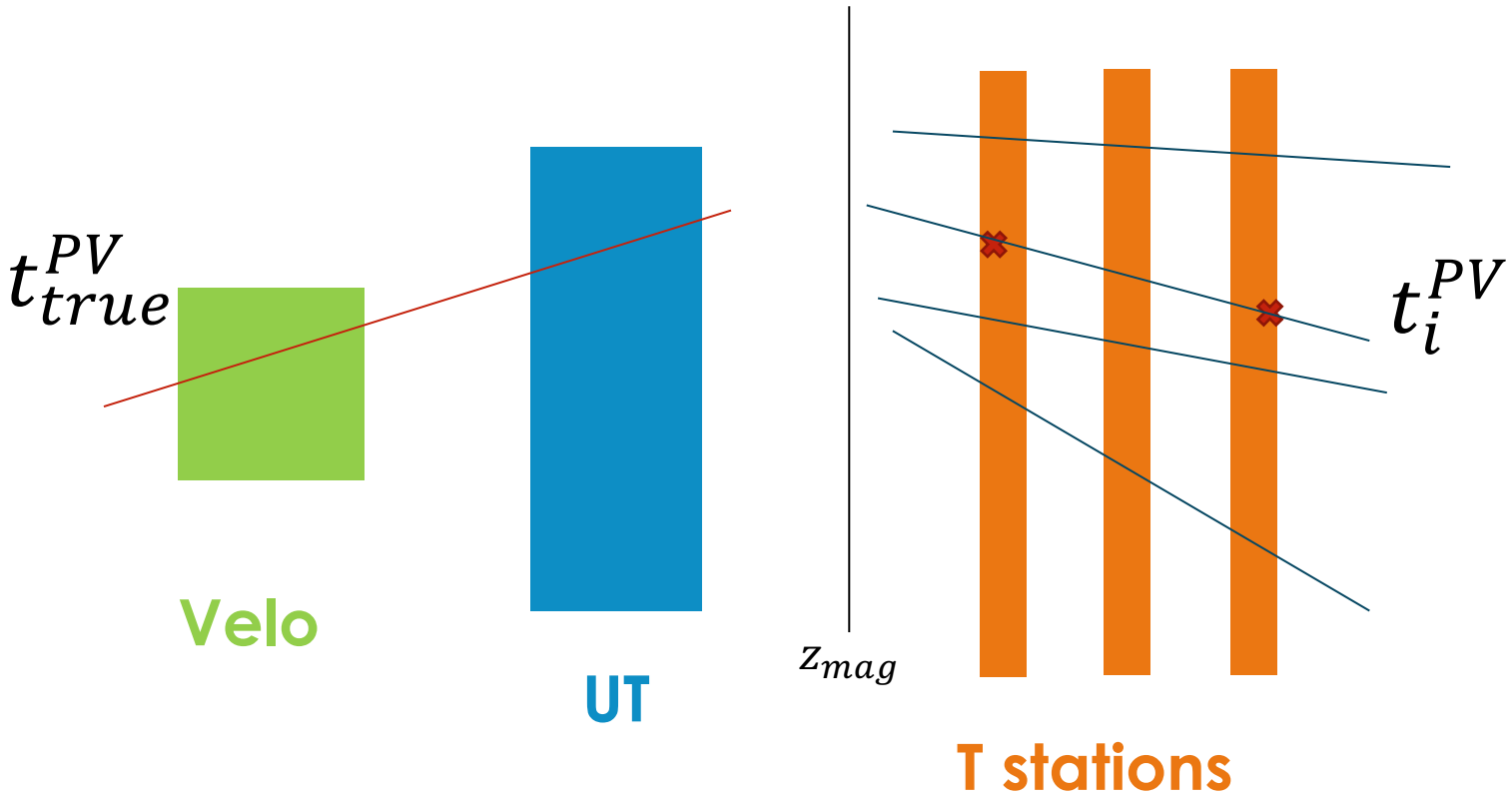
Efficiency	**Efficiency**	**Efficiency**
0.940 ± 0.008	0.958 ± 0.006	0.979 ± 0.005
Ghost Rate	**Ghost Rate**	**Ghost Rate**
0.180 ± 0.011	0.165 ± 0.011	0.146 ± 0.010
Starting χ^2	Fake momentum with expected resolution	Increasing Velo-UT momentum resolution to 1%

INSERT TIME TERM

$$\chi^2_{time} = \frac{(t^{PV}_{velo} - t^{PV}_{Tstat})^2}{(\sigma_{velo})^2 + (\sigma_{Tstat})^2}$$

Let's suppose a time resolution of 30ps

σ_{velo} = 30 ps
σ_{Tstat} = 30 ps



$$t^{PV}_{velo} = t^{PV}_{true} + \sigma_{velo}$$

$$t^{PV}_{Tstat} = t^{PV}_{i} + \sigma_{Tstat}$$

TIME RESULTS

3-4 events for long tracks

Upgrade 2

Efficiency	**Efficiency**	**Efficiency**
0.940 ± 0.008	0.948 +- 0.007	0.97 ± 0.005
Ghost Rate	**Ghost Rate**	**Ghost Rate**
0.180 ± 0.011	0.173 +- 0.011	0.154 ± 0.011
Starting χ^2	Fake time with 30 ps resolution	0.03 by taking out tracks not reaching the T-stations Fake time with 1 ps resolution

Limit of the approximation

CONCLUSIONS AND WAY AHEAD

Upgrade 2

Efficiency
0.940 ± 0.008
Ghost Rate
0.180 ± 0.011

Momentum

Efficiency
0.958 ± 0.006
Ghost Rate
0.165 ± 0.011

Time

Efficiency
0.948 +- 0.007
Ghost Rate
0.173 +- 0.011

To compare with:

Upgrade 1

Efficiency
0.968 ± 0.006
Ghost Rate
0.127 ± 0.010

First study of track matching with Upgrade 2 layout carried out.
Results look promising.

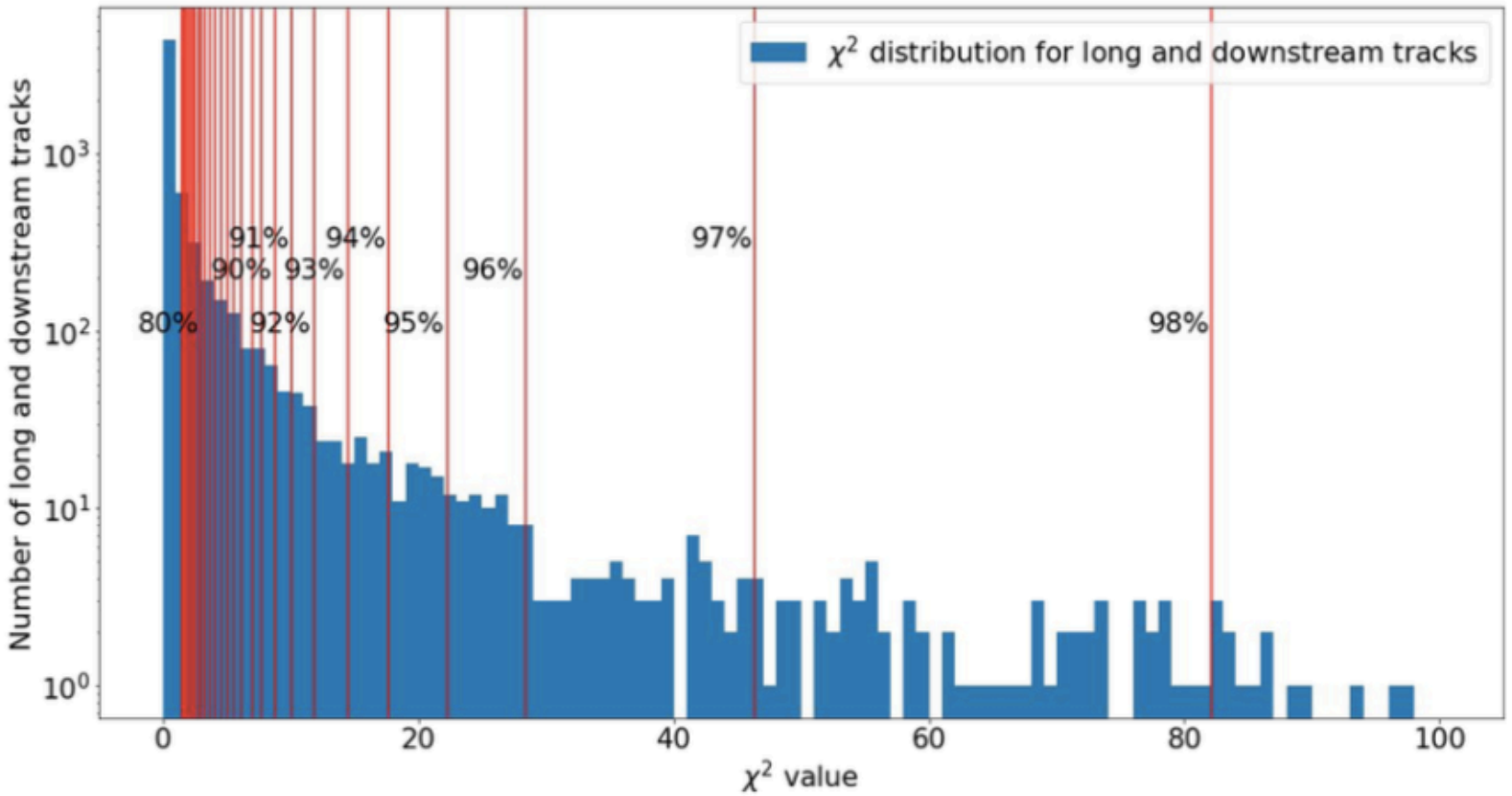
Next steps:

- Use threshold to reject tracks not reaching the T-stations
- Improve the track model by matching curved Velo-UT and T-stat tracks

BACKUP

For more details on the results you can also look at some of the presentations that I gave during Upgrade 2 meetings on Wednesday mornings

CHI2 AND THRESHOLDS



20 events = 6710 long tracks

No Threshold

Efficiency:

0.932 ± 0.003

Ghost rate:

0.173 ± 0.004

Threshold 97%

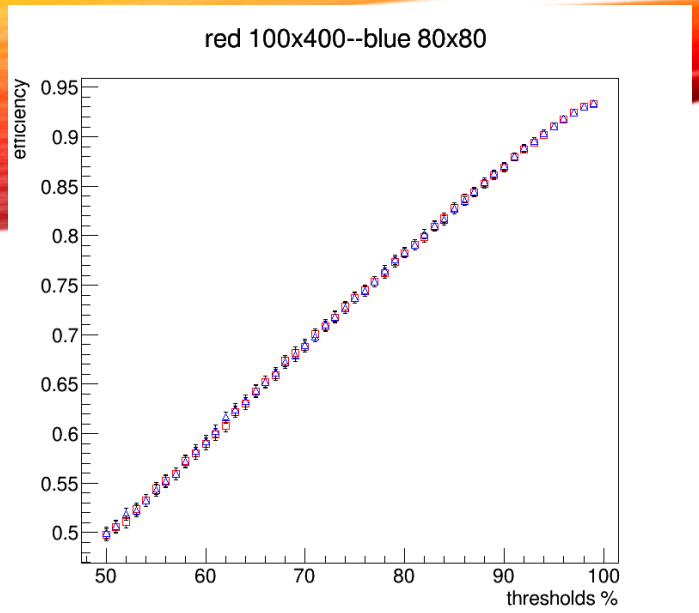
Efficiency:

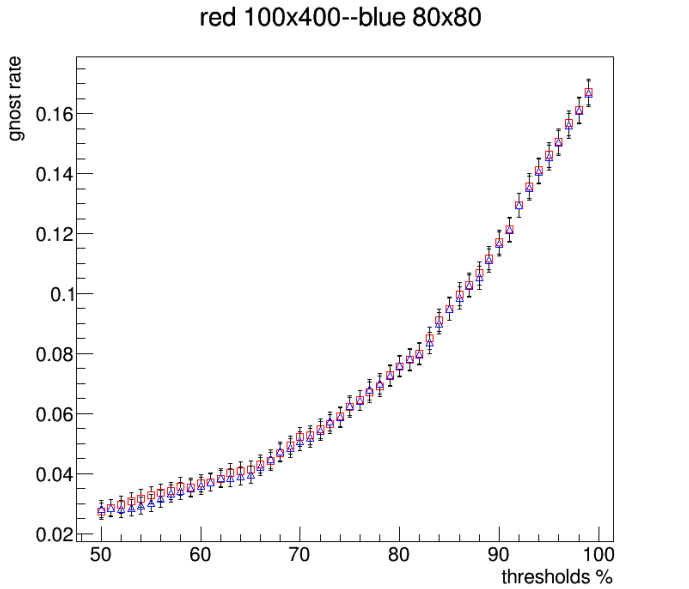
0.922 ± 0.003

Ghost rate:

0.158 ± 0.004

PICKING THRESHOLD





20 events = 6710 long tracks

No Threshold
Efficiency:
0.933 ± 0.003
Ghost rate:
0.171 ± 0.004

Threshold 99%
Efficiency:
0.933 ± 0.003
Ghost rate:
0.167 ± 0.004

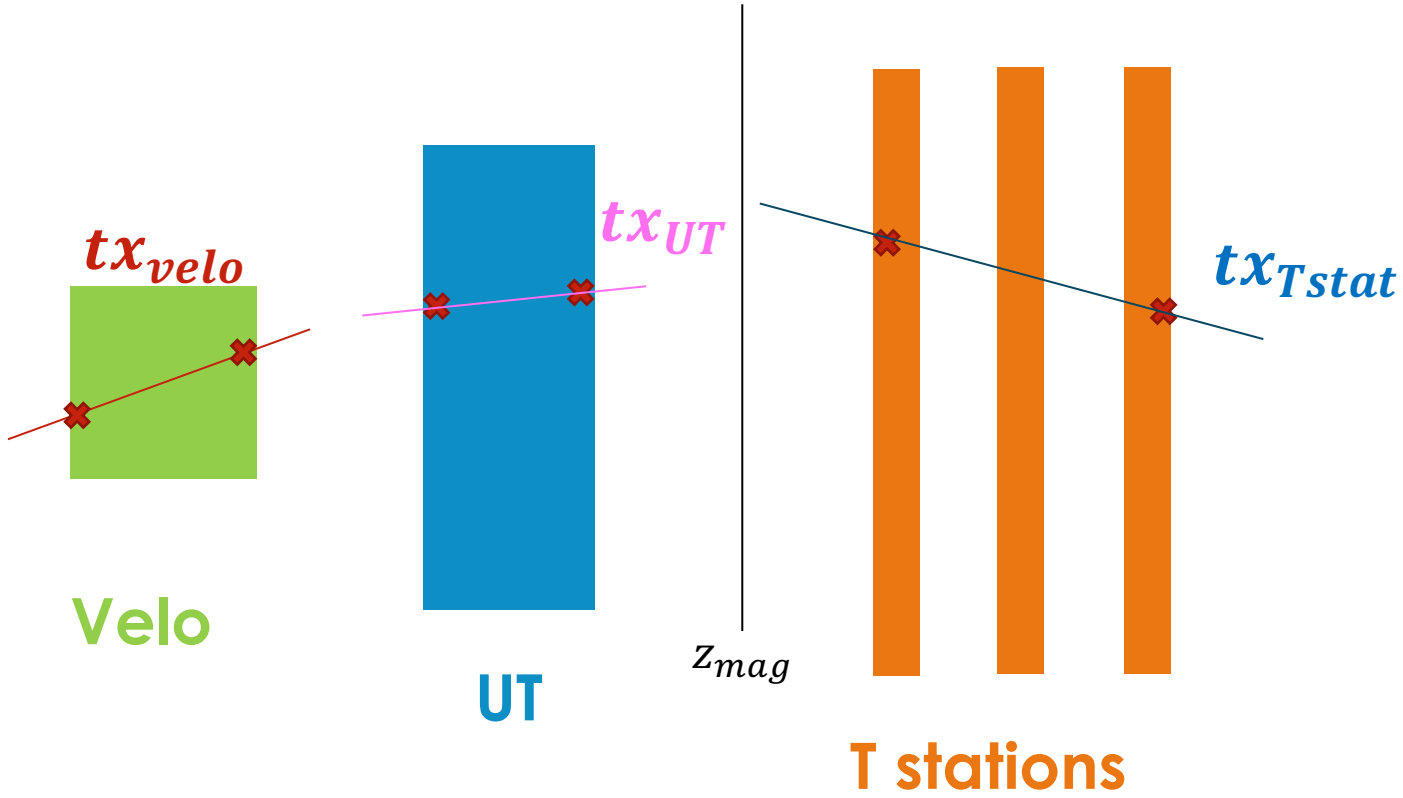
Threshold 98%
Efficiency:
0.930 ± 0.003
Ghost rate:
0.161 ± 0.004

Threshold 97%
Efficiency:
0.924 ± 0.003
Ghost rate:
0.157 ± 0.004

Threshold 96%
Efficiency:
0.917 ± 0.003
Ghost rate:
0.151 ± 0.004

ADDING MOMENTUM TERM

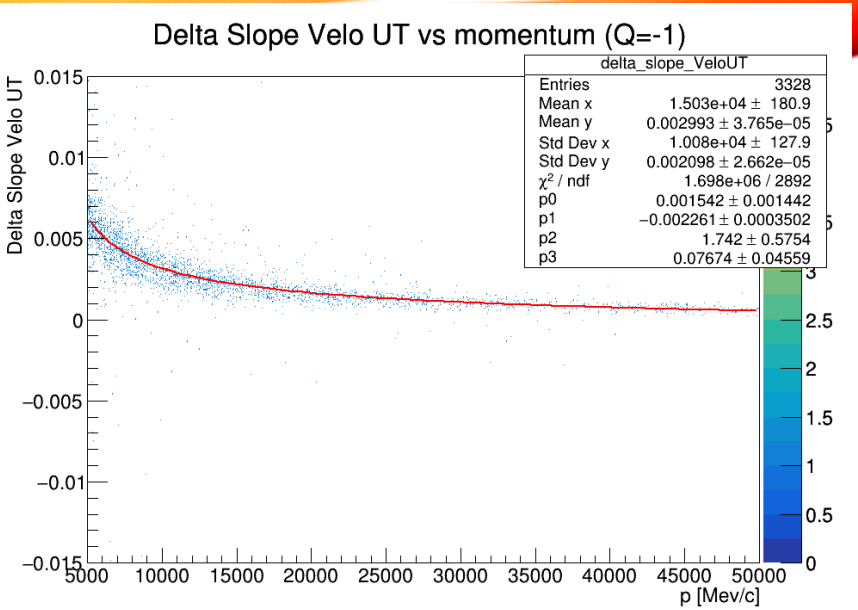
$$\chi^2 = \frac{(x_{pre}-x_{meas})^2}{(\sigma_x)^2} + \frac{(y_{pre}-y_{meas})^2}{(\sigma_y)^2} + \frac{(ty_{pre}-ty_{meas})^2}{(\sigma_{ty})^2} + \frac{(p_{pre}-p_{meas})^2}{(\sigma_p)^2}$$

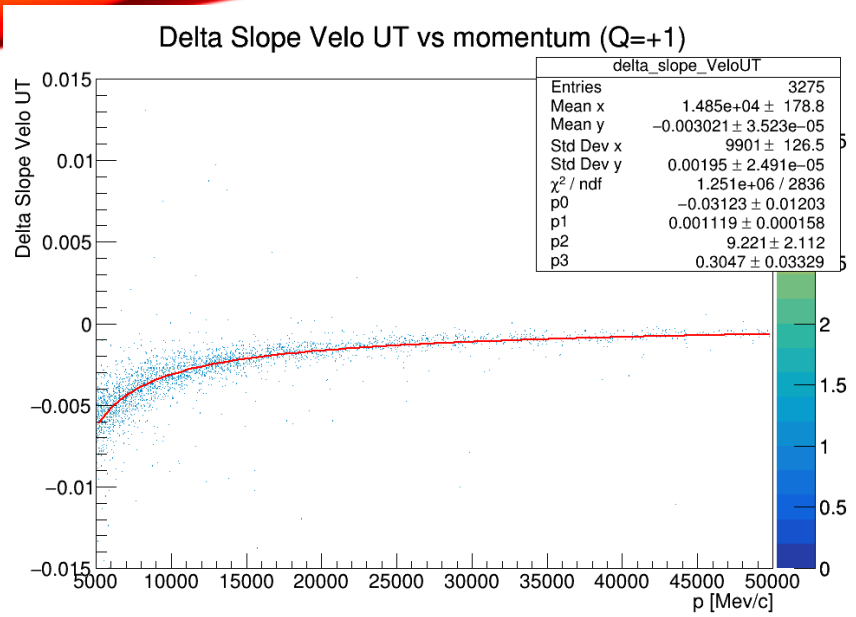


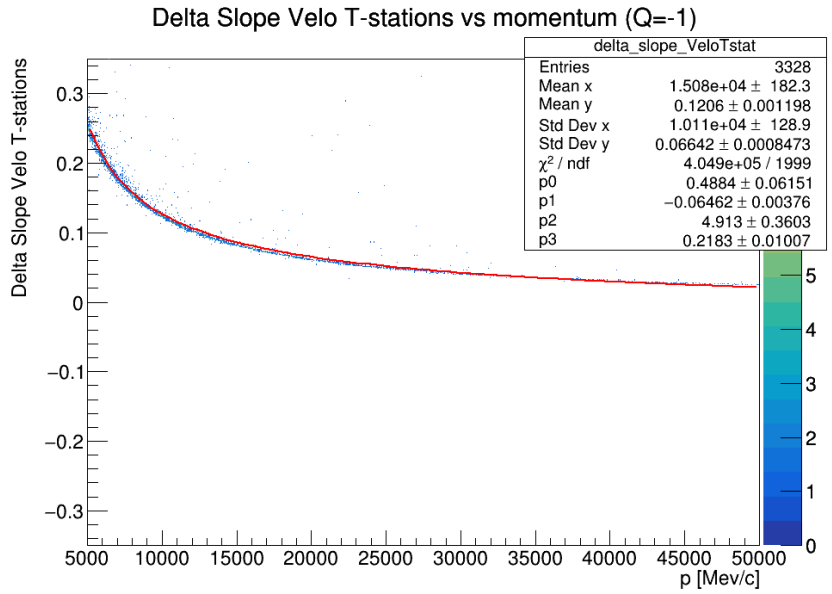
- tx_{UT} - tx_{velo} → p_{pre}
  Expected momentum resolution: ~15%

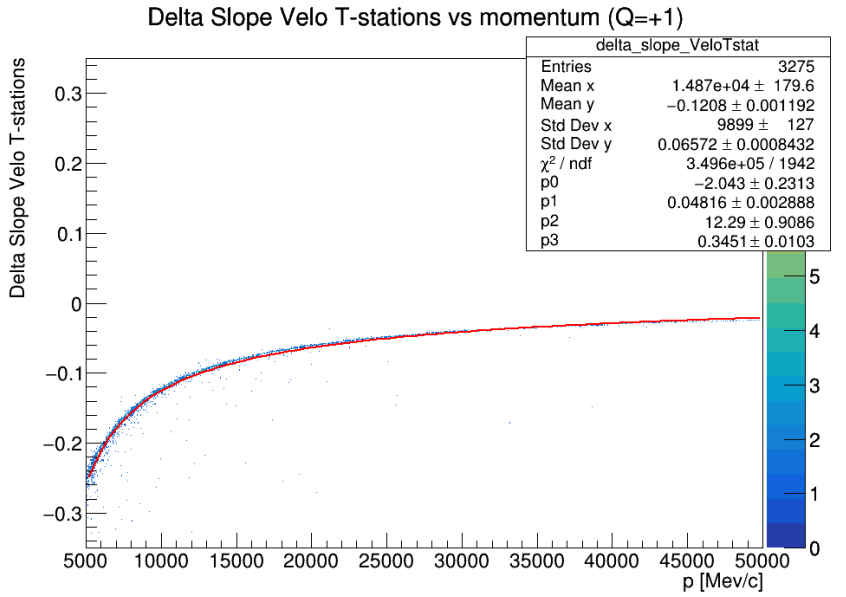
- tx_{Tstat} - tx_{velo} → p_{meas}
  Expected momentum resolution: ~1%

MOMENTUM TERM









Finding dependence on momentum of:

- tx_{UT} - tx_{velo} → p_{pre}
- tx_{Tstat} - tx_{velo} → p_{meas}

Found functions for charge -1 and +1: Different bending

Fit: $\frac{a}{(x^b - c)} + d$

MOMENTUM RESULTS

20 events for long tracks

Upgrade 2

Efficiency

0.932 ± 0.003

Ghost Rate

0.173 ± 0.004

Starting χ^2

Efficiency

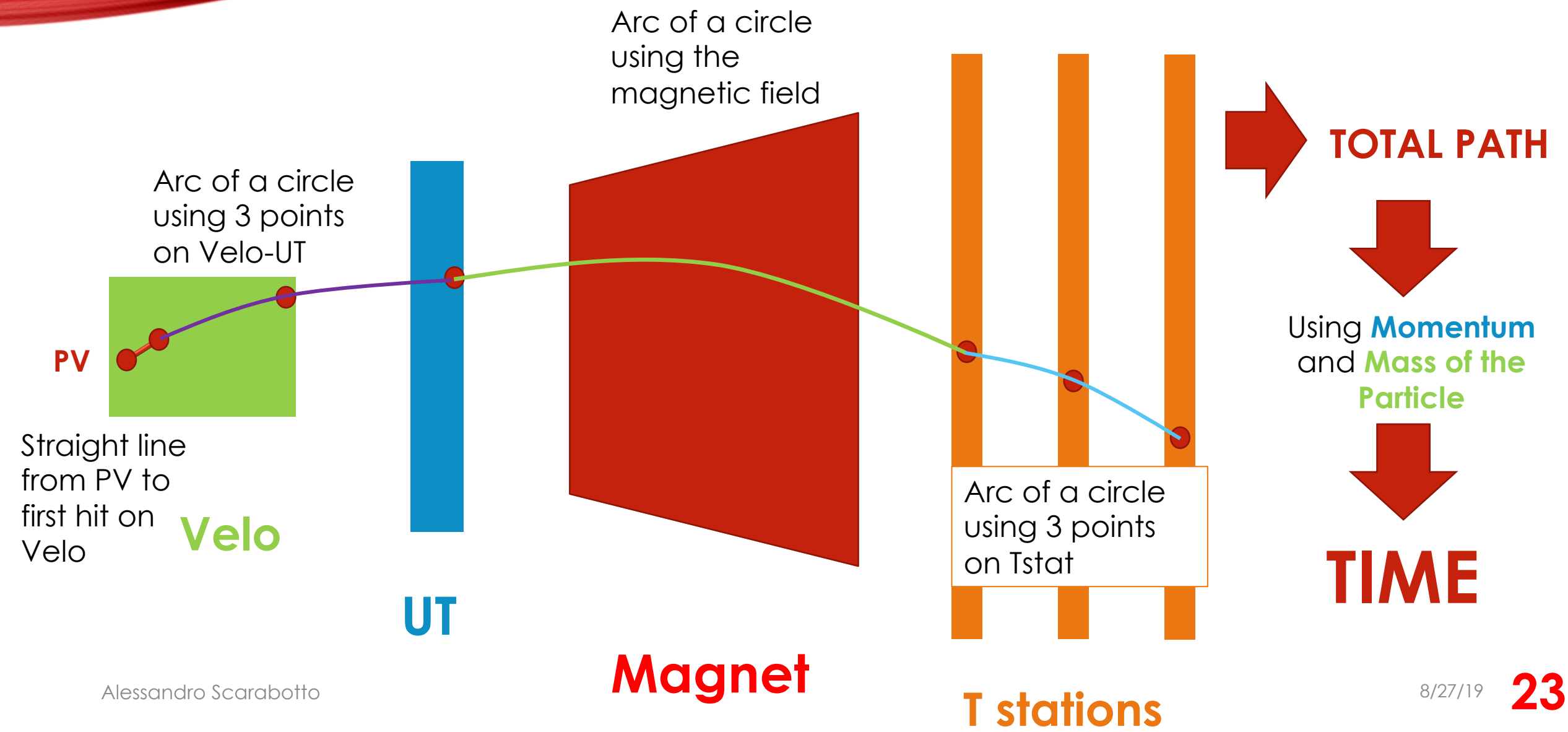
0.942 +- 0.003

Ghost Rate

0.160 +- 0.004

χ^2 with momentum term (by using my momentum estimate)

TIMING IDEA


Arc of a circle using the magnetic field
Arc of a circle using 3 points on Velo-UT
PV
Straight line from PV to first hit on Velo
Velo
UT
Magnet
Arc of a circle using 3 points on Tstat
T stations
TOTAL PATH
Using Momentum and Mass of the Particle
TIME

OCCUPANCY STUDIES