UPGRADE 2 TRACKING SYSTEM

TRACKING AND SIMULATION STUDIES (UPSTREAM AND DOWNSTREAM)

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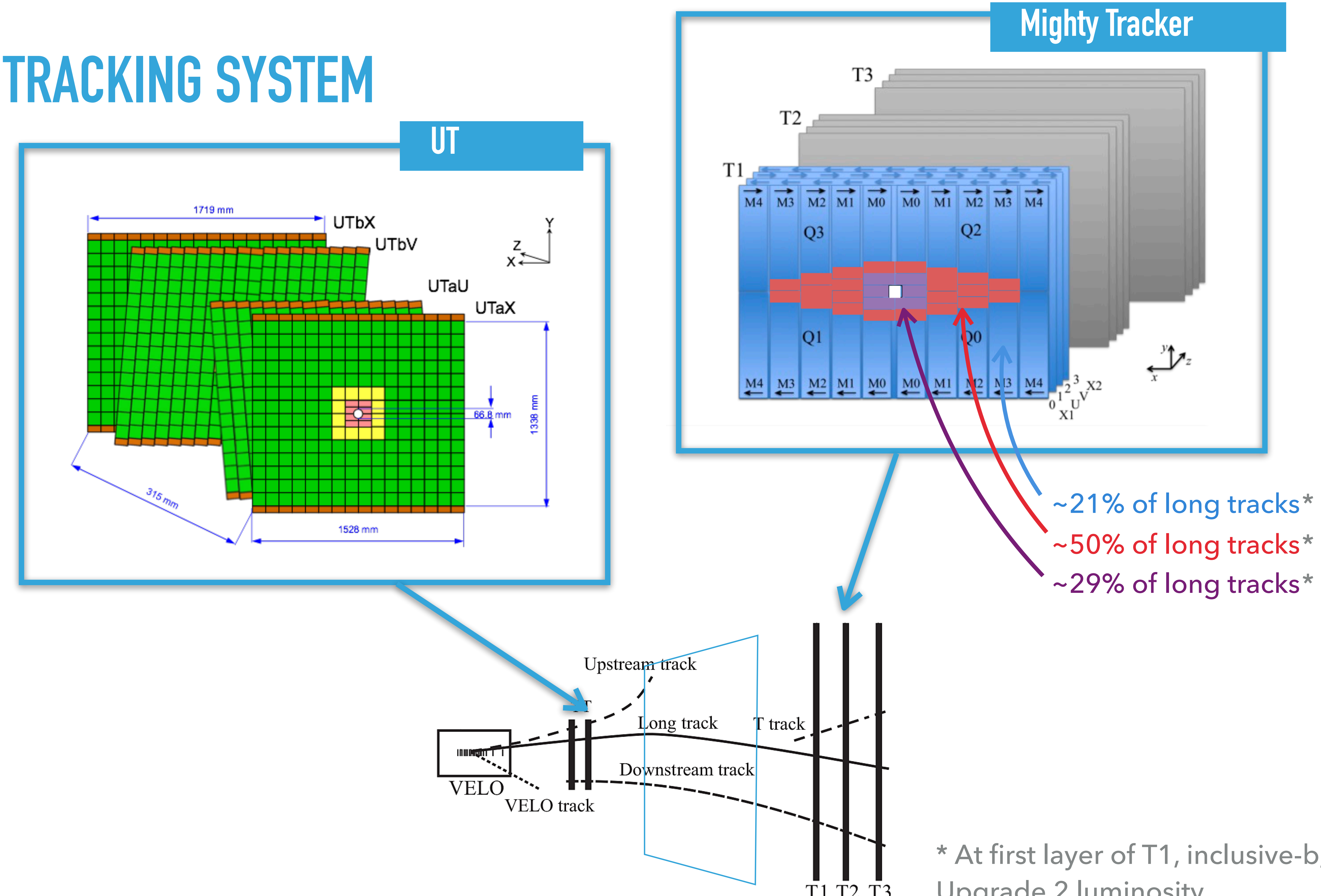
(for the Mighty Tracker group)

5th Workshop on LHCb Upgrade II, Barcelona, 30/03/2020

Apologies for links to LHCb internal documents, those are just for completeness for LHCb colleagues

TRACKING SYSTEM

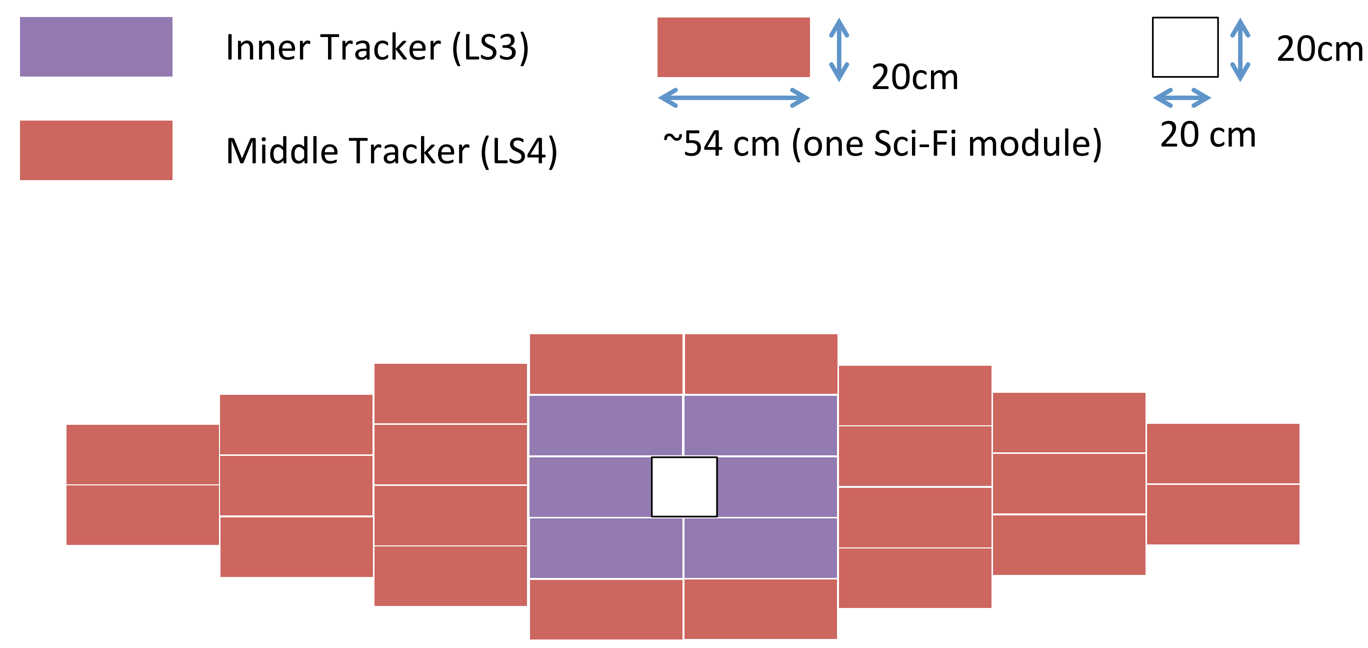


* At first layer of T1, inclusive-b, Upgrade 2 luminosity

MIGHTY TRACKER

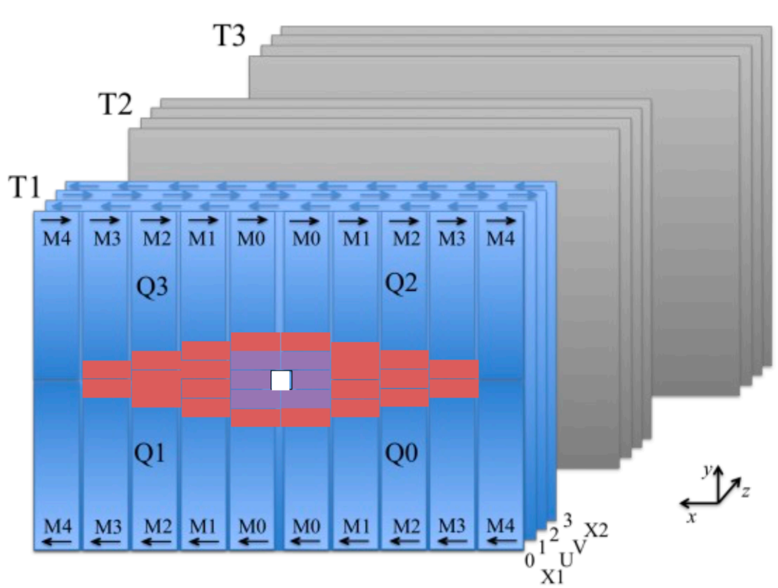
LHCb-INT-2019-007

- HV-CMOS: Inner Tracker (IT), Upgrade 1b + Middle Tracker (MT), Upgrade 2
- Design choices that impact track reconstruction performance (track finding efficiency, fake rate, momentum resolution):



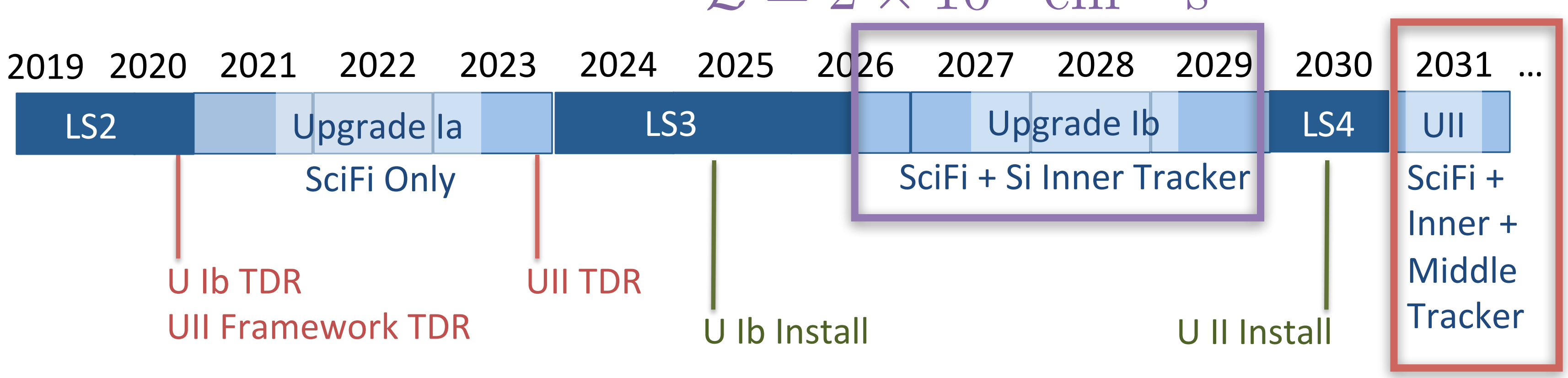
IT
Area per layer = 6 lots of 20x54 cm = 0.7 m^2 (minus beam hole)
Total Area = 6 layers of 0.7 m^2 = 3.9 m^2 (minus beam hole)

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)



$$\mathcal{L} = 1.5 \times 10^{34} \mathrm{cm}^{-2}\mathrm{s}^{-1}$$

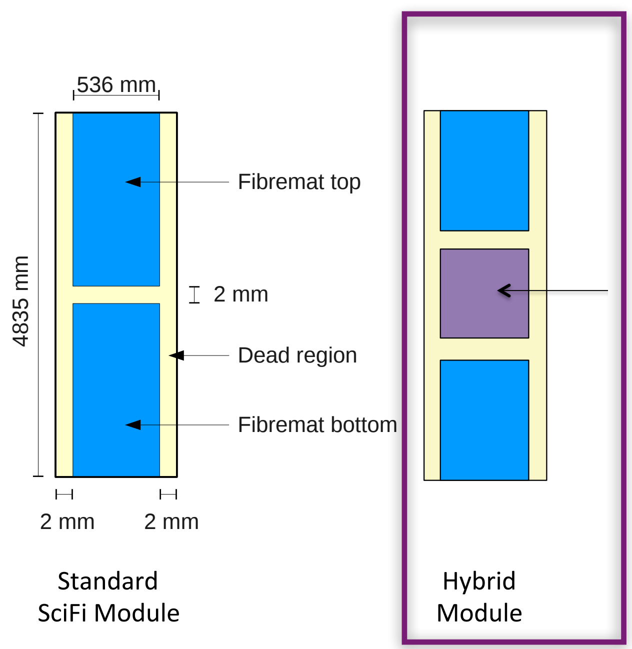
$$\mathcal{L} = 2 \times 10^{33} \mathrm{cm}^{-2}\mathrm{s}^{-1}$$

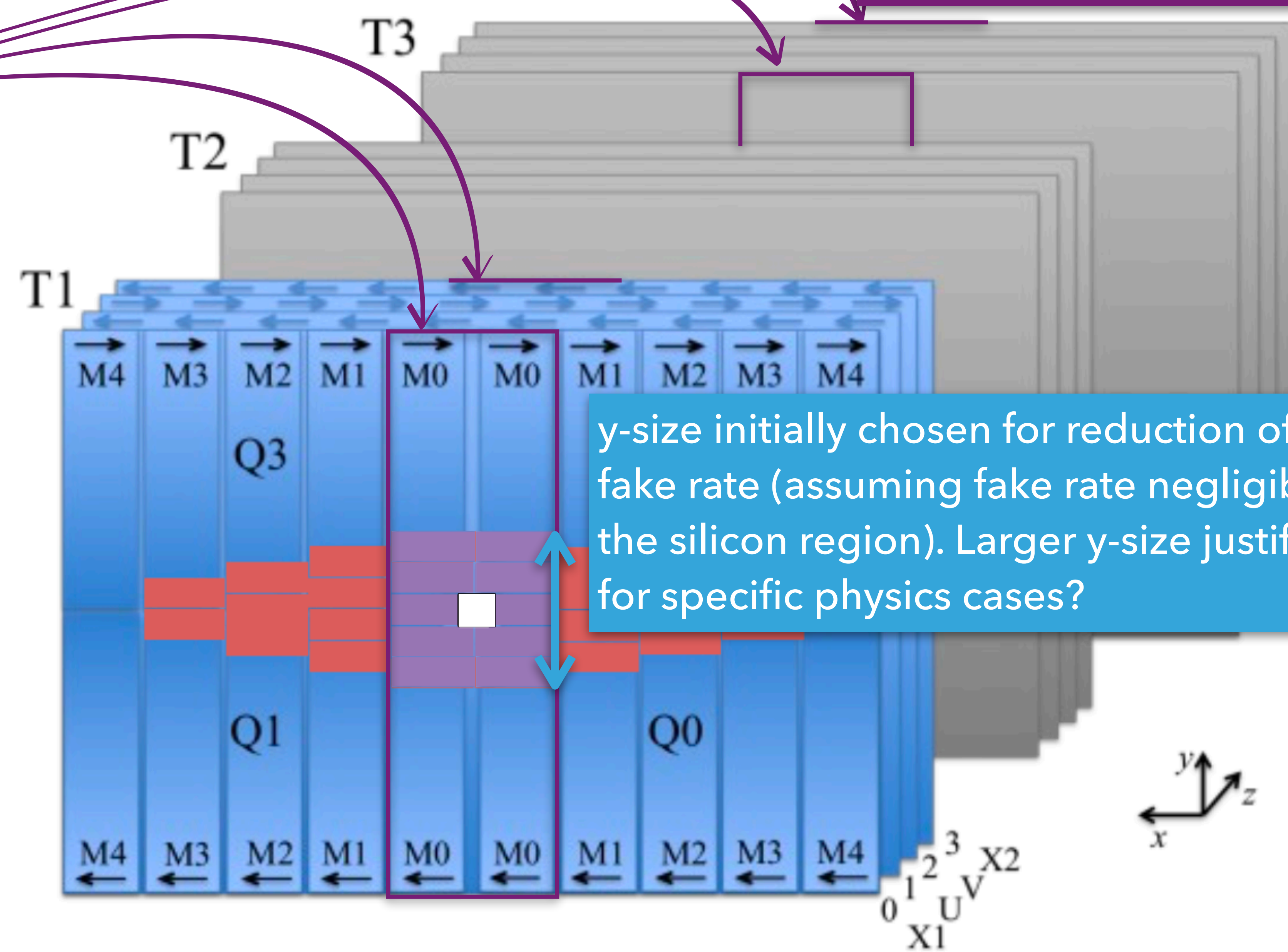


MIGHTY TRACKER – UPGRADE 1B

- Inner Tracker (IT), Upgrade 1b (new ideas)

4 layers of hybrid + 8 fibre modules. How many ‘old’ SciFi modules we can afford for tracking performance?





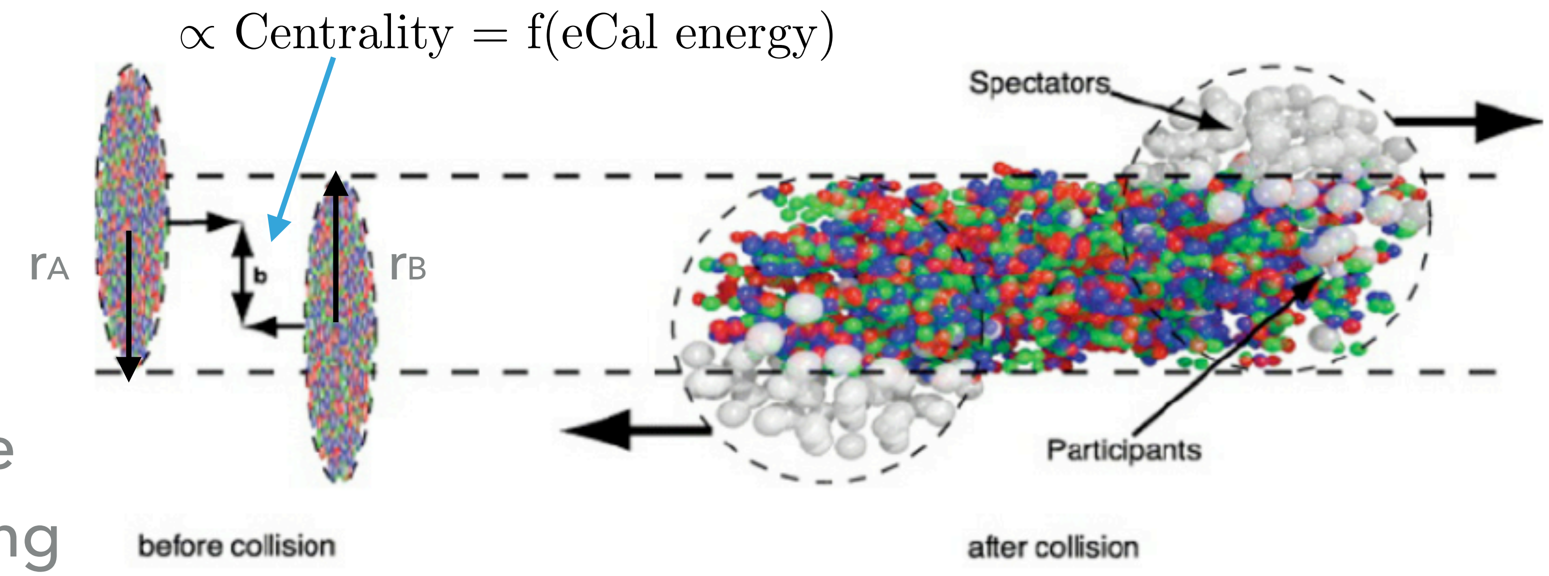
y-size initially chosen for reduction of fake rate (assuming fake rate negligible in the silicon region). Larger y-size justified for specific physics cases?

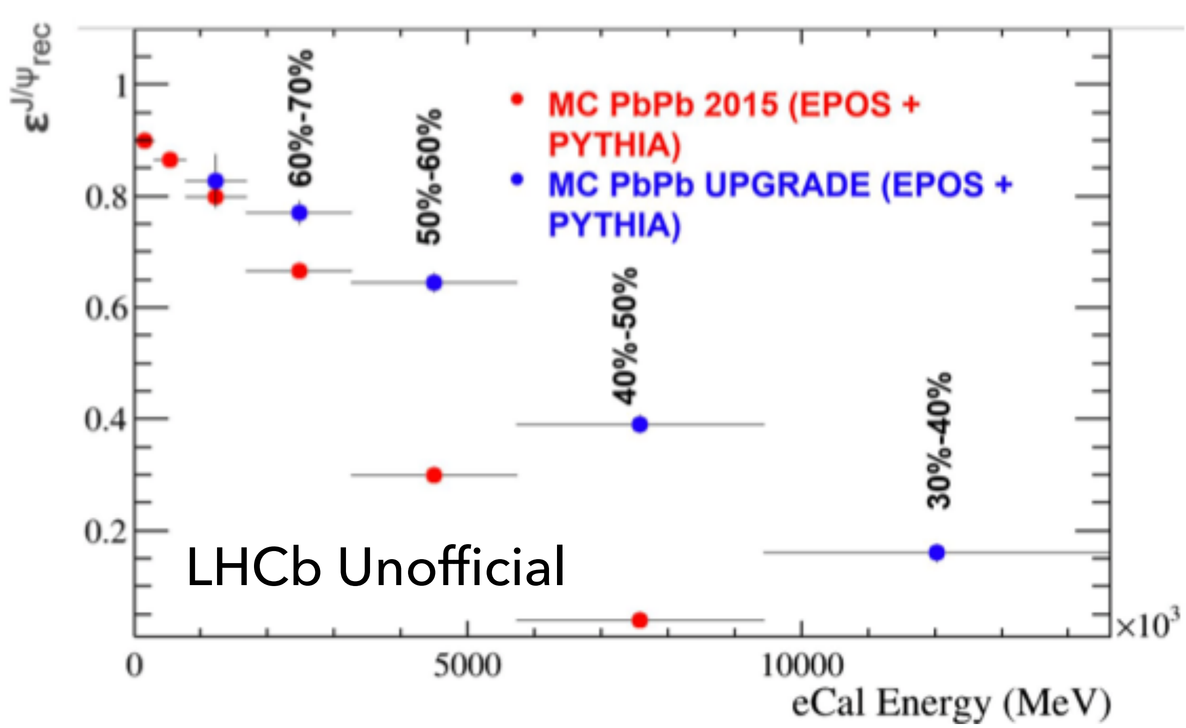
- Additional options?

LHCb performance in PbPb Collisions

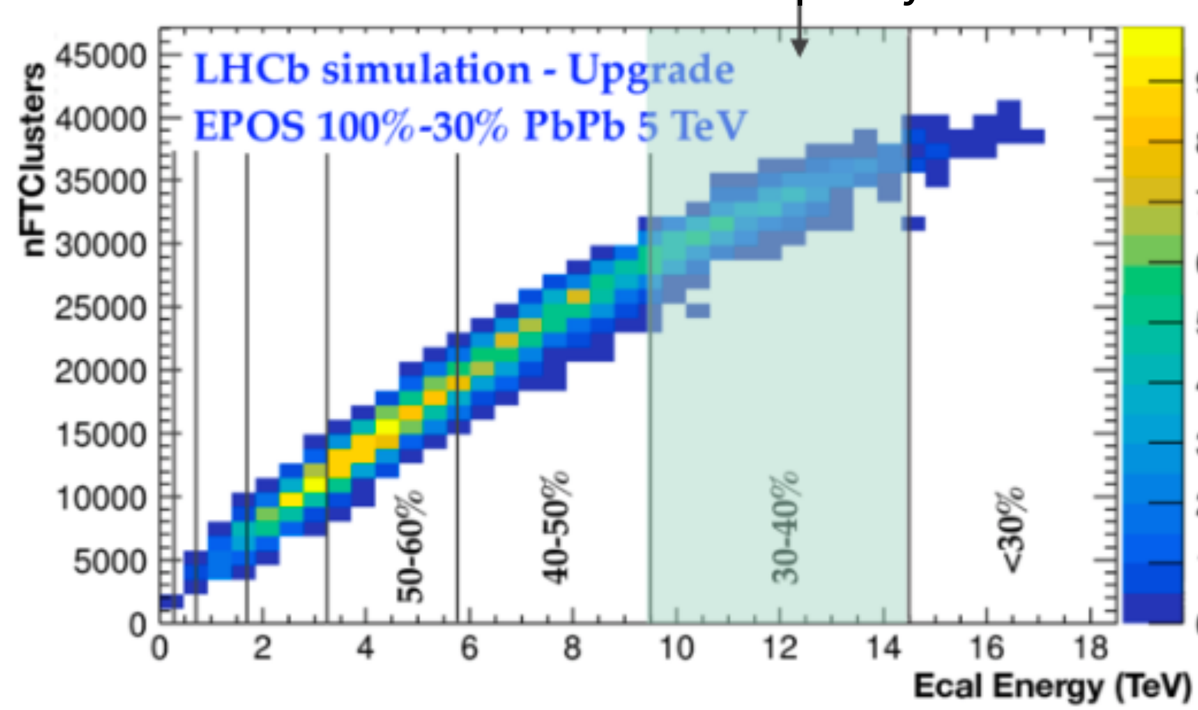
Benjamin Audurier 23.10.2019
LHCb-INT-2020-004

- Higher centrality = higher energy density = creation of Quark-Gluon Plasma
- PbPb track reconstruction up to 30% centrality with the upgrade detector, SciFi occupancy limiting factor





Maximum occupancy of the SciFi



- IT reduces occupancy in the SciFi: which IT geometry would allow to reach 0% centrality?

LHCb performance in PbPb Collisions

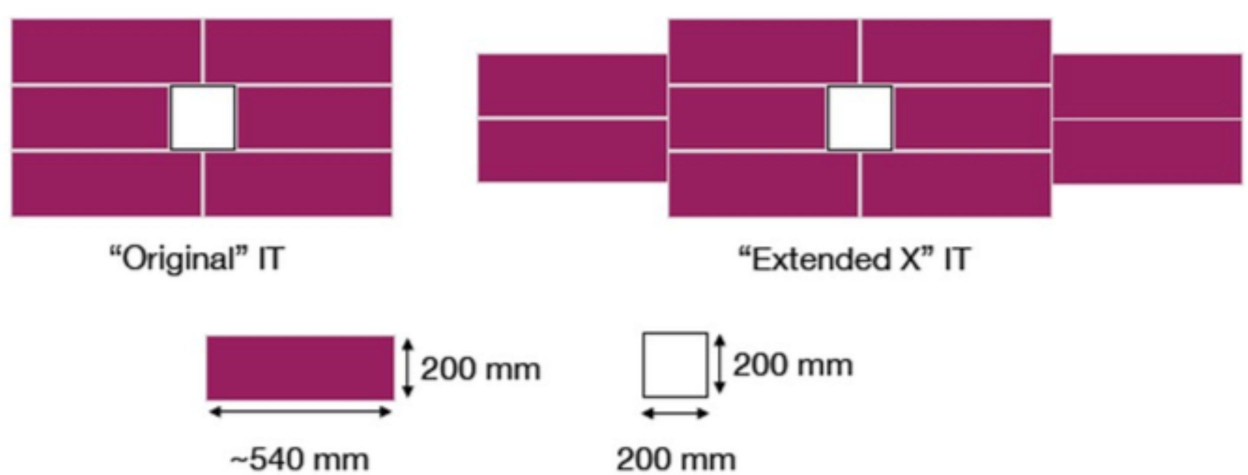
Benjamin Audurier 04.03.2020
LHCb-INT-2020-004

- Method: use ALICE Phys. Lett. B 772 (2017) 457 to estimate charged particle multiplicity in LHCb

multiplicity x 3.5

multiplicity x 2.2

centrality percentile	$2 < \eta < 4.5$	$2 < \eta < 2.5$	$2.5 < \eta < 3$	$3 < \eta < 3.5$	$3.5 < \eta < 4$	$4 < \eta < 4.5$
0%-5%	4074 (× 3.5)	937 (× 3.6)	876 (× 3.5)	828 (× 3.5)	759 (× 3.6)	674 (× 3.5)
5%-10%	3366 (× 2.9)	769 (× 3.0)	724 (× 2.9)	689 (× 2.9)	628 (× 2.9)	556 (× 2.9)
10%-20%	2548 (× 2.2)	578 (× 2.2)	548 (× 2.2)	525 (× 2.2)	475 (× 2.2)	422 (× 2.2)
20%-30%	1736 (× 1.5)	392 (× 1.5)	374 (× 1.5)	360 (× 1.5)	323 (× 1.5)	287 (× 1.5)
30%-40%	1150	258	248	239	213	191



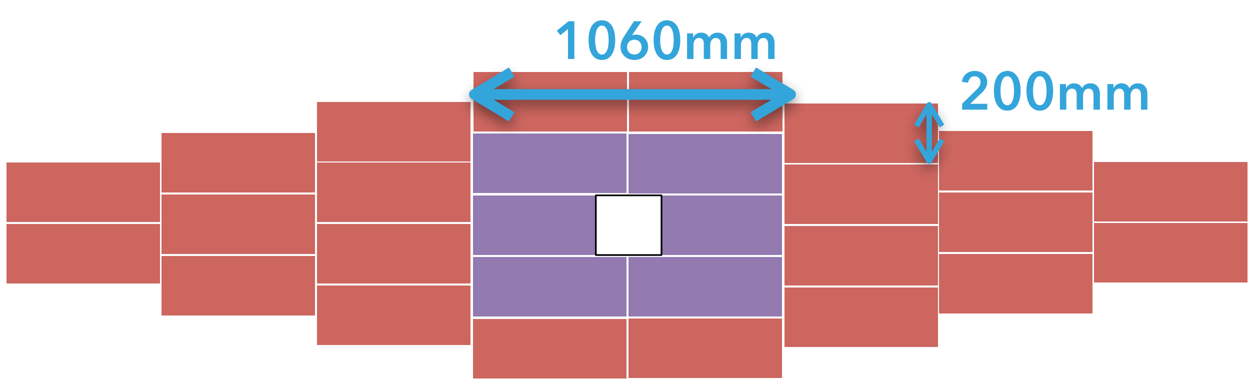
detector configuration	Upgrade Ib	Upgrade II
SciFi only	3.2 ± 0.2	18.4 ± 0.4
SciFi with IT	1.4 ± 0.1 (×1/2.3)	6.8 ± 0.3 (×1/2.7)
SciFi with extended-X IT	0.8± 0.1 (×1/4)	4.2 ± 0.2 (×1/4.4)

SciFi occupancy estimation

- IT extended to 2nd to most central modules is needed to reach 0% centrality
- Additional technical complications and/or costs
- "Original" IT allows to reach 10%-20% centrality

LHCb-INT-2019-007

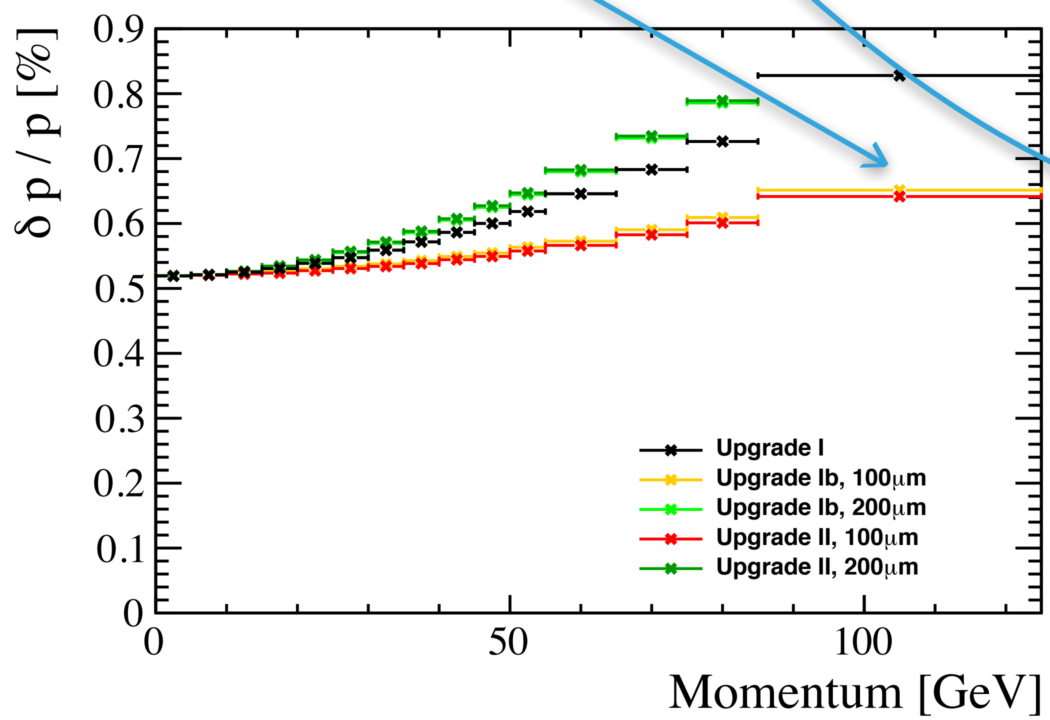
MIGHTY TRACKER: BASELINE DESIGN UPGRADE 2

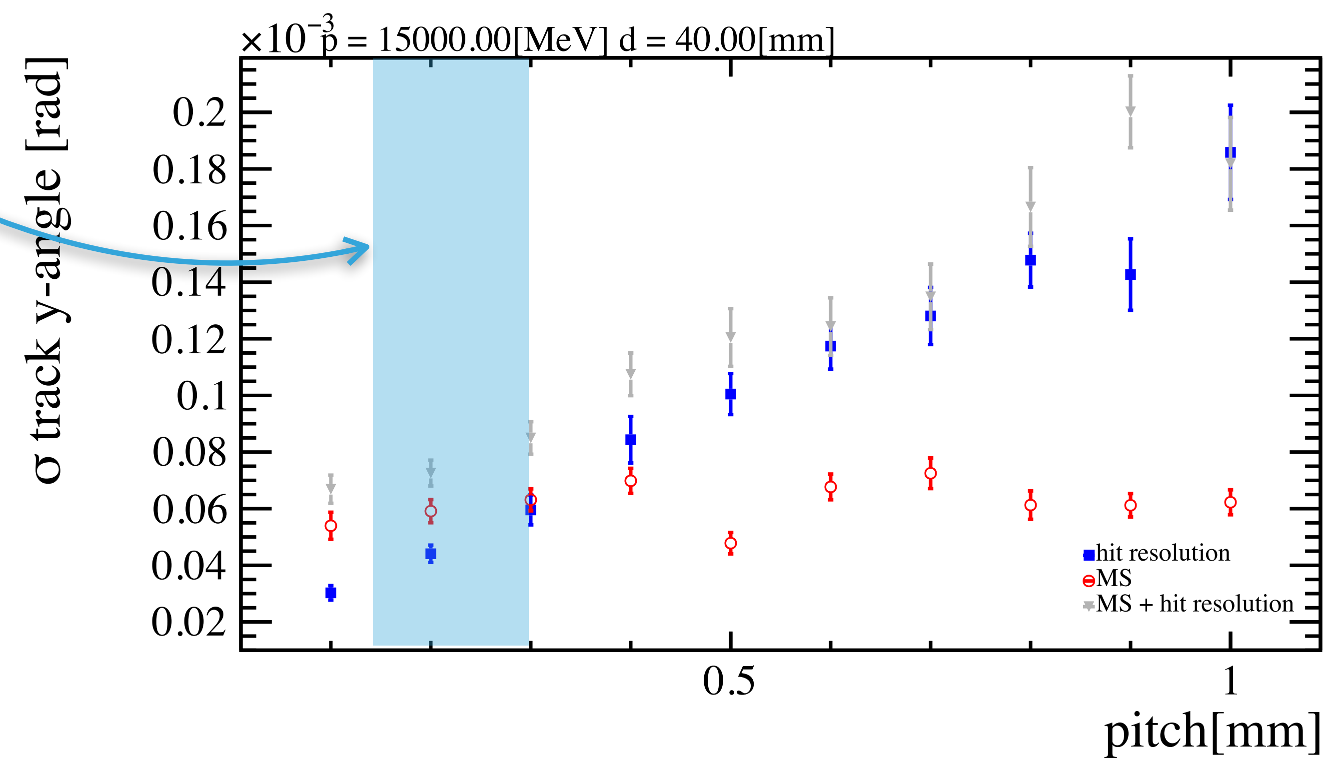


- Extension of IT/MT/SciFi regions
  - Geometrical constraints; Occupancy per SciFi fibre < 2% (MT region)
- IT/MT # layers and arrangement
  - Pixels: track finding efficiency close to 100% if dead area is < 5% with 6 layers
- IT/MT pixel/strip size
  - Occupancy: strips shorter than 100mm needed in IT Upgrade 2
  - Pixel size in x to have momentum resolution as good as Upgrade 1: 100µm
  - Pixel size in y to maximise track angle (wrt then beam axis) resolution. Multiple scattering dominates for pixel size larger than (100-400)µm for tracks of (1.5-40)GeV, with 40mm spacing between layers

MightyPix – pixel size

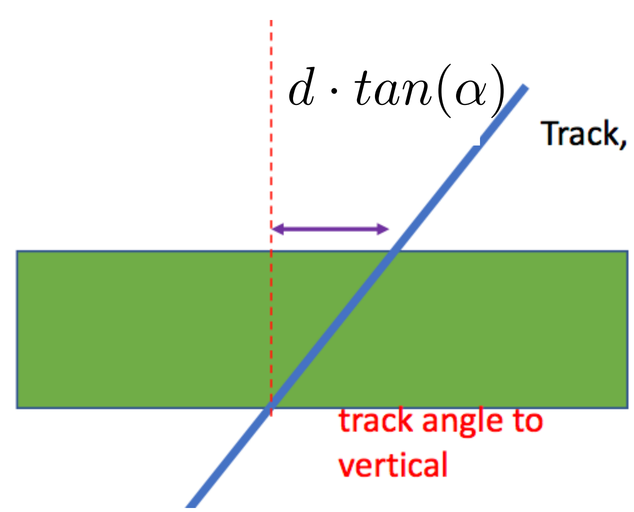
- Baseline: 100µm x 300µm other sizes up to 50µm x 150µm

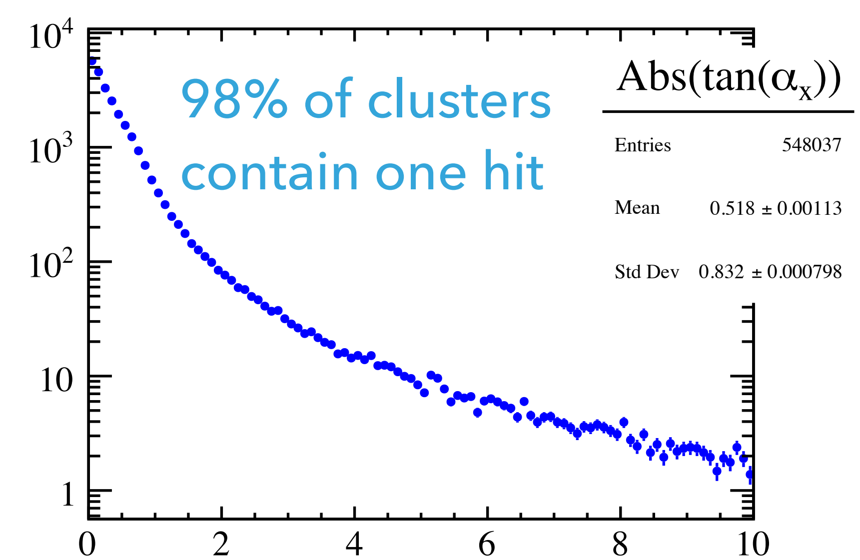




- Further studies on going to refine this number

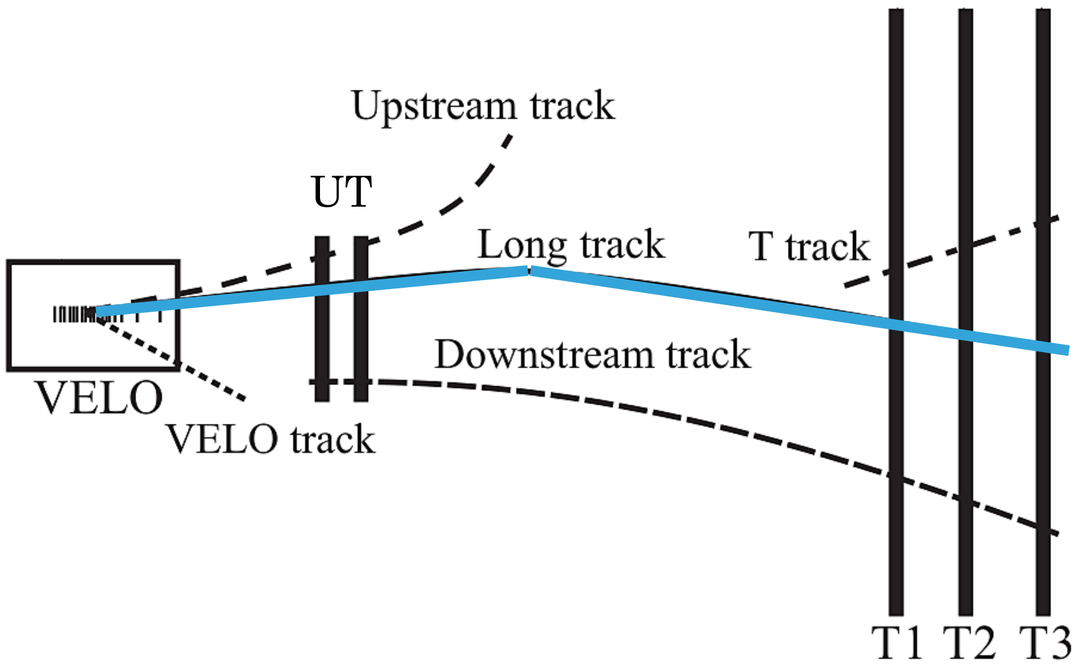
- Cluster size~ 1.02 pixel from geometrical considerations (slope between exit and entry points) other effects may dominate



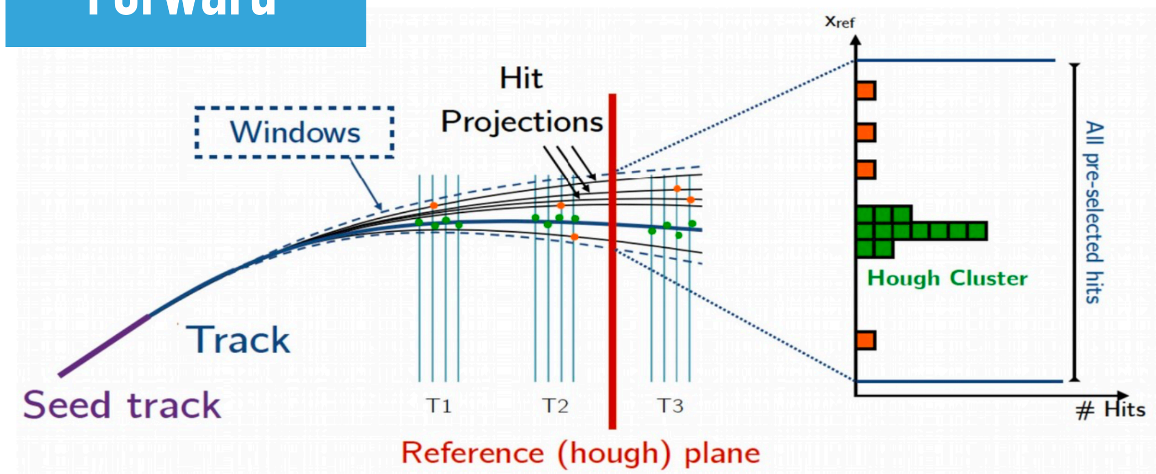


FINDING “LONG: TRACKS – TODAY

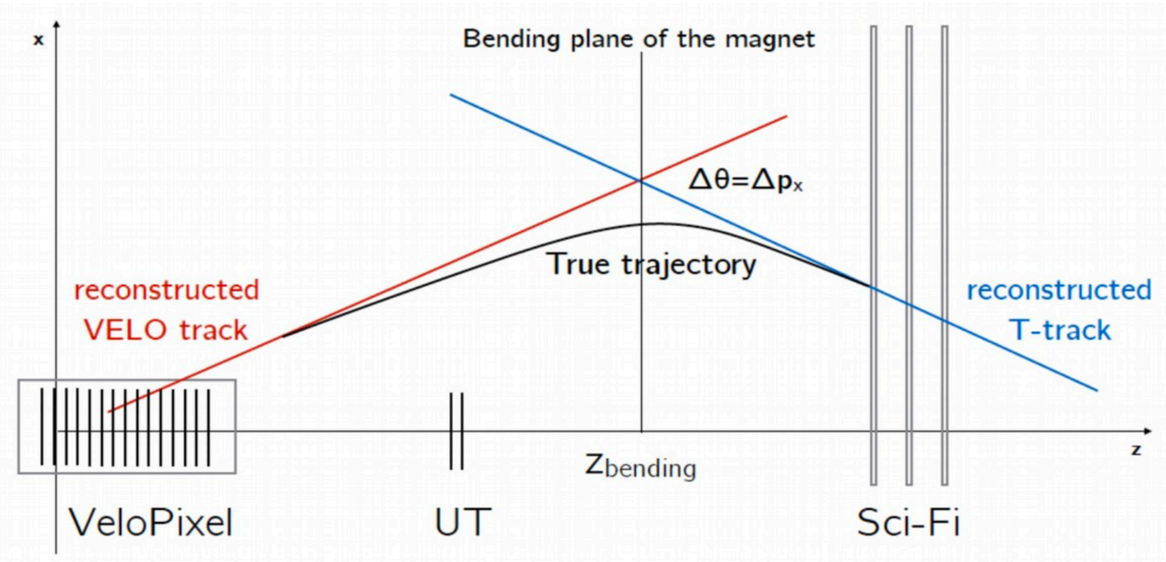
- Long (+downstream) tracks:
  what everyone needs



“Forward”

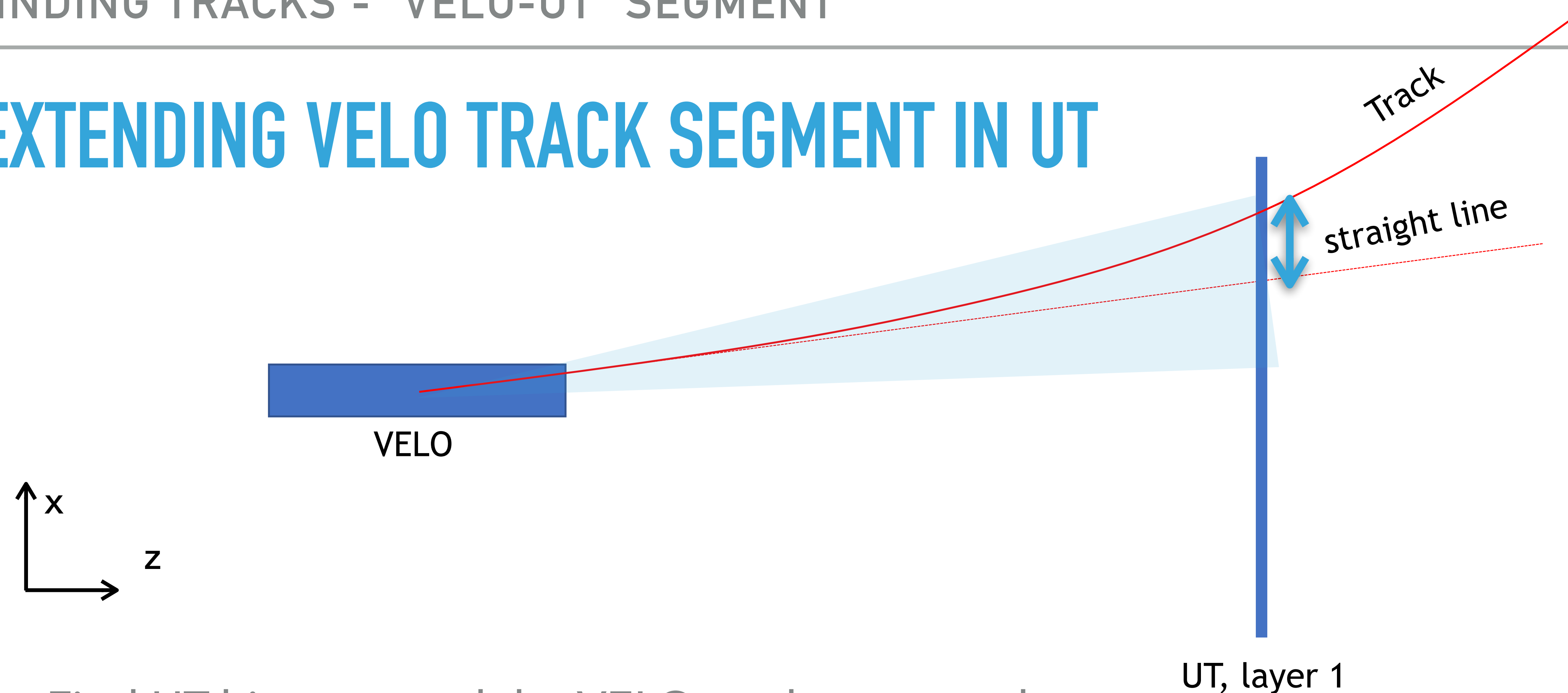


“Matching”

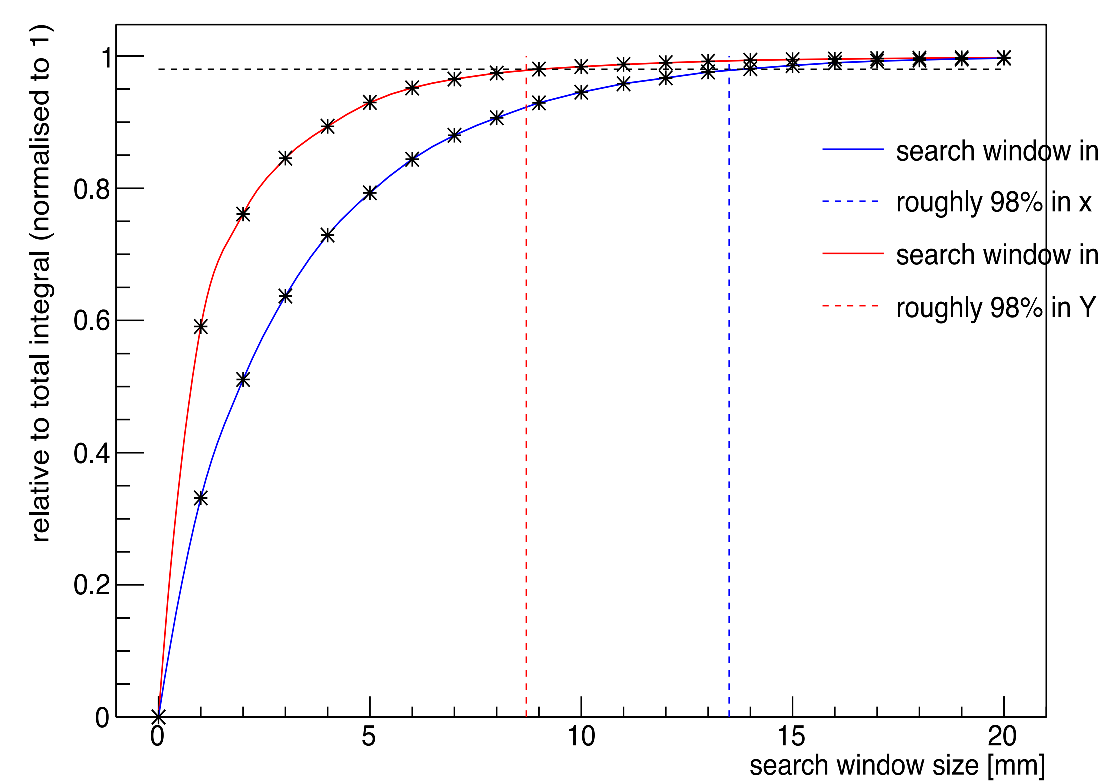


- You need to match VELO(UT) track and either hits on T-stations or T-track
- Following studies use Bs→φφ MC, generated with Upgrade 2 luminosity and Upgrade 1 geometry. MCHits are used (+ smearing to add hit resolution effect)

EXTENDING VELO TRACK SEGMENT IN UT



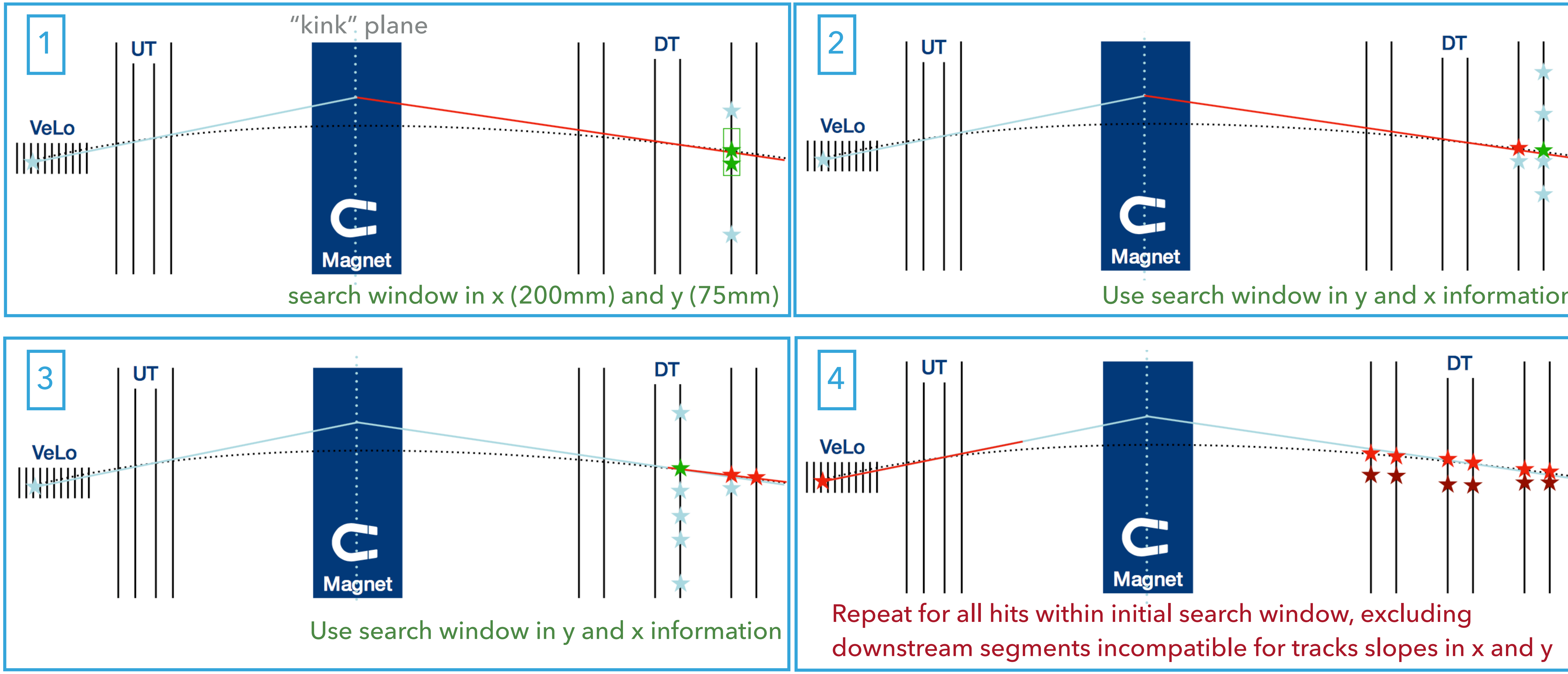
- Find UT hit to extend the VELO track segment by opening a search window in x and y
- 14mm x 9mm search window ensures the correct hit is within the search window more than 98% of the cases; average 7-11 hits within search window
- Next steps: include region dependence and try to reduce fake rate (timing?)



Luke Mitchell, Edinburgh summer student project

Vadym Denysenko 12.02.2020

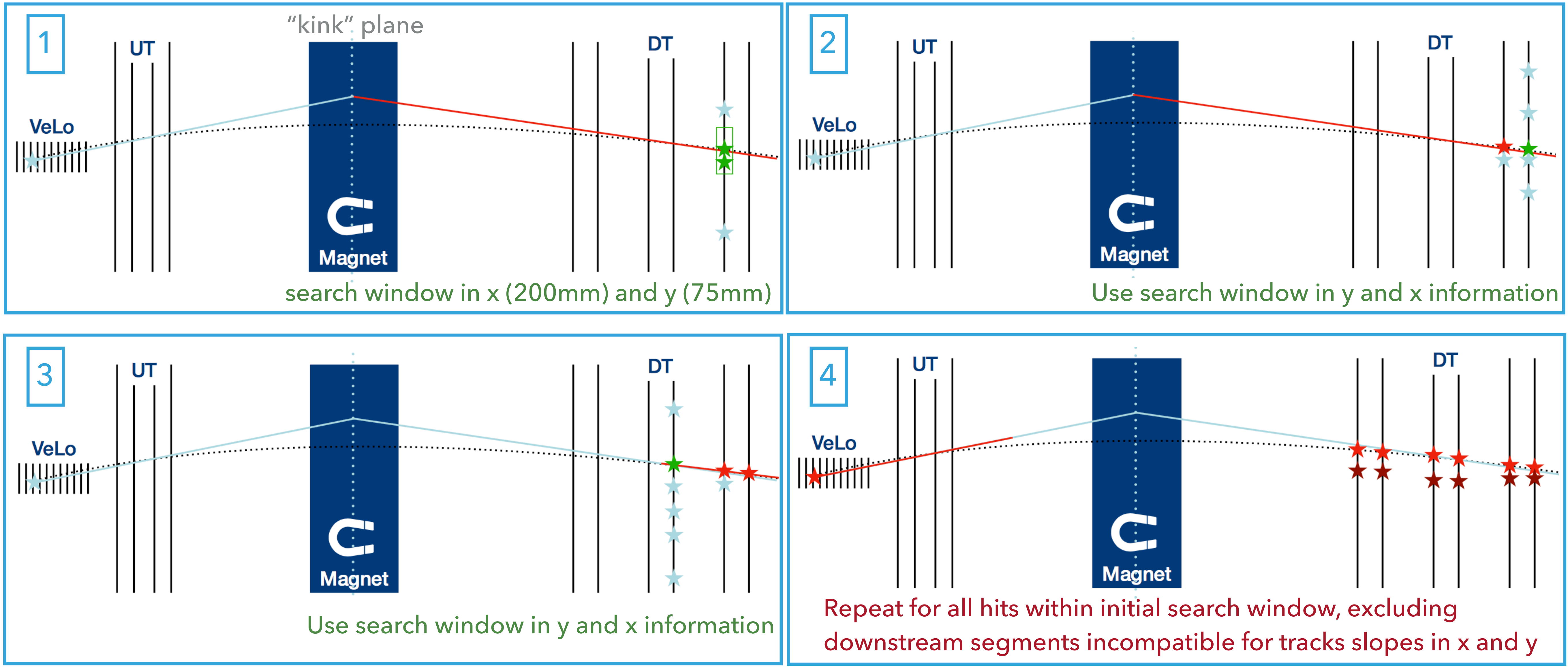
FORWARD TRACKING



- Assuming VeloUT segment
- Find tracks passing basic criteria: not electrons, no secondary interactions between last upstream hit and first downstream hit, minimum number of hits and momentum

FORWARD TRACKING

Vadym Denysenko 12.02.2020



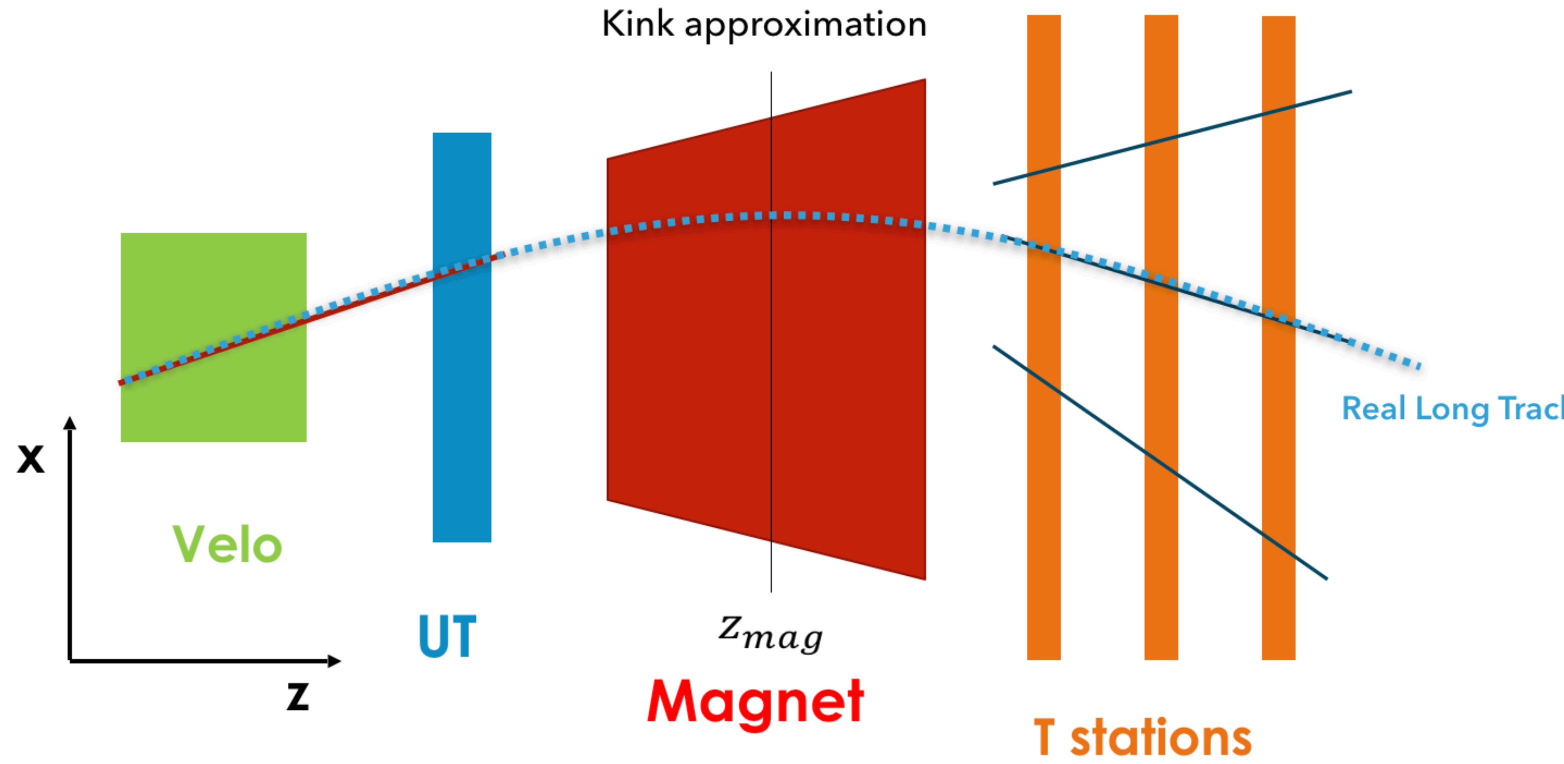
At least 3 downstream hits (1 per station belonging to the correct particle)

$$efficiency = \frac{correctly\ reconstructed\ tracks}{tracks\ used\ (reconstructible\ tracks)} * 100\,\% \quad \sim 95\%$$

$$ghost\ rate = \frac{wrongly\ reconstructed\ tracks}{reconstructed\ tracks\ (wrong + correct)} * 100\,\% \quad \sim 33\%$$

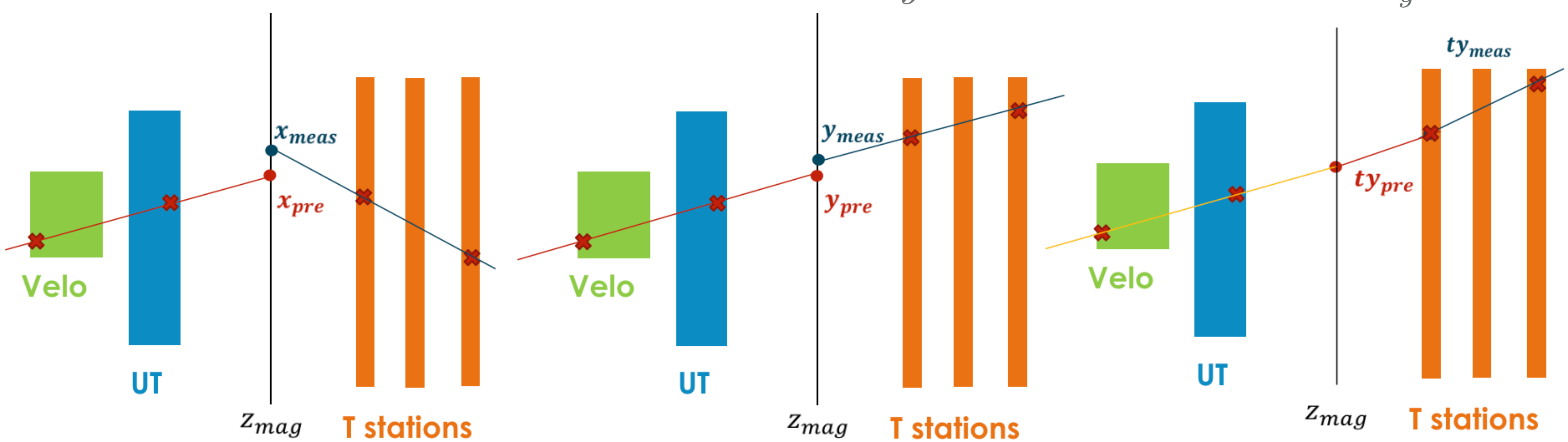
- **First study**. Next steps: investigate strategies to reduce the fake rate

TRACK MATCHING



- Assuming stand-alone track reconstruction in then T-stations is possible,
- Match the VELO-UT segments to the T-station segments, by minimising:

$$\chi^2_{\text{match}} = \frac{(x_{pred} - x_{meas})^2}{\sigma_x^2} + \frac{(y_{pred} - y_{meas})^2}{\sigma_y^2} + \frac{(t_{y\,pred} - t_{y\,meas})^2}{\sigma_{t_y}^2}$$



Irene Cortinovis, Zurich student project   Alessandro Scarabotto, CERN summer student project

TRACK MATCHING

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

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

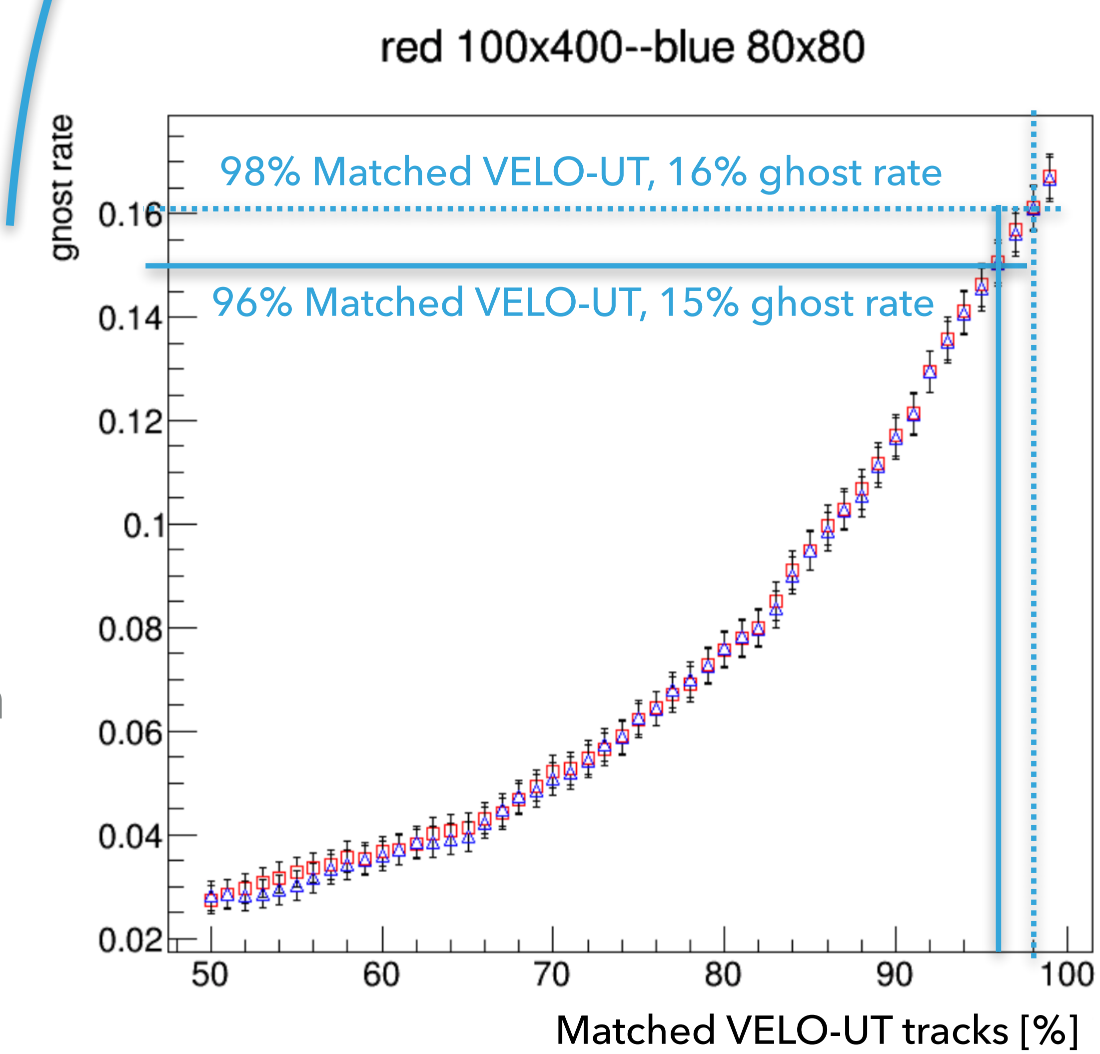
	Upgrade 1	Upgrade 2
Efficiency	0.968 ± 0.005	0.932 ± 0.003
Ghost rate	0.127 ± 0.008	0.173 ± 0.004

Upgrade 1 luminosity, using same algorithm

- Dominant contribution to these ghost rates is from tracks not reaching the T-stations (cut applied for following studies)

If for every VELO-UT track a match is found.

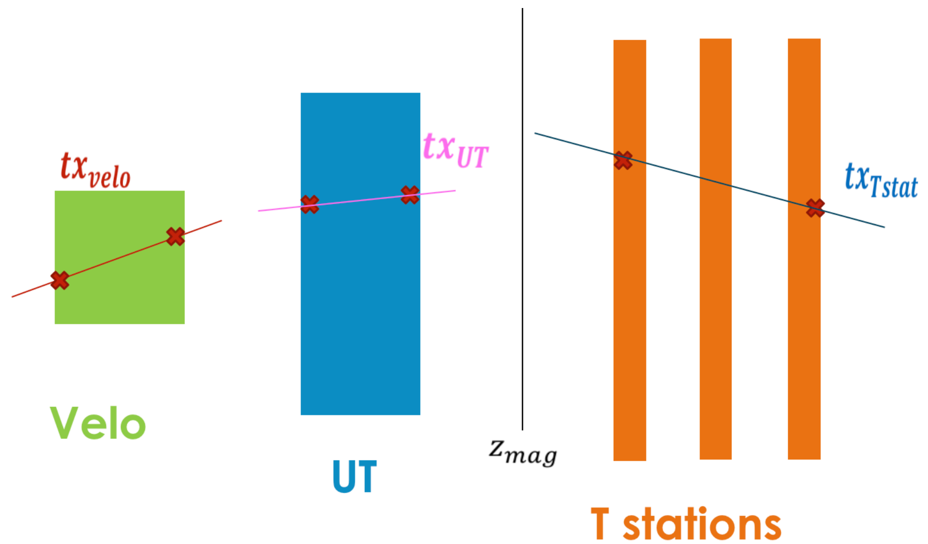
Discarding VELO-UT with too high X^2:



Irene Cortinovis, Zurich student project Alessandro Scarabotto, CERN summer student project

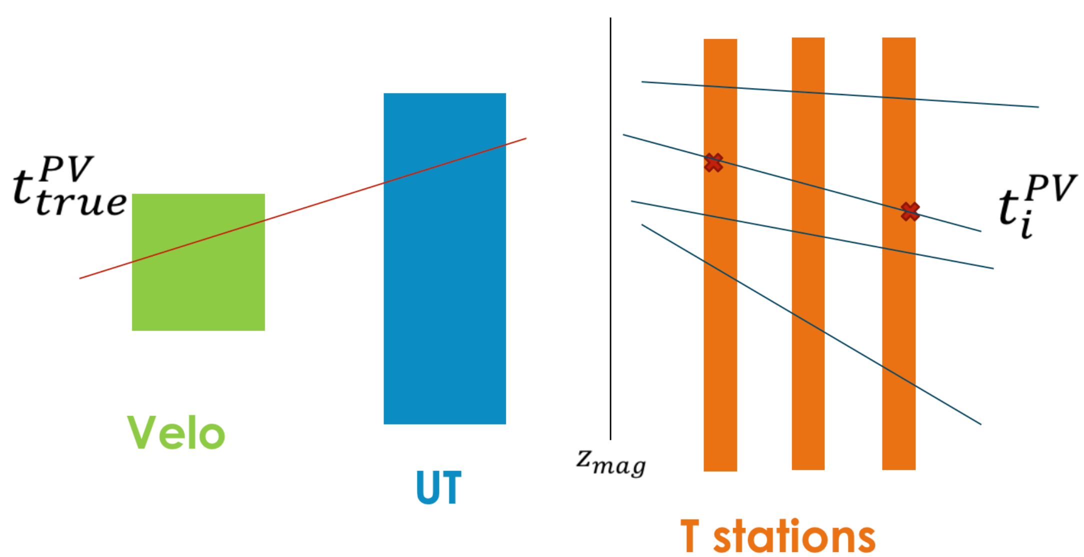
TRACK MATCHING – ADDING MOMENTUM & (PV) TIMING

$$\chi^2_{\mathrm{match}} = \frac{(x_{pred} - x_{meas})^2}{\sigma_x^2} + \frac{(y_{pred} - y_{meas})^2}{\sigma_y^2} + \frac{(t_{y_{pred}} - t_{y_{meas}})^2}{\sigma_{t_y}^2} + \frac{(p_{VeloUT} - p_{Tstat})^2}{\sigma^2_{p,VeloUT} + \sigma^2_{p,Tstat}}$$



- VELO-UT momentum resolution ~15%
- VELO-T-stations momentum resolution ~2%

$$\chi^2_{\mathrm{match}} = \frac{(x_{pred} - x_{meas})^2}{\sigma_x^2} + \frac{(y_{pred} - y_{meas})^2}{\sigma_y^2} + \frac{(t_{y_{pred}} - t_{y_{meas}})^2}{\sigma_{t_y}^2} + \frac{(t^{PV}_{velo} - t^{PV}_{Tstat})^2}{\sigma^2_{velo} + \sigma^2_{Tstat}}$$

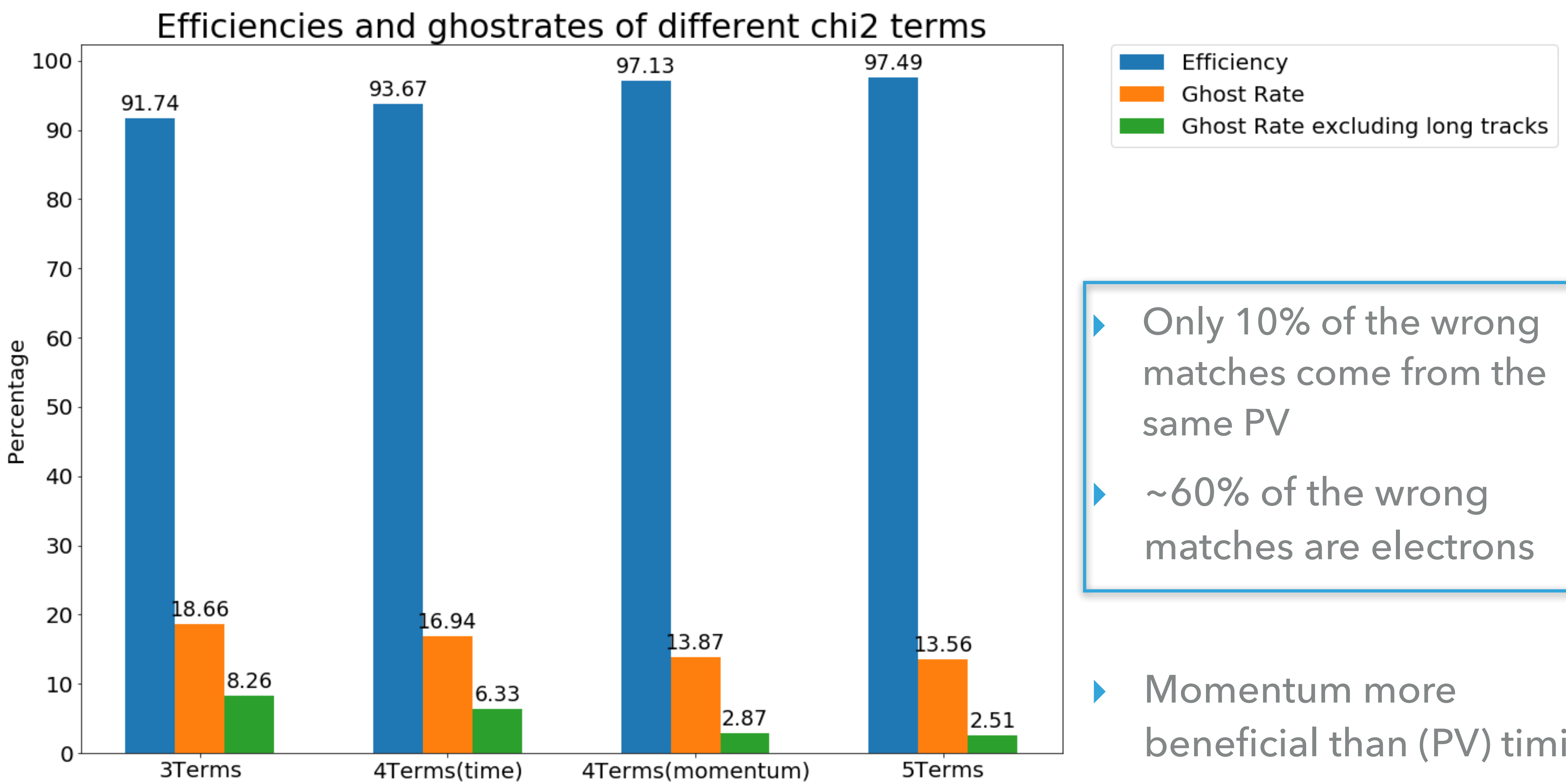


- time resolution assumed to be 30ps $\sigma_{velo}, \sigma_{Tstat}$

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

TRACK MATCHING – MOMENTUM & TIMING

$$\chi^2_{\text{match}} = \frac{(x_{pred} - x_{meas})^2}{\sigma_x^2} + \frac{(y_{pred} - y_{meas})^2}{\sigma_y^2} + \frac{(t_{y\,pred} - t_{y\,meas})^2}{\sigma_{t_y}^2} + \frac{(p_{VeloUT} - p_{Tstat})^2}{\sigma^2_{p,VeloUT} + \sigma^2_{p,Tstat}} + \frac{(t^{PV}_{Velo} - t^{PV}_{Tstat})^2}{\sigma^2_{t,Velo} + \sigma^2_{t,Tstat}}$$

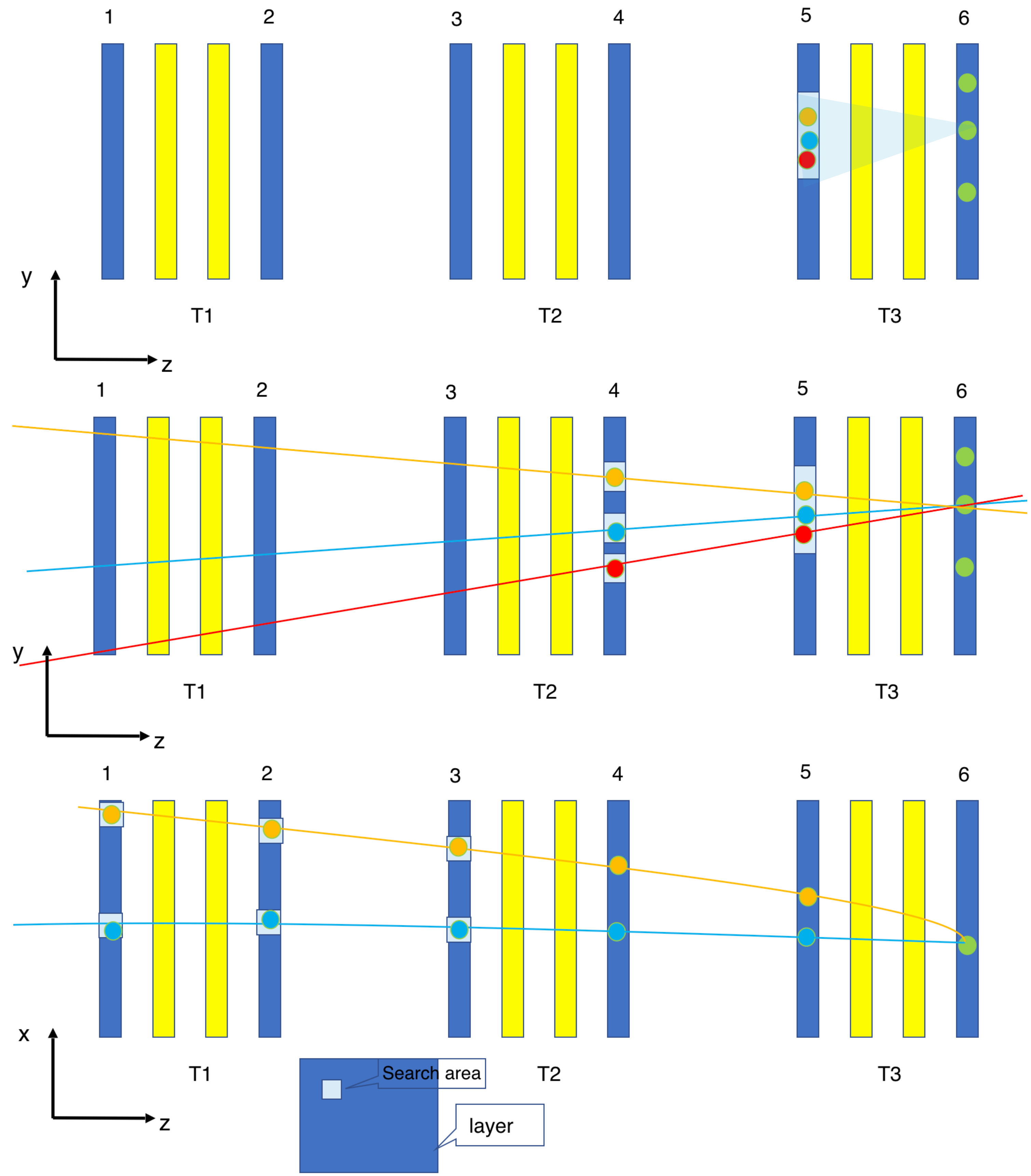


- Only 10% of the wrong matches come from the same PV
- ~60% of the wrong matches are electrons

- Momentum more beneficial than (PV) timing

T-TRACK FINDING

- distance between pair of layers is current x1-x2 distance, baseline pixels: good hit resolution in x and y
- start from all the hits in the highest z layer and open a search window in y
- for each pair of hits search third hit within y search window
- for each set of 3 hits used linear and parabolic extrapolation to centre a x-y search window to find the hits in the following layers



Jiazhen Tang, CERN summer student project

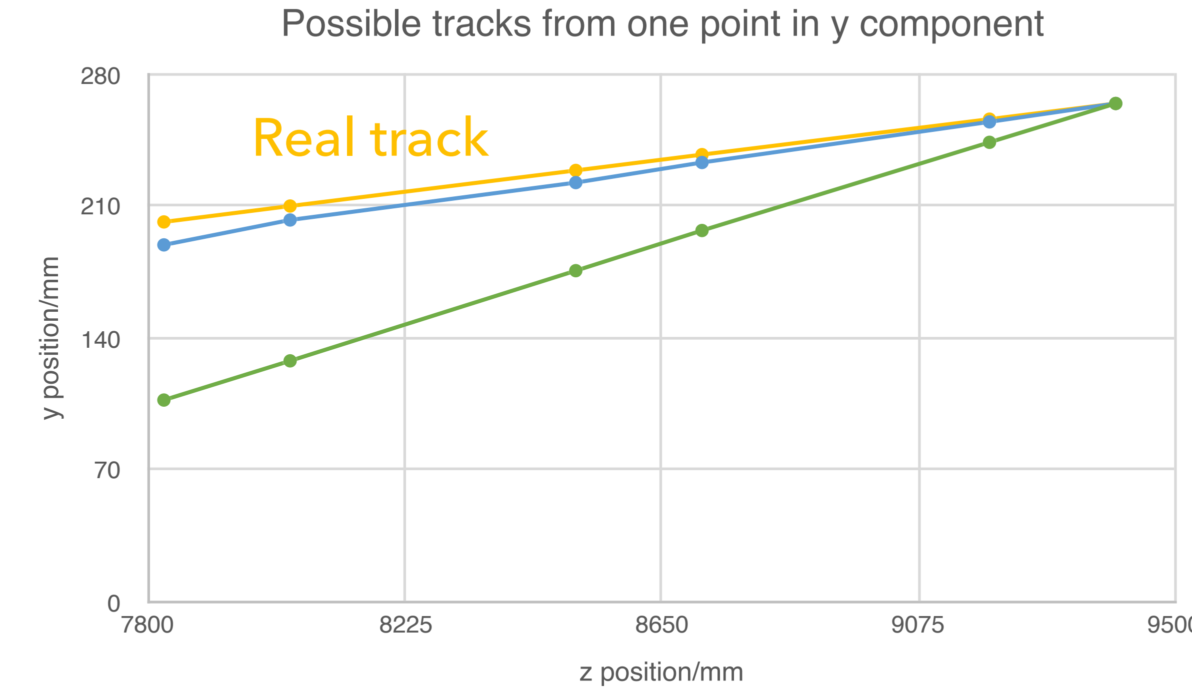
T-TRACK FINDING

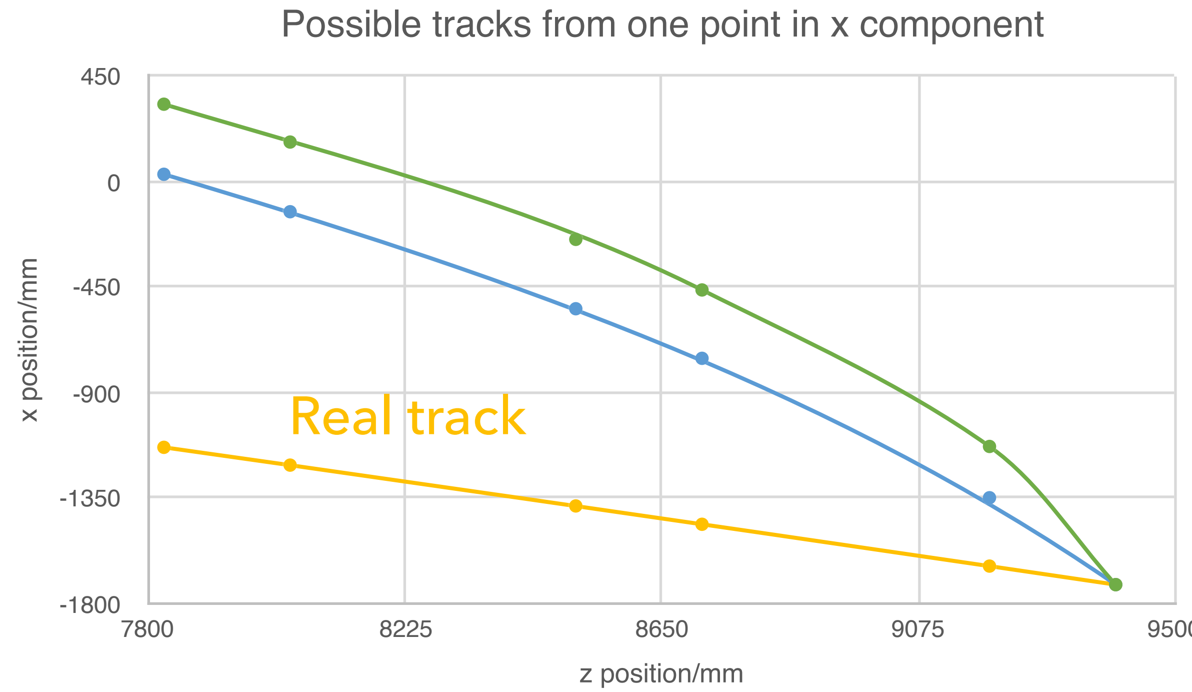
- Multiple track candidates for the same initial hit: for p>5GeV the less curved candidate (in x) is the real track in most of the cases, for now choosing candidate including hits closer to the predictions

$$Efficiency = \frac{reconstructed\ track}{reconstructible\ track}$$

$$Ghost\ Rate = \frac{fake\ track}{reconstructed\ track}$$

	tight search window	loose search window
Efficiency	89.0%	93.9%
Ghost rate	12.9%	15.7%





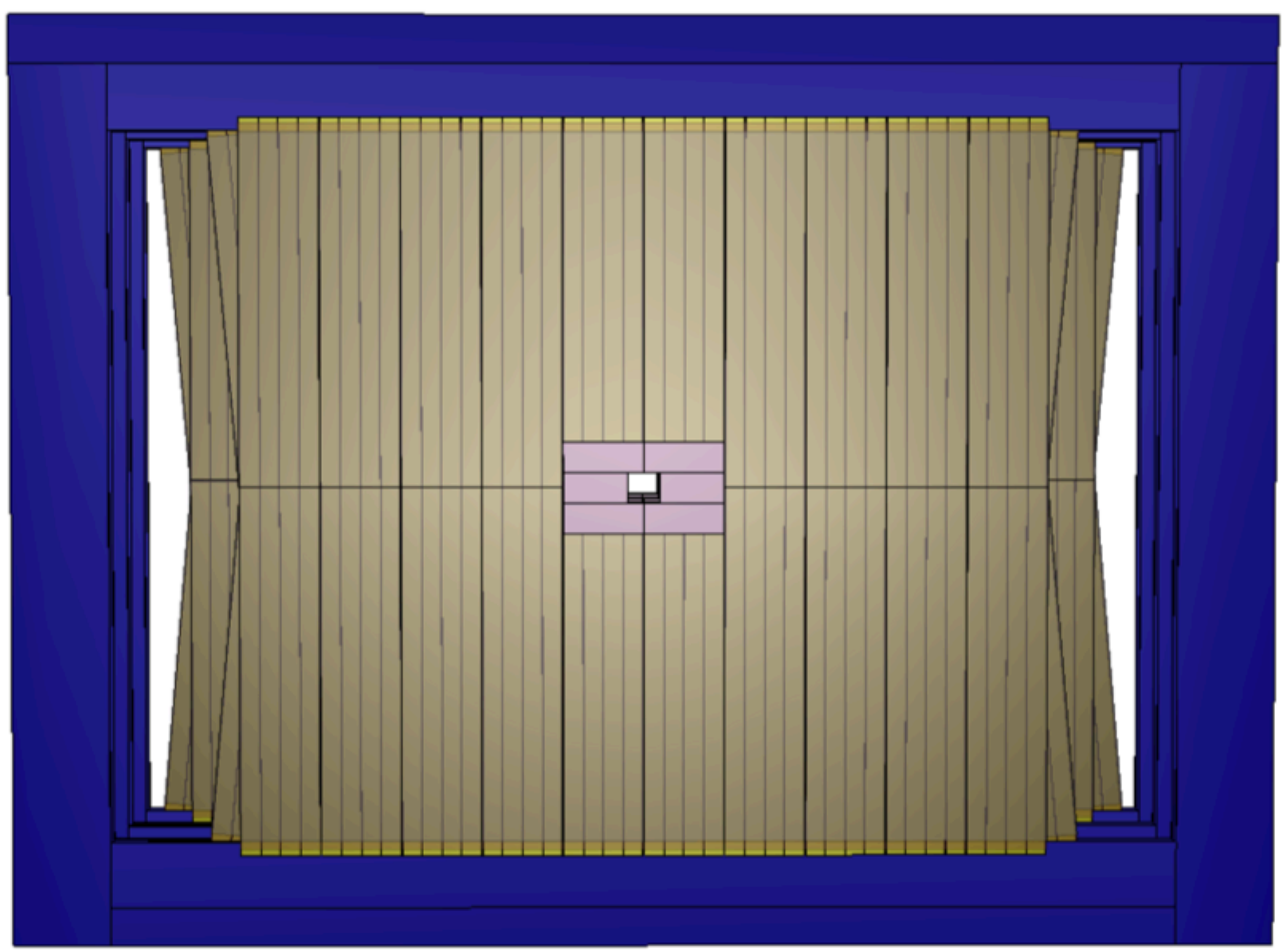
- **Very first study**. several improvements to make it more performing and more realistic

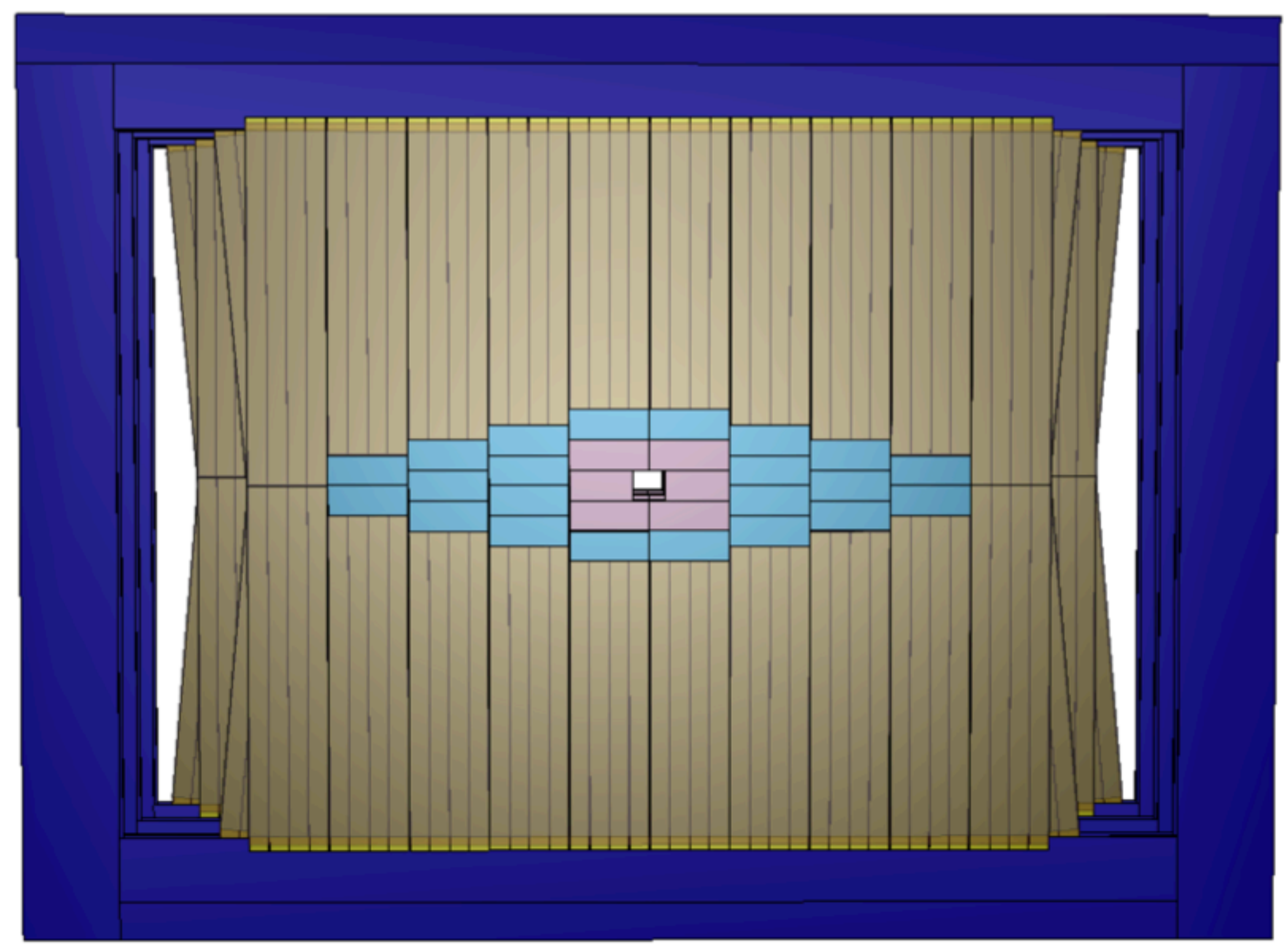
Jiazhen Tang, CERN summer student project

DETECTOR DESCRIPTION

Tai-Hua Lin 04.03.2020

- Full geometry of Mighty Tracker implemented in DD4hep
- Passive material not (decided and) implemented yet
- Some details like gap sizes needs to be confirmed
- Will allow for more realistic track reconstruction studies!





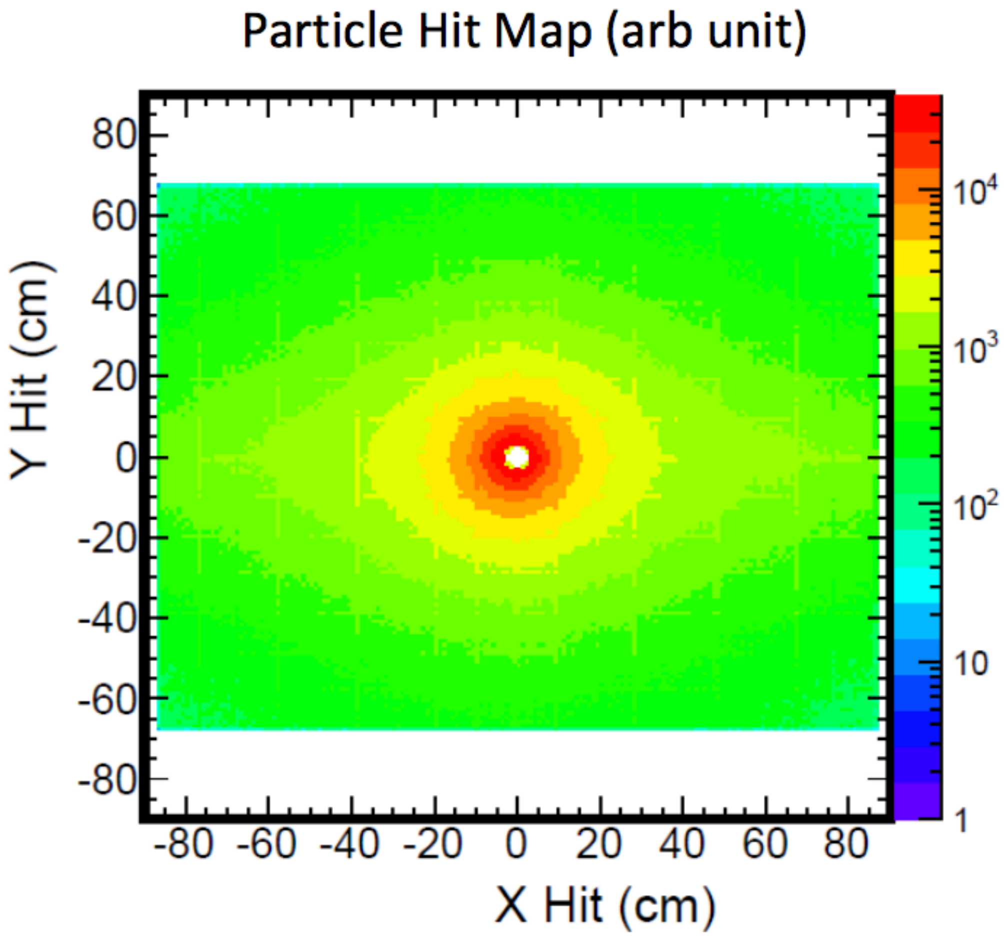
OUTLOOK

- Open design questions/optimization
  - Pixel size, module design (material, support, structure), strategy for Upgrade 1b
- First track reconstruction performance studies (using MCHits)
  - First pattern recognition algorithm for MT implemented - few more ideas to be tried and hits in the fibre region to be added: tool to optimise pixel size/layer spacing
  - Extension of VELO track segment with UT hits and downstream hits to be better investigated (might be profit from timing?)
  - Upstream/downstream track segment matching looks promising, momentum looks more beneficial than timing
- Progress in DD4hep detector geometry description
  - Geometry implemented in DD4hep, next steps: material implementation and realistic tracking studies
- Good progress so far, but a lot still to do

BACKUP

UT OCCUPANCY – UPGRADE 1

Jianchun Wang, Quan Zou, Yiming Li, 18.03.2020



- Minimum bias (MB) events used to estimate the strip occupancy and the number of hits to be recorded
- At inner sensors the average occupancy is ~1%. Some ASICs are higher ~2%

Number of Strips / Event / Sensor

0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3
0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3
0.4	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.2	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4
0.5	0.5	0.6	0.8	0.9	1.1	1.4	1.6	1.8	1.9	1.6	1.3	1.1	0.9	0.7	0.6	0.5	0.5
0.6	0.7	0.8	1.0	1.3	1.6	2.0	2.7	3.2	3.1	2.5	2.0	1.5	1.2	1.0	0.7	0.6	0.5
0.7	0.8	1.0	1.3	1.7	2.2	2.9	5.8	7.8	7.7	5.2	2.9	2.1	1.6	1.3	1.0	0.8	0.7
1.0	1.1	1.3	1.6	2.0	2.7	3.9	9.2	20.2	18.1	7.9	3.7	2.6	2.0	1.6	1.3	1.1	1.0
1.0	1.1	1.3	1.6	2.0	2.7	4.0	9.4	19.6	18.1	7.7	3.7	2.5	2.0	1.6	1.3	1.1	1.0
0.7	0.9	1.1	1.4	1.7	2.2	3.1	5.9	8.0	7.5	5.1	2.8	2.1	1.6	1.3	1.0	0.8	0.7
0.6	0.7	0.8	1.0	1.3	1.6	2.1	2.8	3.1	3.2	2.5	2.0	1.5	1.2	0.9	0.8	0.6	0.5
0.5	0.6	0.7	0.8	1.0	1.1	1.4	1.7	1.8	1.9	1.6	1.3	1.1	0.9	0.7	0.6	0.5	0.4
0.4	0.5	0.5	0.6	0.7	0.8	0.9	1.1	1.1	1.2	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4
0.4	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3
0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3

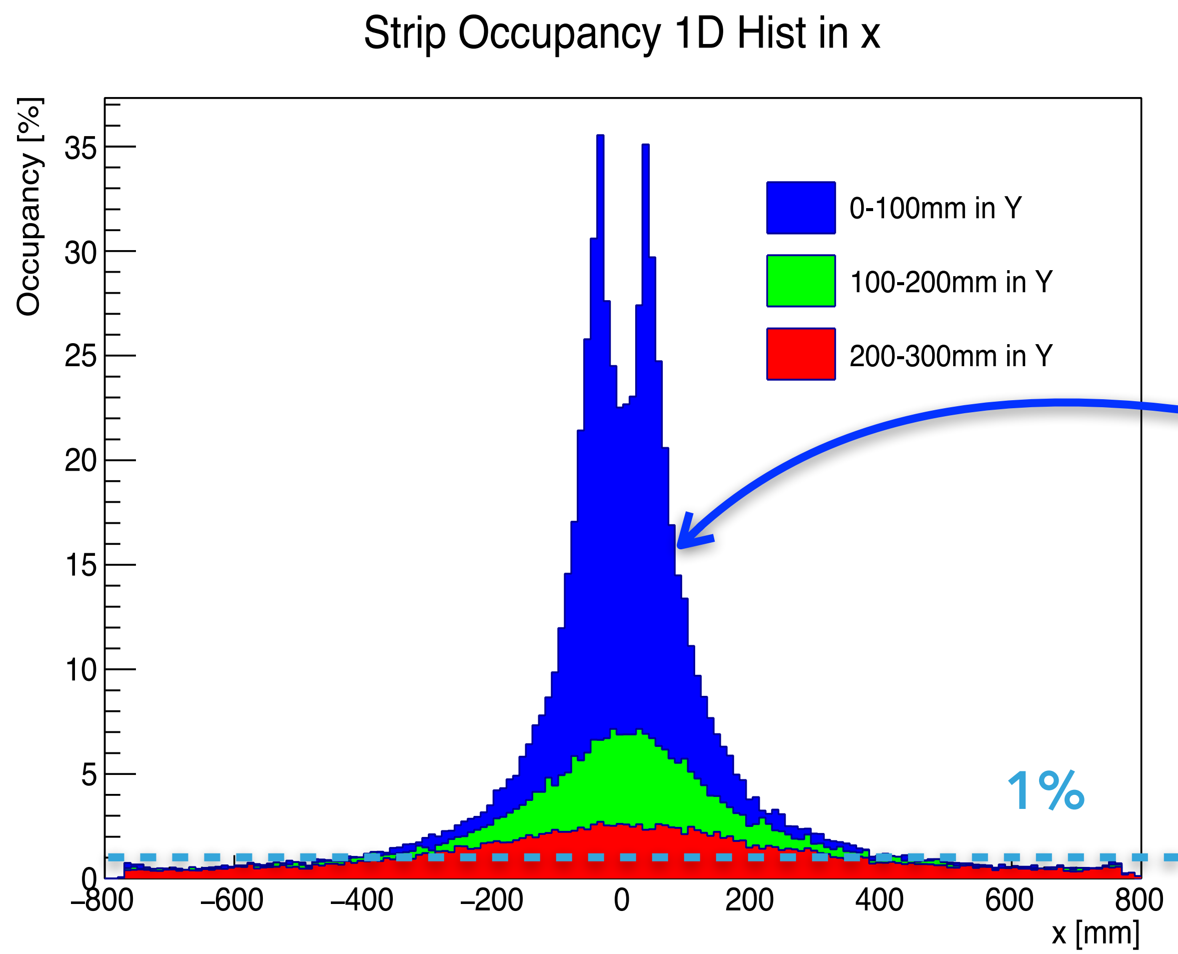
Strip Occupancy in MB events (%)

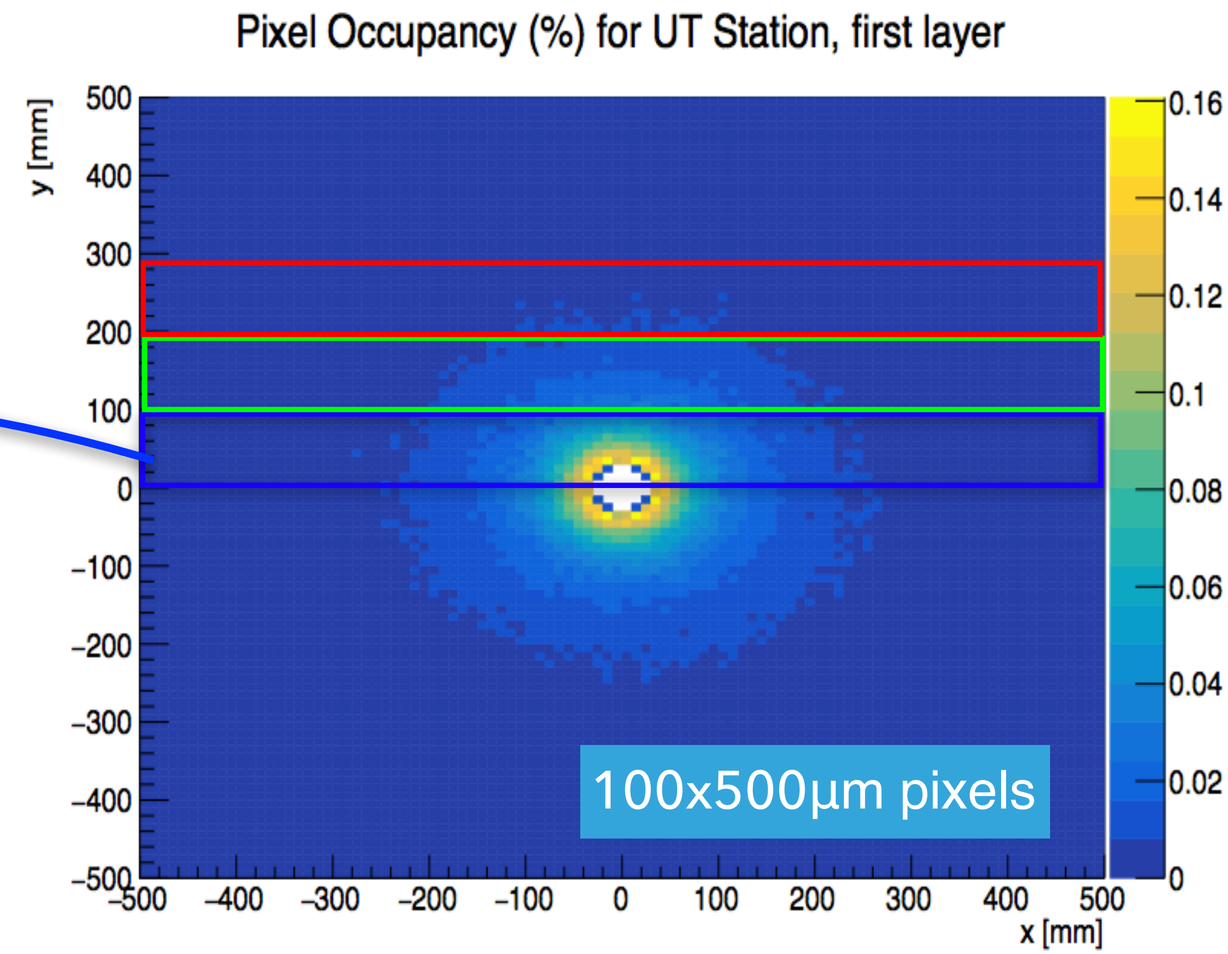
0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.11	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.06
0.07	0.08	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.15	0.14	0.13	0.11	0.10	0.09	0.08	0.07	0.07
0.08	0.09	0.10	0.12	0.13	0.16	0.18	0.20	0.22	0.23	0.20	0.17	0.15	0.13	0.11	0.10	0.08	0.07
0.09	0.11	0.13	0.15	0.18	0.22	0.26	0.32	0.35	0.36	0.31	0.26	0.21	0.17	0.14	0.12	0.10	0.09
0.11	0.13	0.16	0.19	0.24	0.31	0.39	0.52	0.62	0.61	0.49	0.38	0.30	0.24	0.19	0.15	0.12	0.11
0.13	0.16	0.20	0.26	0.32	0.43	0.58	0.57	0.76	0.75	0.50	0.57	0.41	0.32	0.25	0.20	0.16	0.13
0.19	0.22	0.26	0.31	0.40	0.52	0.76	0.90	0.99	0.88	0.77	0.72	0.50	0.38	0.31	0.26	0.22	0.19
0.19	0.22	0.26	0.32	0.39	0.54	0.77	0.91	0.96	0.89	0.76	0.72	0.49	0.39	0.31	0.26	0.22	0.19
0.14	0.17	0.21	0.26	0.33	0.44	0.60	0.58	0.79	0.73	0.50	0.55	0.41	0.31	0.24	0.20	0.16	0.13
0.11	0.14	0.16	0.20	0.25	0.32	0.40	0.54	0.61	0.62	0.48	0.38	0.29	0.24	0.19	0.15	0.12	0.11
0.10	0.11	0.13	0.15	0.19	0.22	0.27	0.33	0.36	0.36	0.31	0.26	0.21	0.17	0.14	0.12	0.10	0.09
0.08	0.09	0.10	0.12	0.14	0.16	0.18	0.21	0.22	0.23	0.20	0.18	0.15	0.13	0.11	0.10	0.08	0.07
0.07	0.08	0.09	0.09	0.11	0.12	0.13	0.15	0.15	0.15	0.14	0.12	0.11	0.10	0.09	0.08	0.07	0.07
0.06	0.07	0.07	0.08	0.09	0.10	0.10	0.11	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.07	0.06	0.06

Luke Mitchell, Edinburgh summer student project

UT OCCUPANCY - UPGRADE 2

- Could imagine equipping using HVCMOS of IT and/or outer part with silicon strips
- Occupancy / radiation requirements an order of magnitude higher than in Mighty Tracker

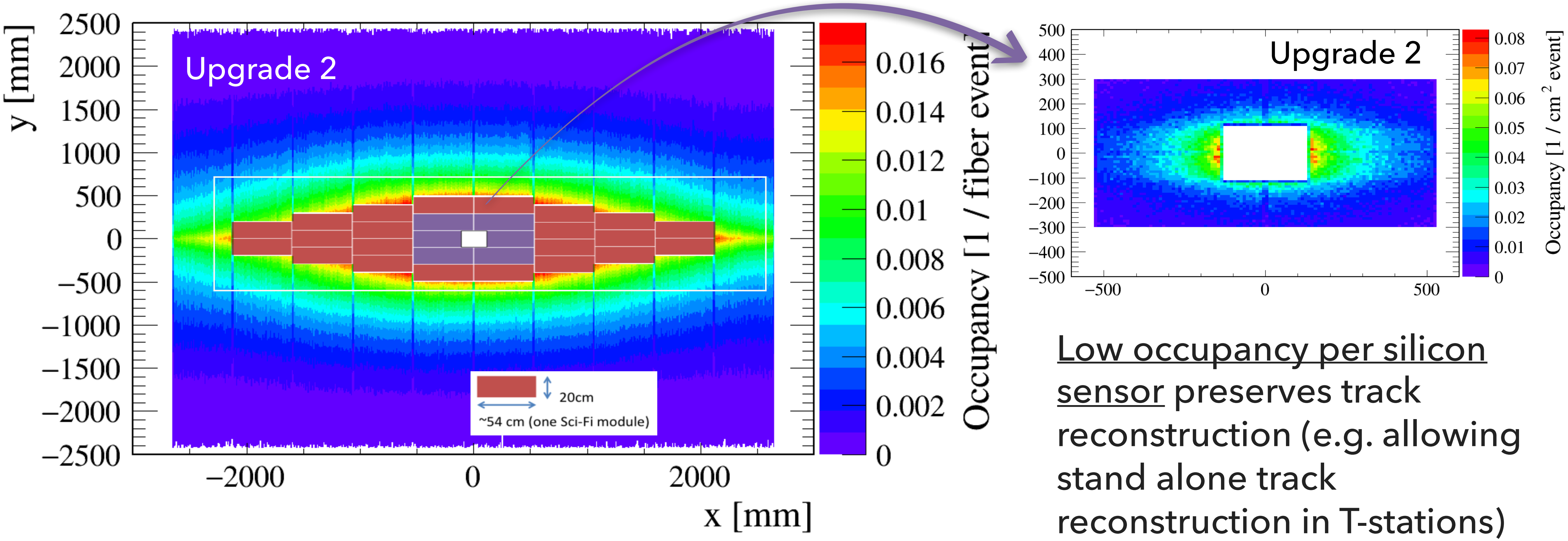




- From occupancy considerations, strips in external region (2/3 of the area) feasible, pixels internally (1/3 of the area)

OCCUPANCY STUDIES

- Hybrid modules: same width for IT/MT and SciFi modules



Low occupancy per silicon sensor preserves track reconstruction (e.g. allowing stand alone track reconstruction in T-stations)

Constraint on occupancy of the SciFi to Upgrade 1 occupancy (to preserve tracking performance and contain radiation damage of the fibres) sets the MT dimension

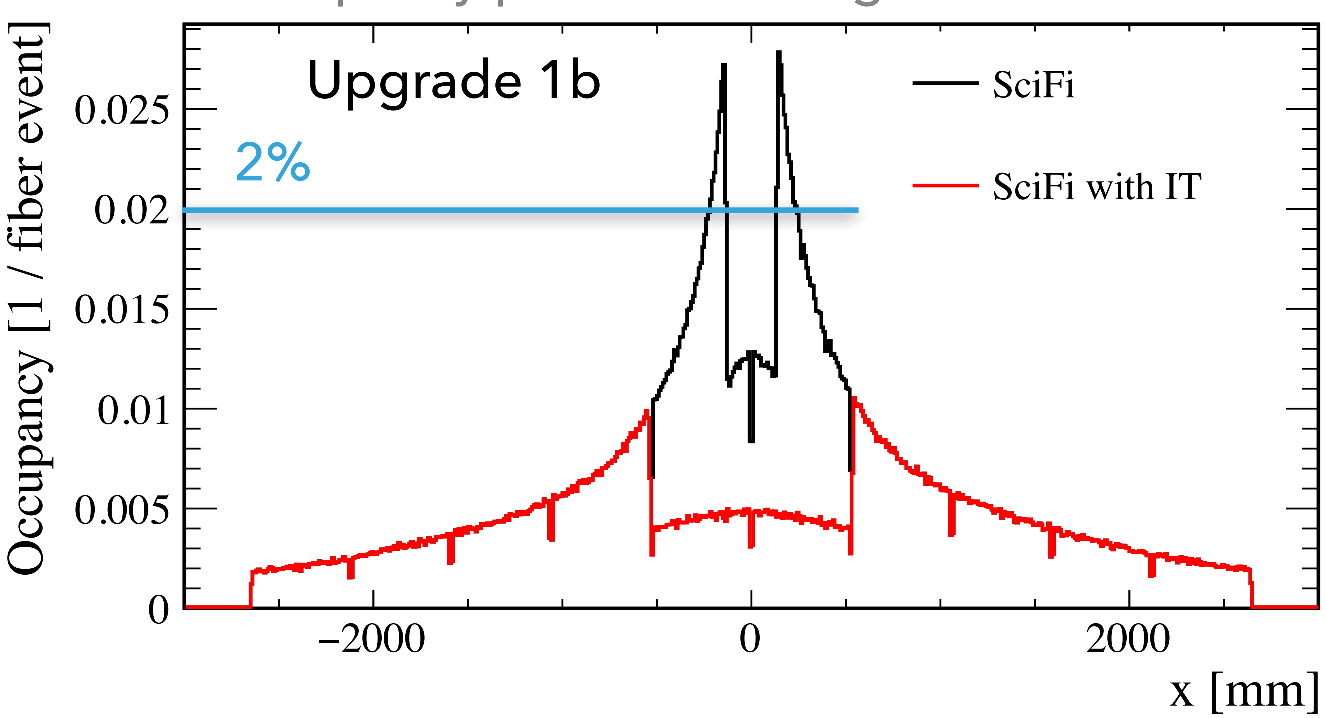
- Number of hits obtained from Geant4 simulation (MCHits) - safety factors needed for: pp collisions, tracking threshold, material assumes the full SciFi

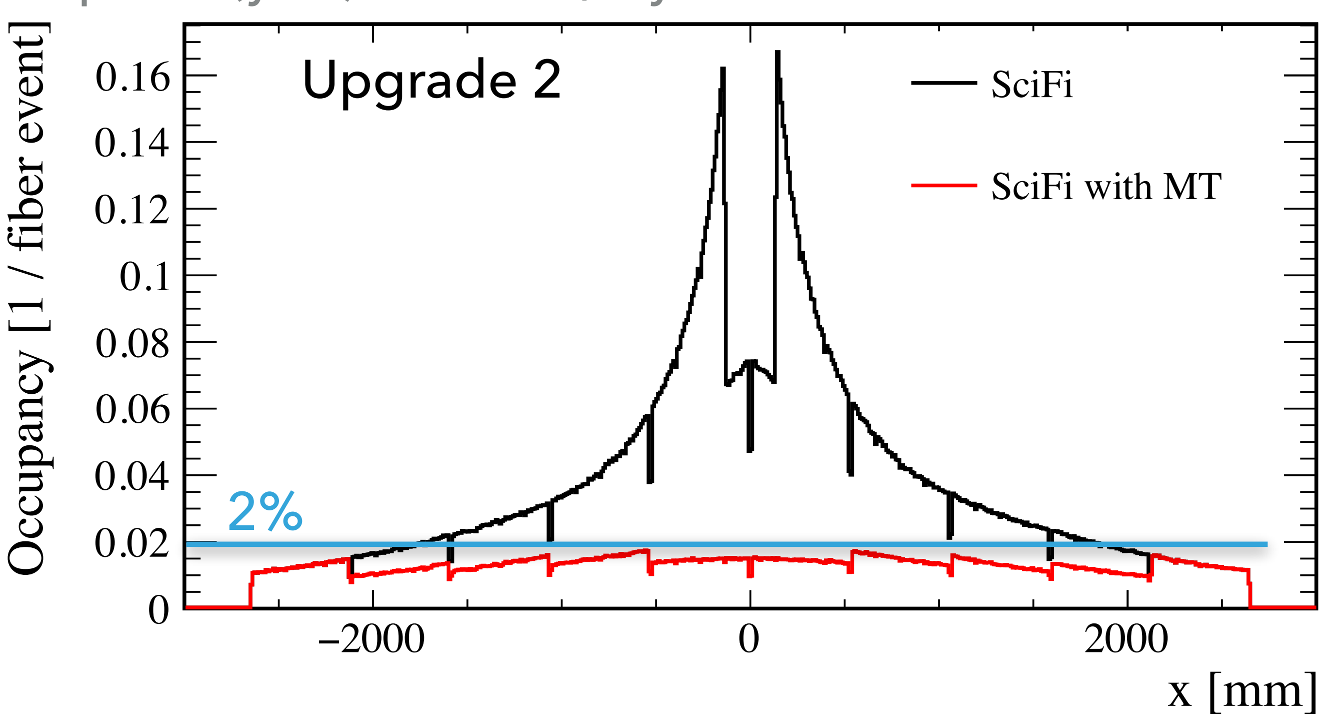
OCCUPANCY STUDIES - SCIFI

- Choice of MT size: maximum occupancy in Upgrade 2 in SciFi does not exceed the occupancy of SciFi in Upgrade 1
- Maximum integrated occupancies along the fibres

	Maximum integrated occupancy in %	
	Upgrade Ib	Upgrade II
SciFi only	3.2 ± 0.2	18.4 ± 0.4
With IT	1.4 ± 0.1	6.8 ± 0.3
With IT + MT	-	1.7 ± 0.1

Occupancy per fibre averaged over 40 fibres in top half (y>0) station 1, layer 1





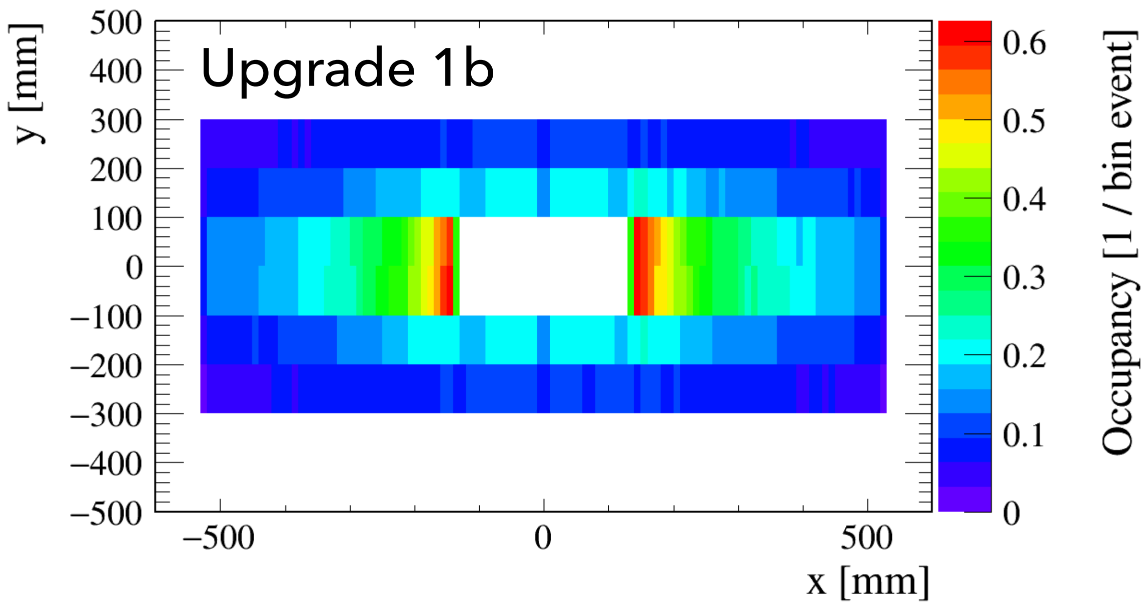
OCCUPANCY STUDIES – IT & MT

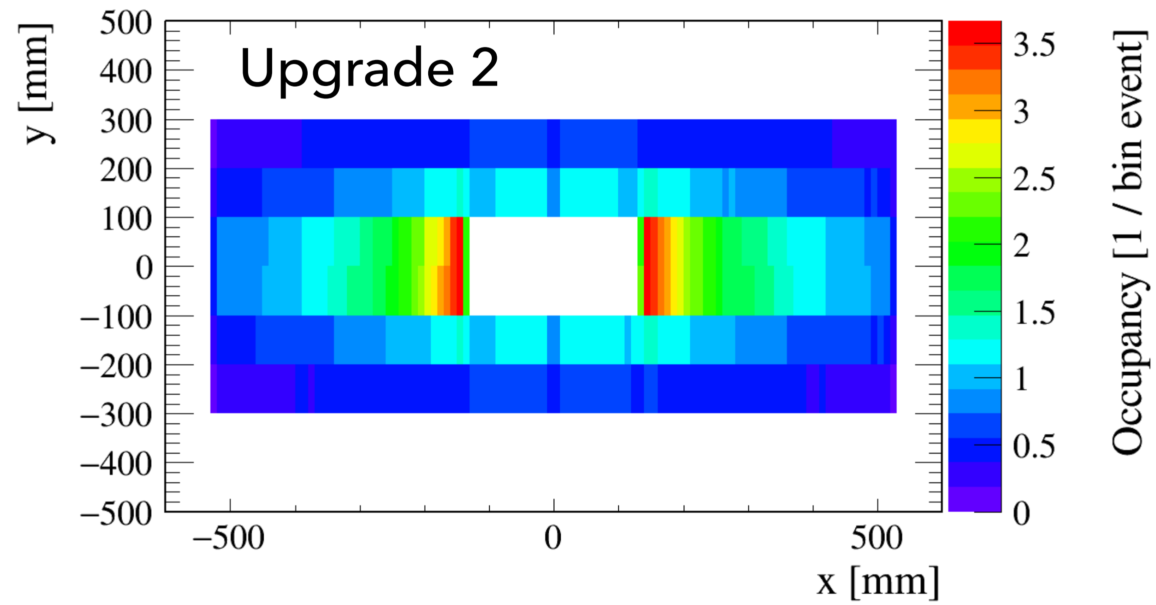
- Could we use silicon strips?
- Estimated the occupancy per pixel/strip in IT & MT

	Maximum IT occupancy [hits/(pixel or strip)/event] in %	
	(100 × 500) µm pixels	(0.1 × 100) mm strips
Upgrade Ib	0.0032 ± 0.0002	0.65 ± 0.01
Upgrade II	0.019 ± 0.001	3.8 ± 0.3

	Maximum MT occupancy [hits/(pixel or strip)/event] in %	
	(100 × 500) µm pixels	(0.1 × 100) mm strips
Upgrade II	0.0041 ± 0.0007	0.82 ± 0.13

Occupancy per bin (0.1mm x100 mm - strip size) per event

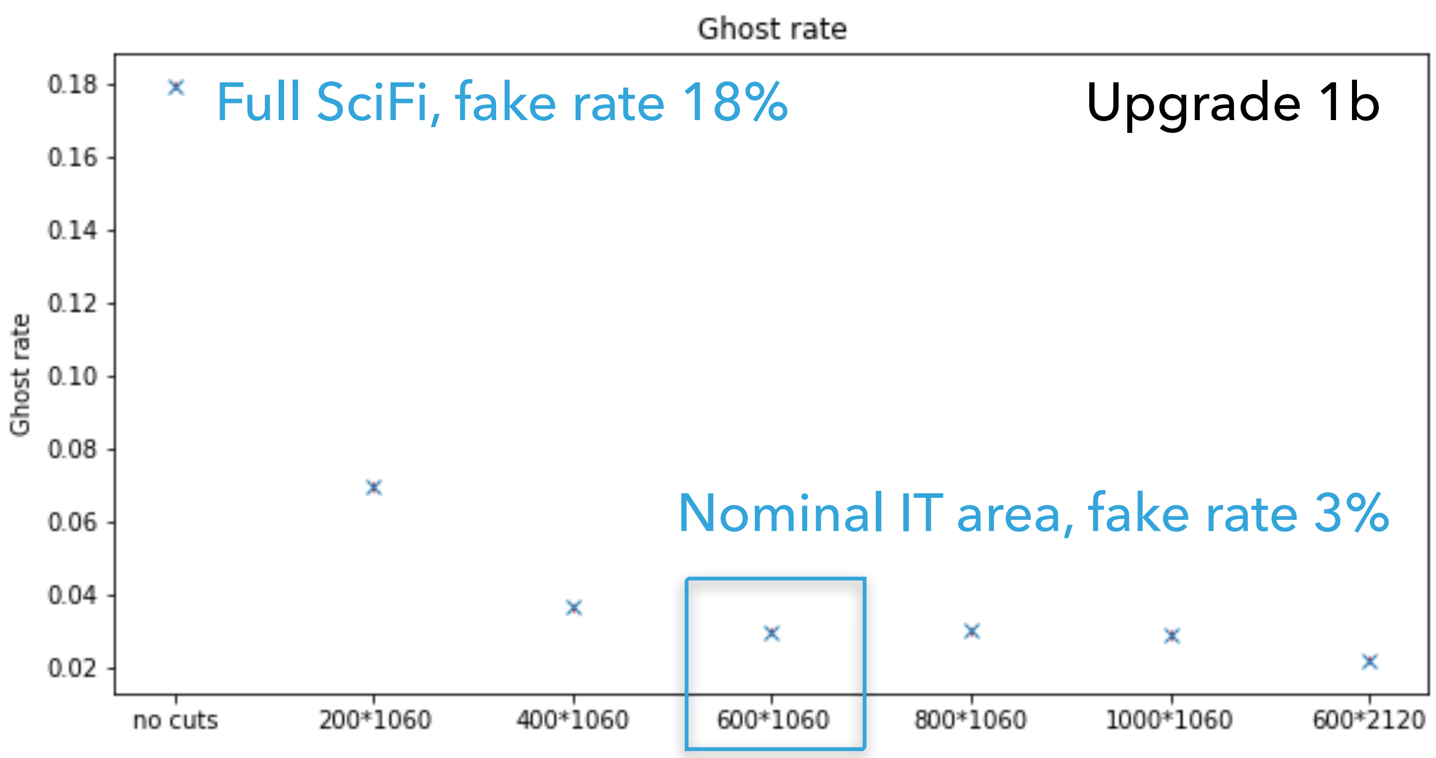




- All acceptable values for Upgrade 1b, likely shorter strips needed for Upgrade 2

INNER TRACKER: FIRST ESTIMATE OF FAKE RATE REDUCTION

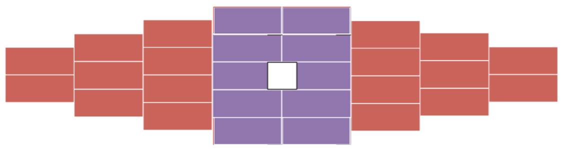
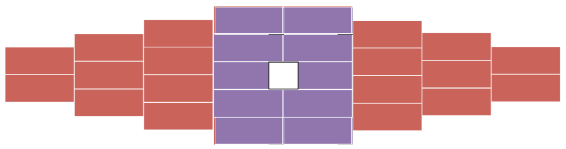
- While the horizontal dimension of IT is constrained to be 1060mm by the width of the two (central) SciFi module dimension, there is room for optimisation of the vertical size
- Hits in different IT region are removed to estimate the improvement in fake rate (in the SciFI)



- VELO-like track reconstruction in the IT assumed

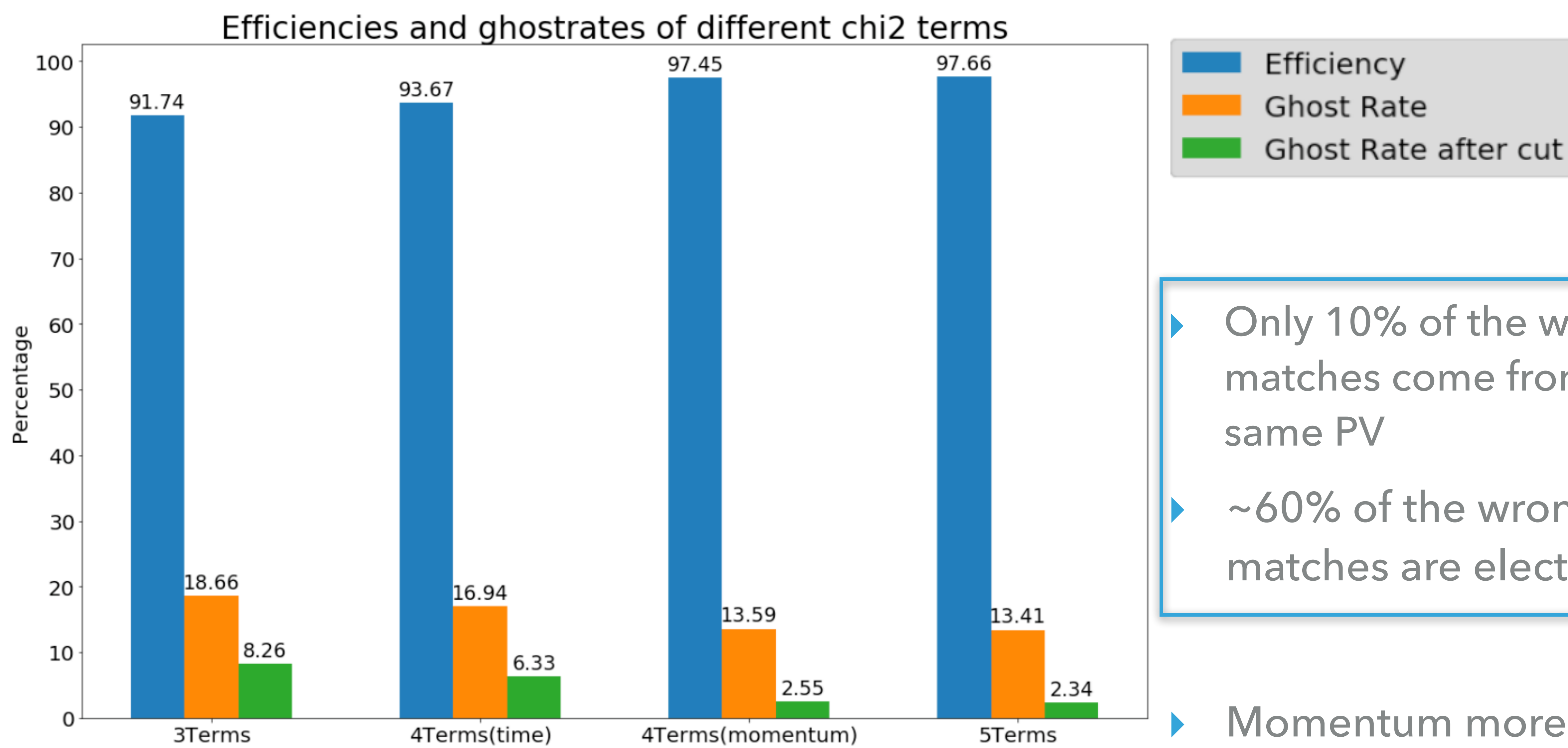
UPGRADE 1B – QUICK CHECK

- Hits in different IT region are removed, standard (in the SciFI - VELO-like track reconstruction is assumed)
- B+->J/psiK+ sample, $\mathcal{L} = 2 \times 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$, O(1k) events digitised & reconstructed,
- Attenuation maps considered for the fibres https://gitlab.cern.ch/lhcb-conddb/SIMCOND/tree/upgrade/master/Conditions/FT/Calibration (documented here: http://cdsweb.cern.ch/record/2673602/files/LHCb-PUB-2019-007.pdf),

		Full SciFi	 x 6	 x4
$25\mathrm{fb}^{-1}$	Eff(long>5GeV) Ghost rate	95.4% 14.6%	96.0% 5.5%	95.9% 8.8%
$50\mathrm{fb}^{-1}$	Eff(long>5GeV) Ghost rate	95.2% 13.8%		95.4% 8.3%
$100\mathrm{fb}^{-1}$	Eff(long>5GeV) Ghost rate	93.5% 14.2%		94.2% 8.2%

TRACK MATCHING – MOMENTUM & TIMING

$$\chi^2_{\text{match}} = \frac{(x_{pred} - x_{meas})^2}{\sigma_x^2} + \frac{(y_{pred} - y_{meas})^2}{\sigma_y^2} + \frac{(t_{y\,pred} - t_{y\,meas})^2}{\sigma_{t_y}^2} + \frac{(p_{VeloUT} - p_{Tstat})^2}{\sigma^2_{p,VeloUT} + \sigma^2_{p,Tstat}} + \frac{(t^{PV}_{Velo} - t^{PV}_{Tstat})^2}{\sigma^2_{t,Velo} + \sigma^2_{t,Tstat}}$$



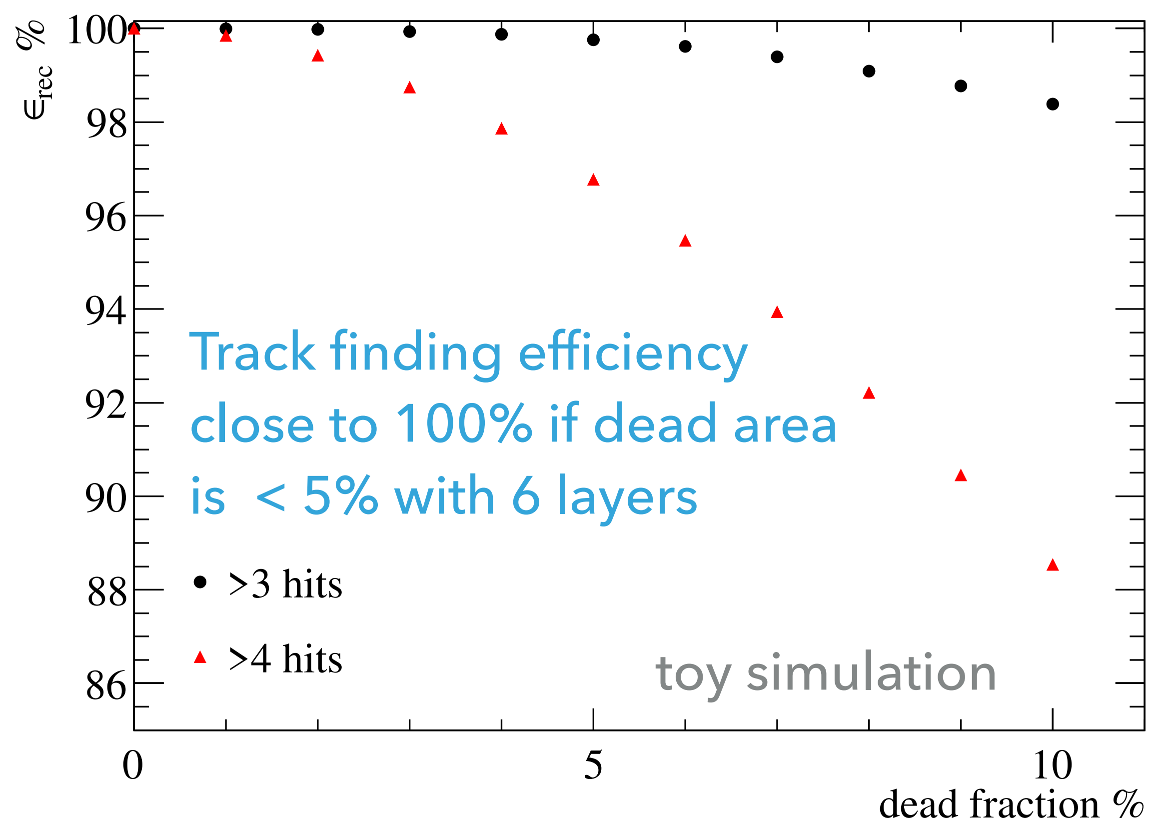
- Only 10% of the wrong matches come from the same PV
- ~60% of the wrong matches are electrons

- Momentum more beneficial than (PV) timing

- VELO-T-stations momentum resolution **~1%**

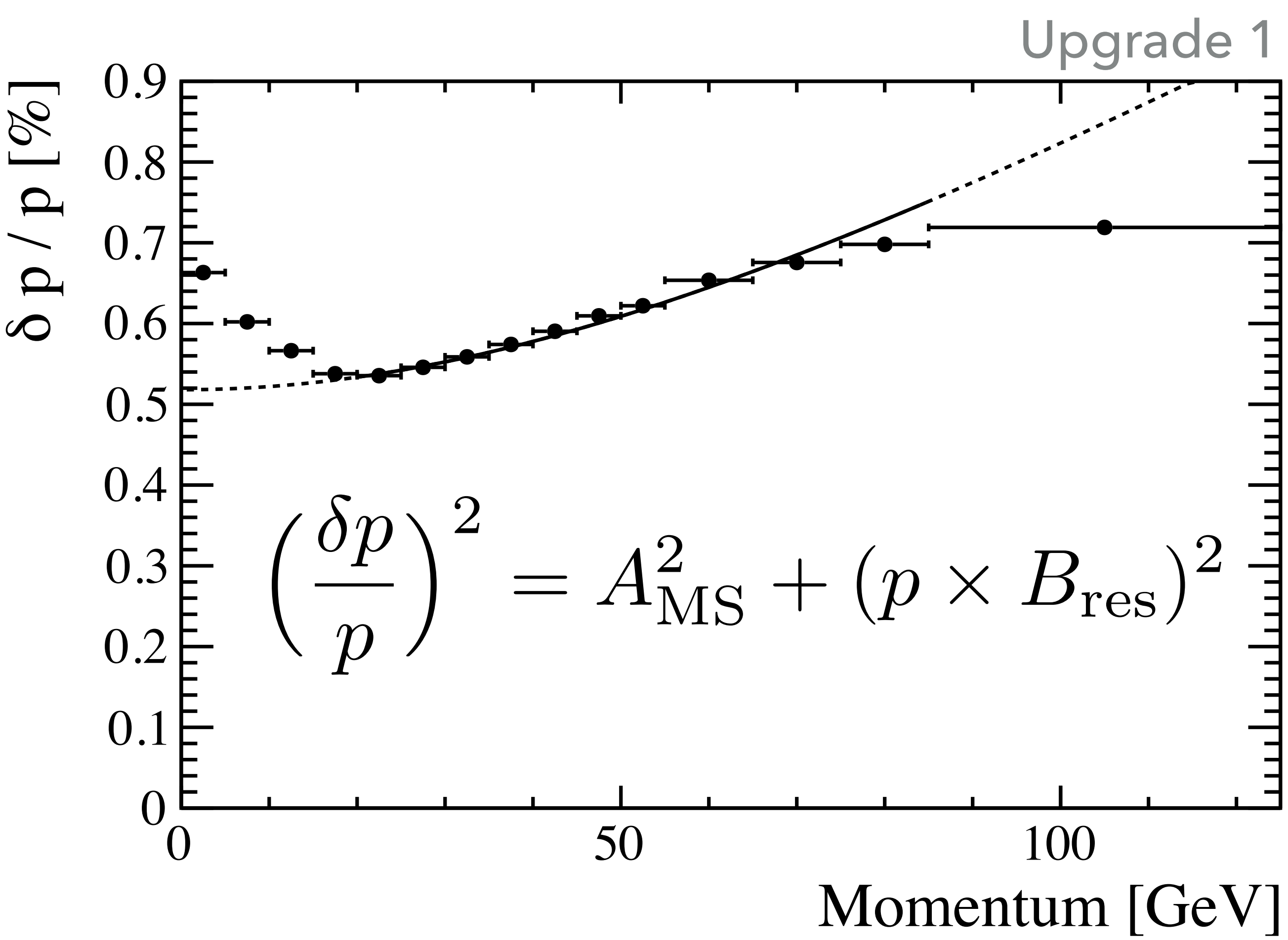
PIXELS – TRACKING IN Y – 6 LAYERS

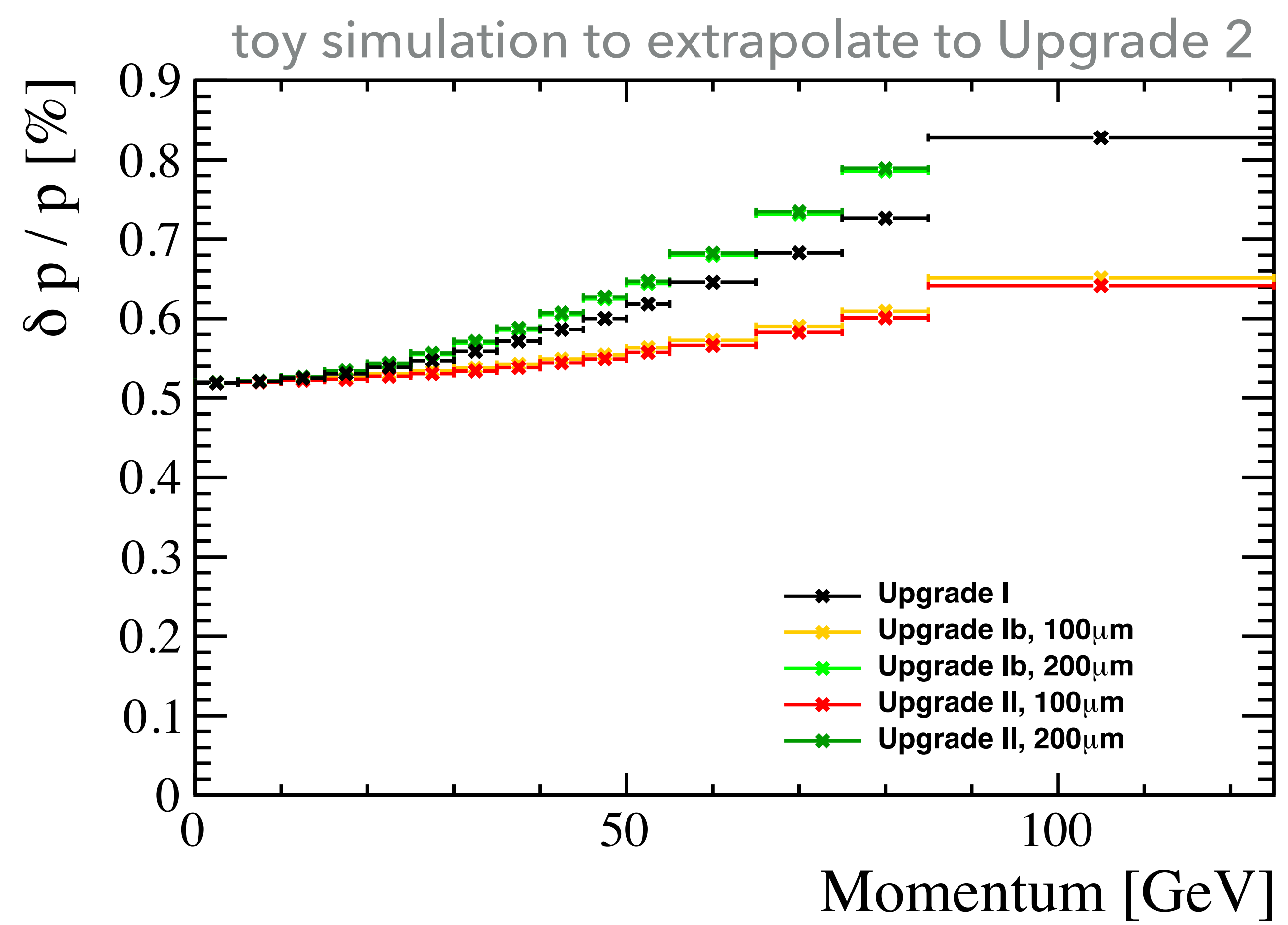
- Pattern recognition not only in the bending plane ?
- Pixels: high resolution in x and y: for pixel based IT/MT the number of layers can be reduced, achieving similar or better resolution
- With 100% sensor active area (possible if DMAPS pixel chips are arranged to overlap in each layer), 6 layers would obtain the effective measurements of the current IT



MOMENTUM RESOLUTION

- Momentum resolution studied on D→Kππ Upgrade 1 sample, described accounting for Multiple Scattering (MS) and hit resolution (res)

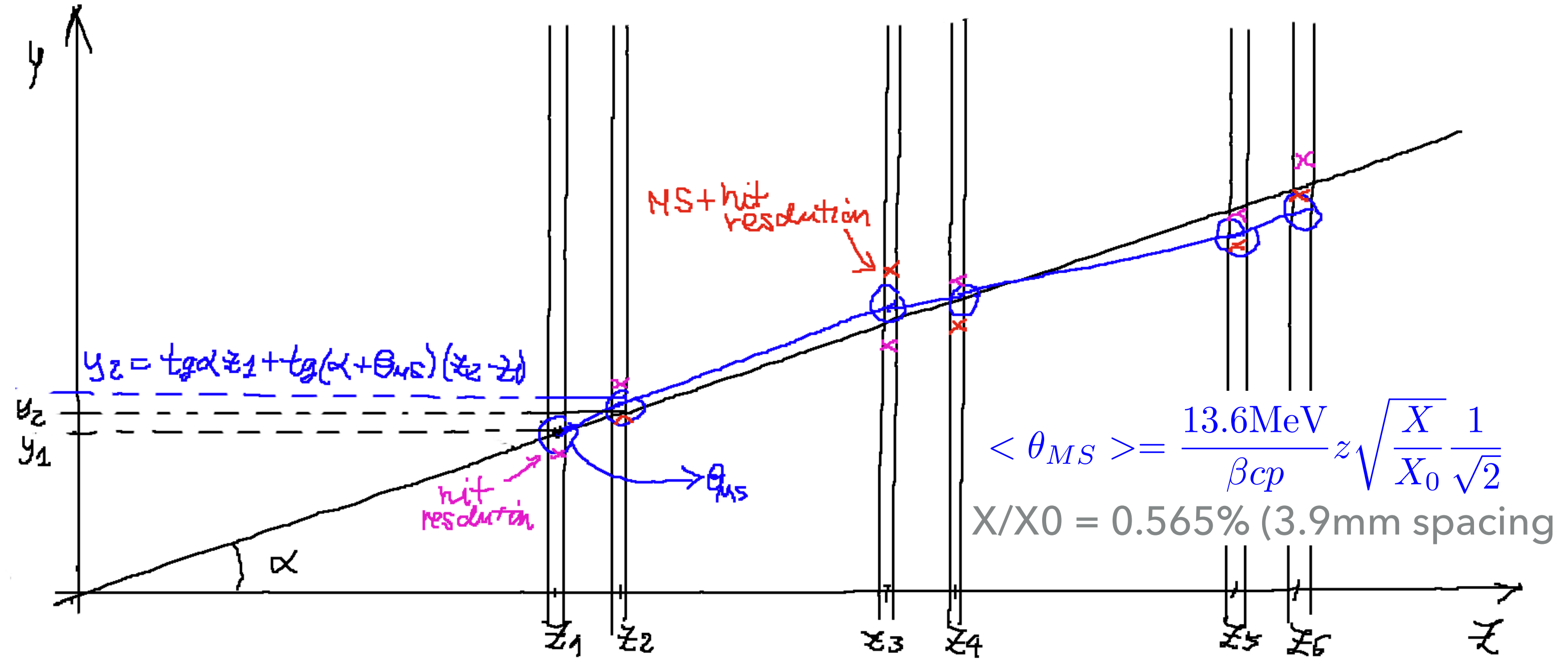




- Pixel size 200µm results in a slightly worse momentum resolution, pixel size <u>100µm results in an improvement (up to 20% at high momentum)</u>

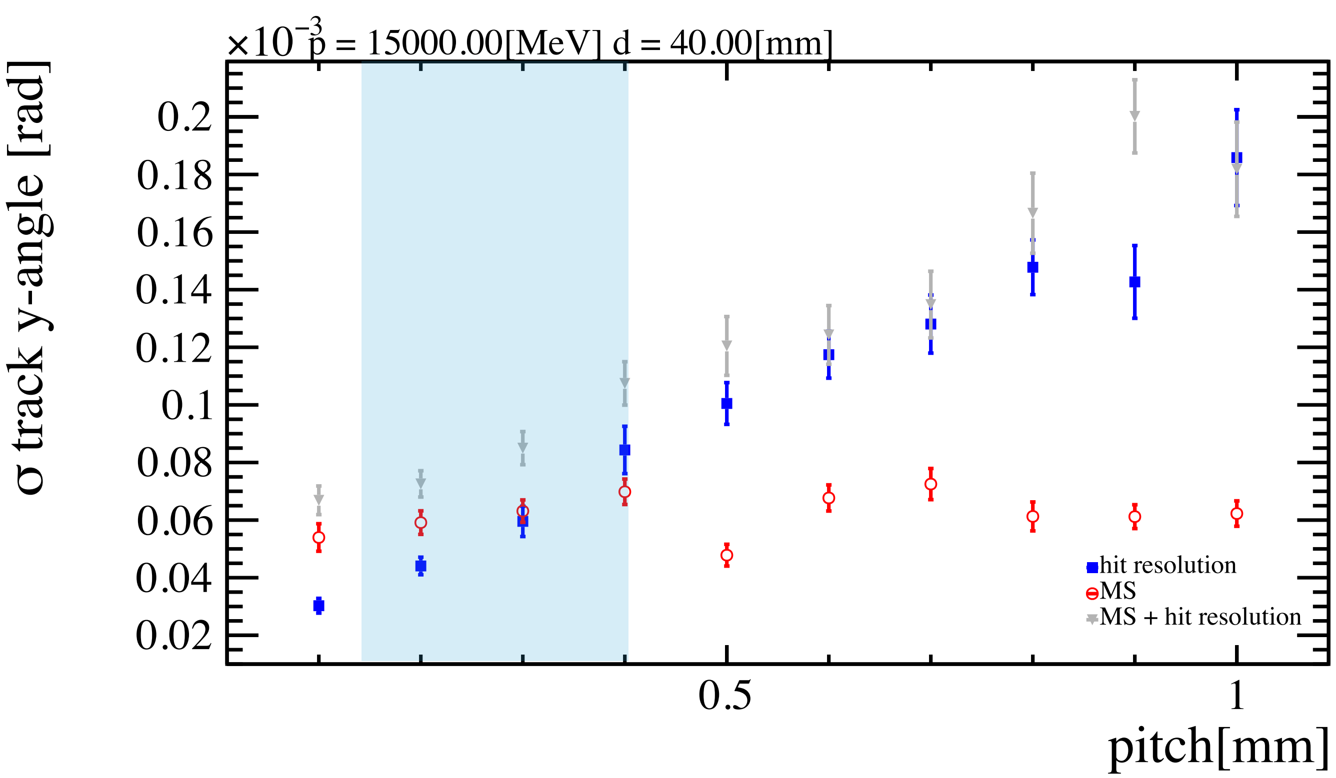
TRACK ANGLE RESOLUTION

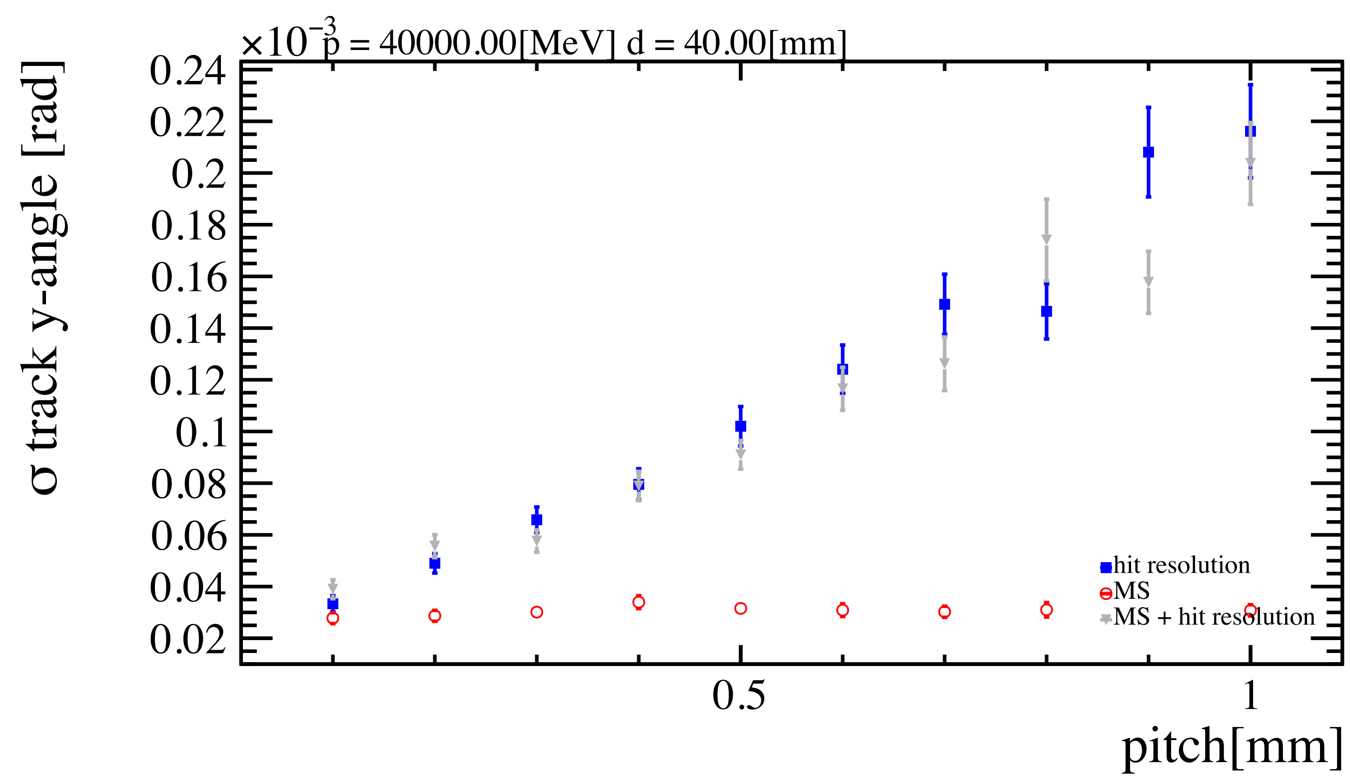
- Track toy (linear segment) obtained from a truth angle, and hits from smearing due to hit resolution and Multiple Scattering (MS)



- A "per-track" quantity allows to account for the pixel size and position of the tracker layers at the same time: track angle resolution (in y)

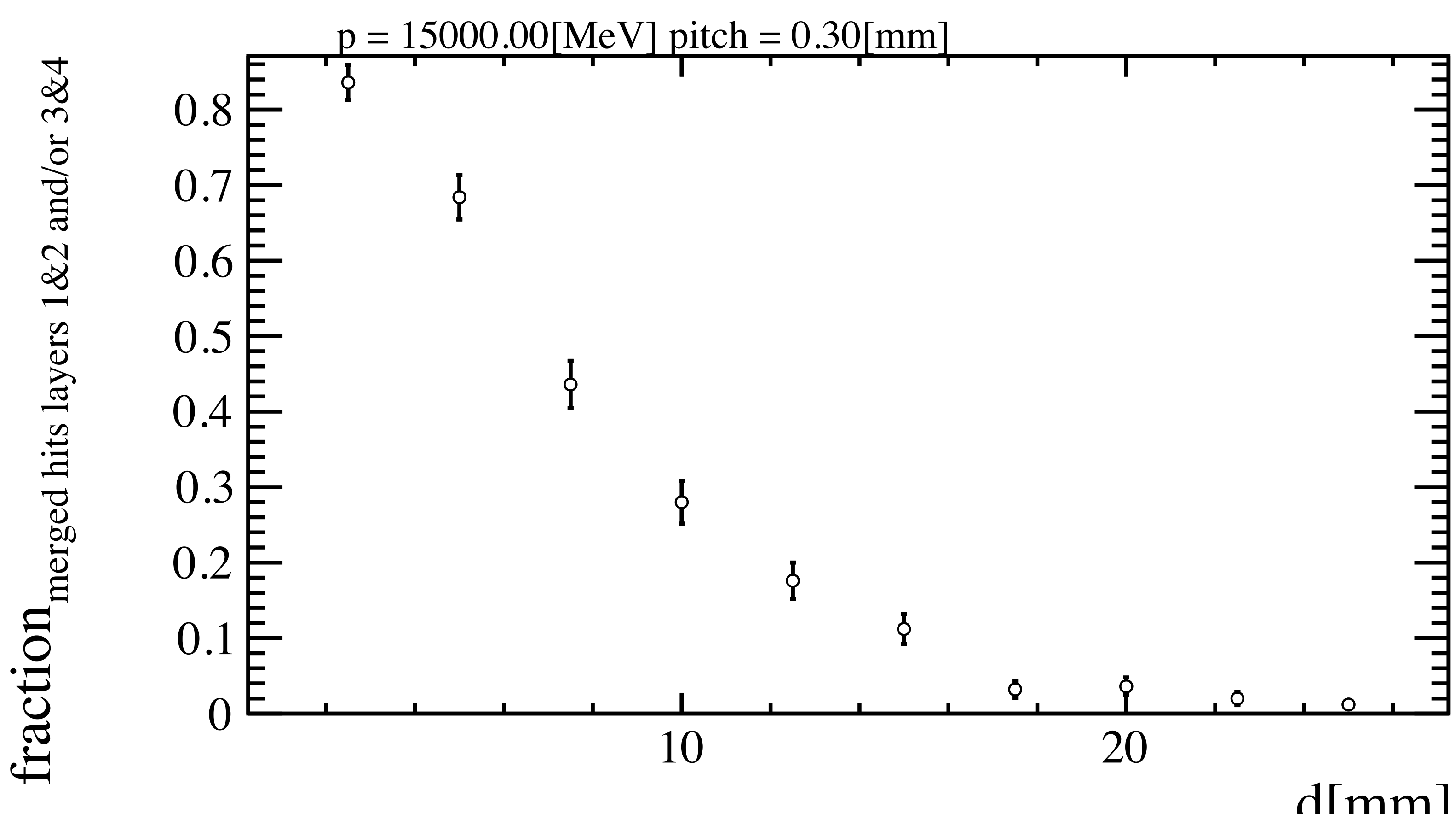
- Pixel size in y of (100-400)µm optimal for tracks of (1.5-40)GeV

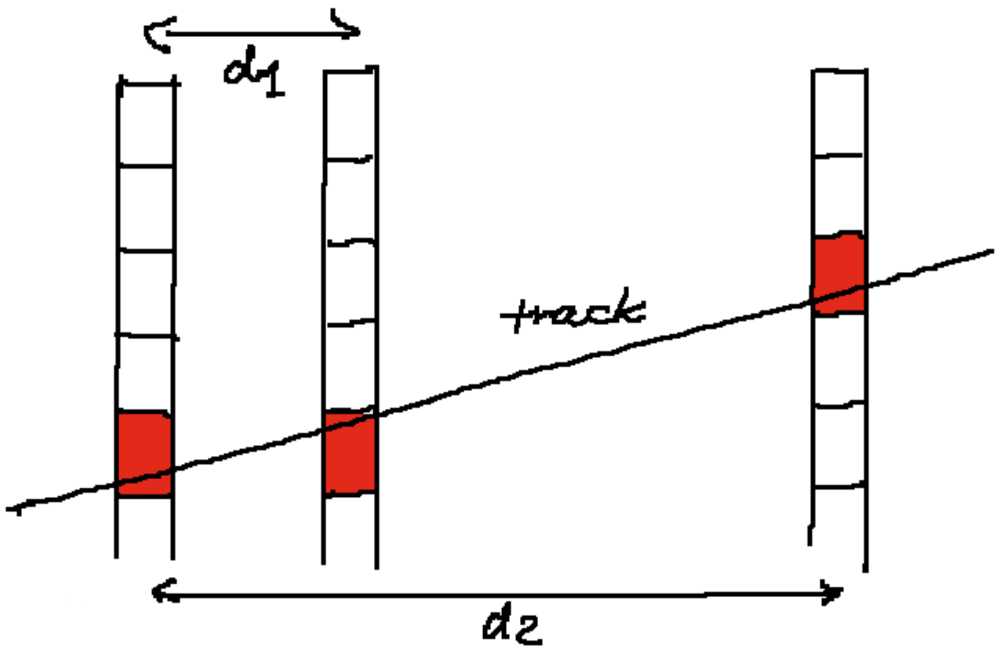




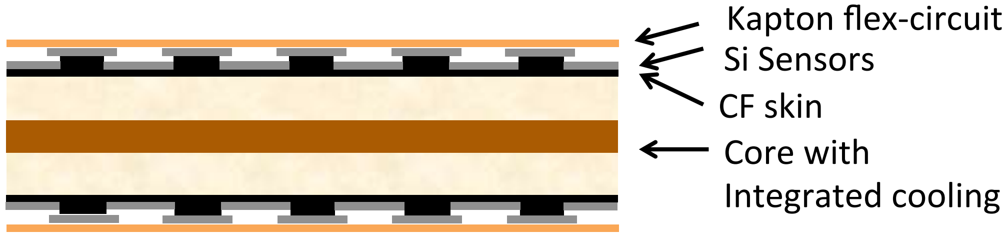
SPACING BETWEEN LAYERS

- Detector material considered for a double layer design (3.9mm spacing)
- When the layers in each doublet are too close, the hits are not distinguishable, and cannot provide a direction useful for the pattern recognition (larger search windows needed, extra random hits…)
- Which fraction of tracks has the same hit position in y?



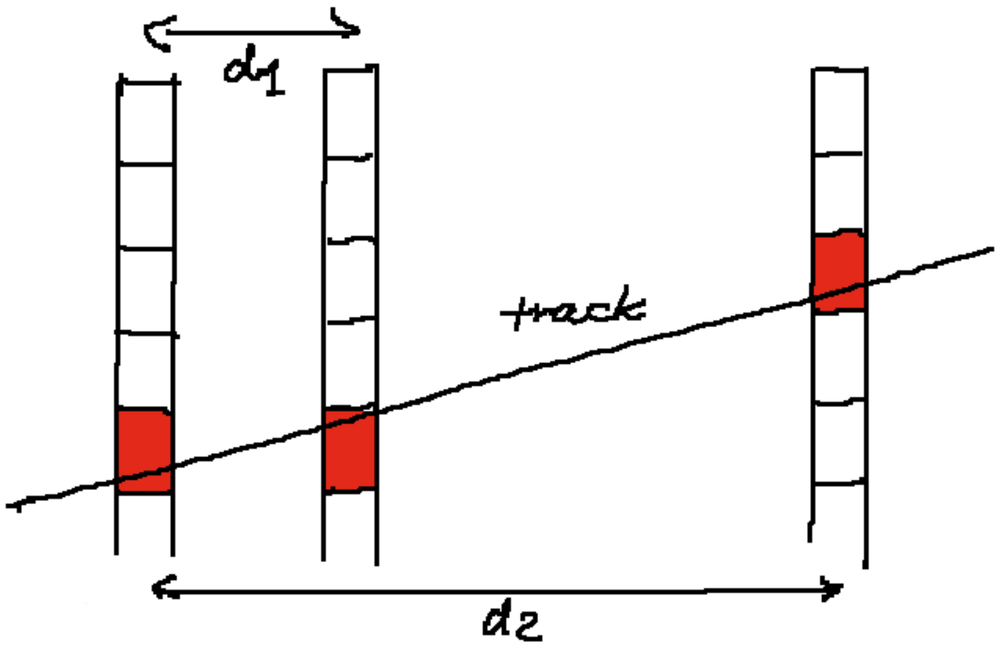


ARRANGEMENT OF LAYERS



- Minimise the material: 3 double-sided layers with the sensor layers separated by (3.9-40)mm - constraints: support, cooling structure needed

- Distance between layers in each doublet should be good enough for pattern recognition to form starting seeds (2 hits, direction information)



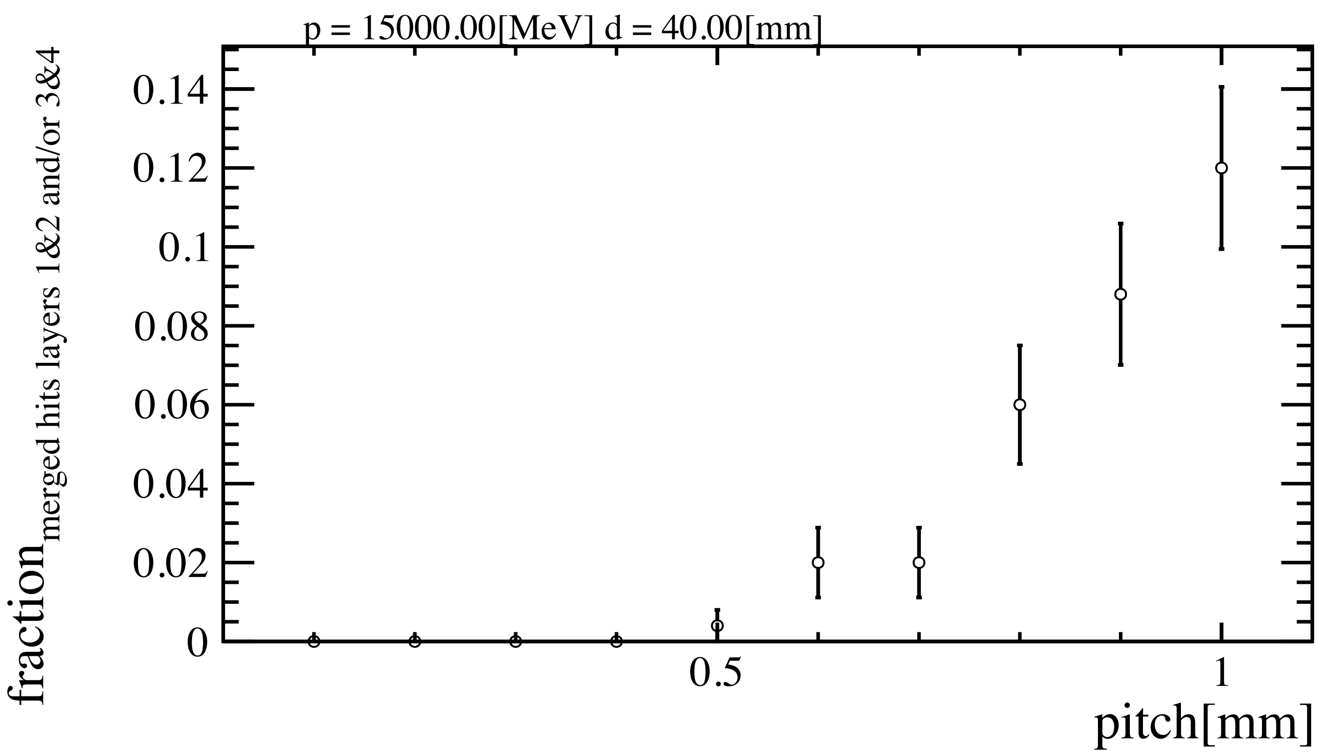
- Spacing between layers to be studied together with pixel size

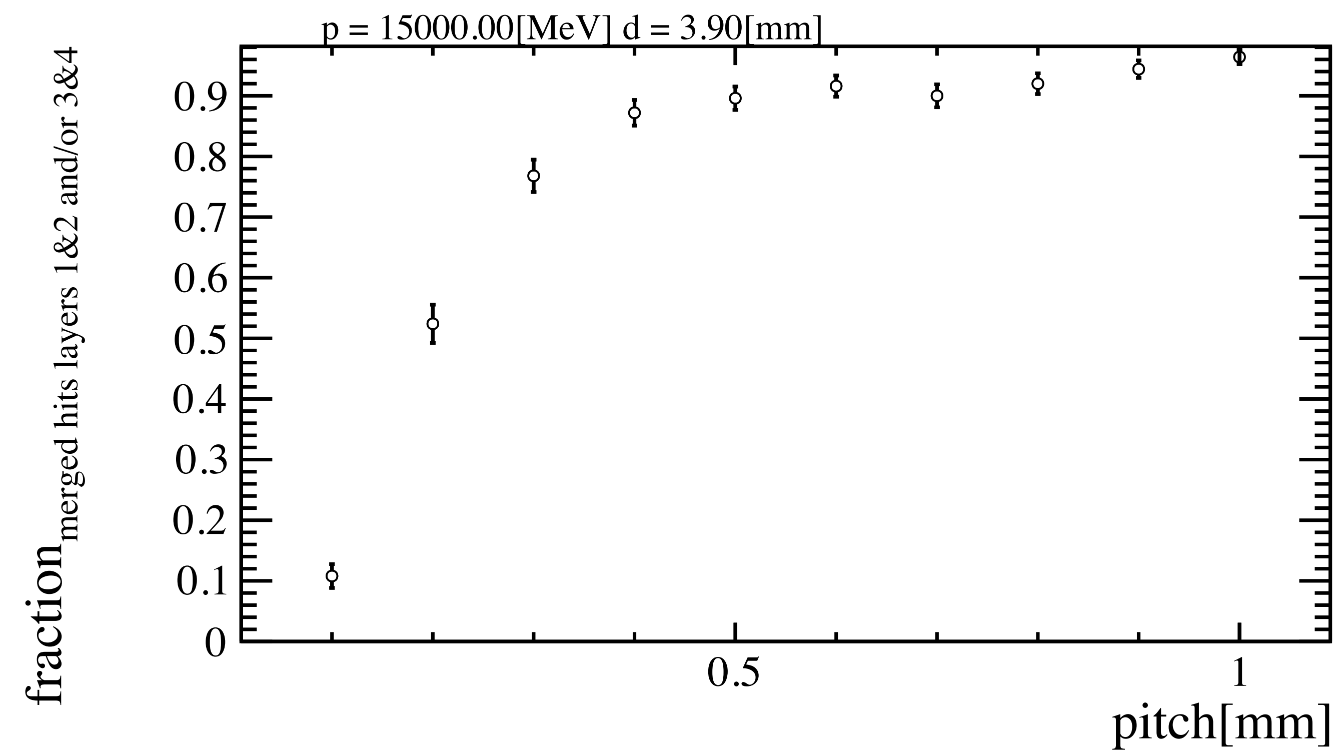
- Alternative to 3 double-sided layers, giving larger spacing but increasing material budget is to locate the 6 layers in the x layers of the x-u-v-x of SciFi

- Alternative to the 6 layers is 8 layers, arranged in 2:2:4 for T stations 1:2:3, to minimise the material seen by the SciFi

IF THE LAYERS OF THE DOUBLETS ARE TOO CLOSE

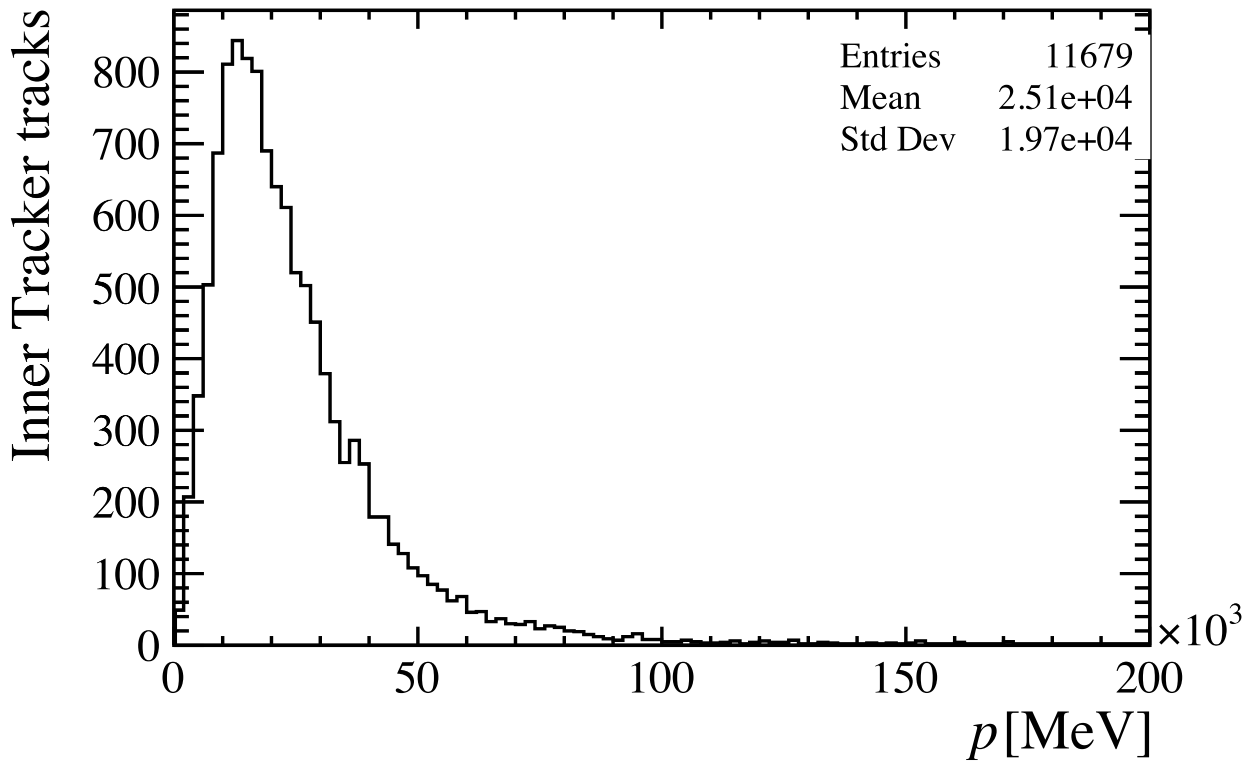
- Detector material considered for a double layer design (3.9mm spacing)
- When the layers in each doublet are too close, the hits are not distinguishable, and cannot provide a direction useful for the pattern recognition (larger search windows needed, extra random hits…)
- Which fraction of tracks has the same hit position in y?

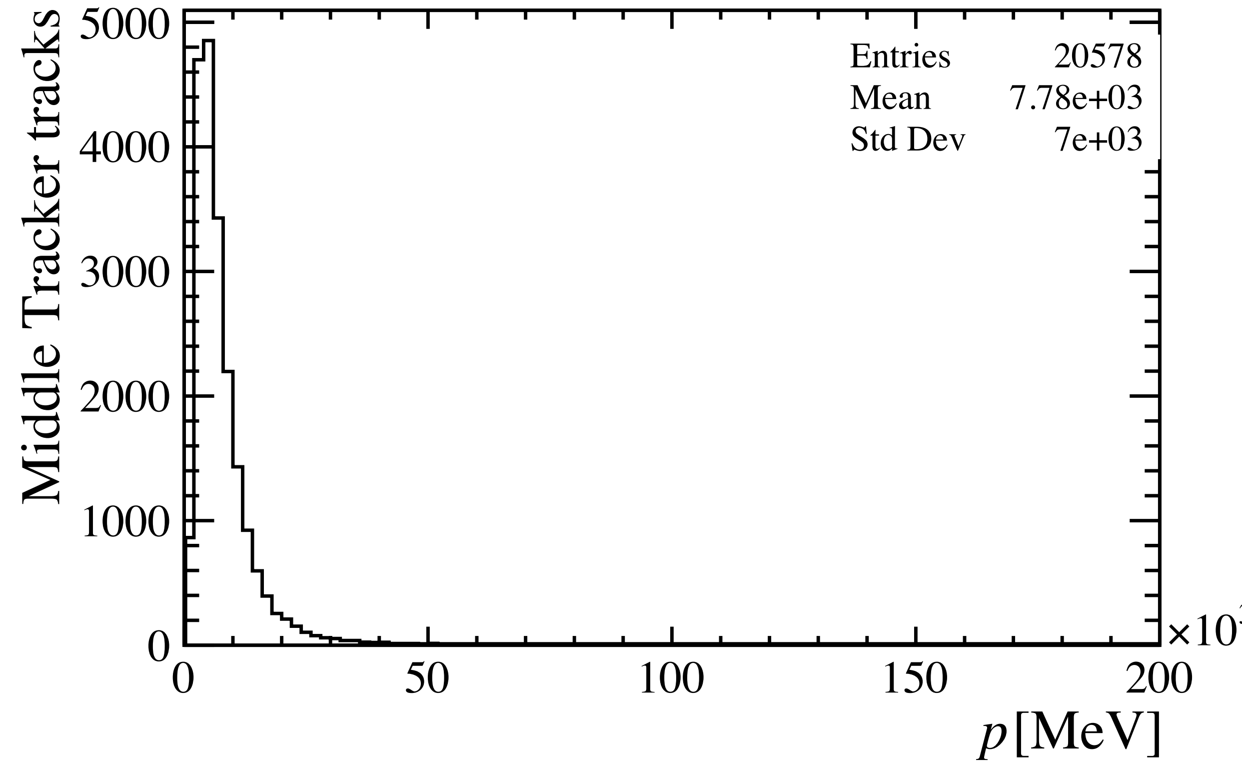




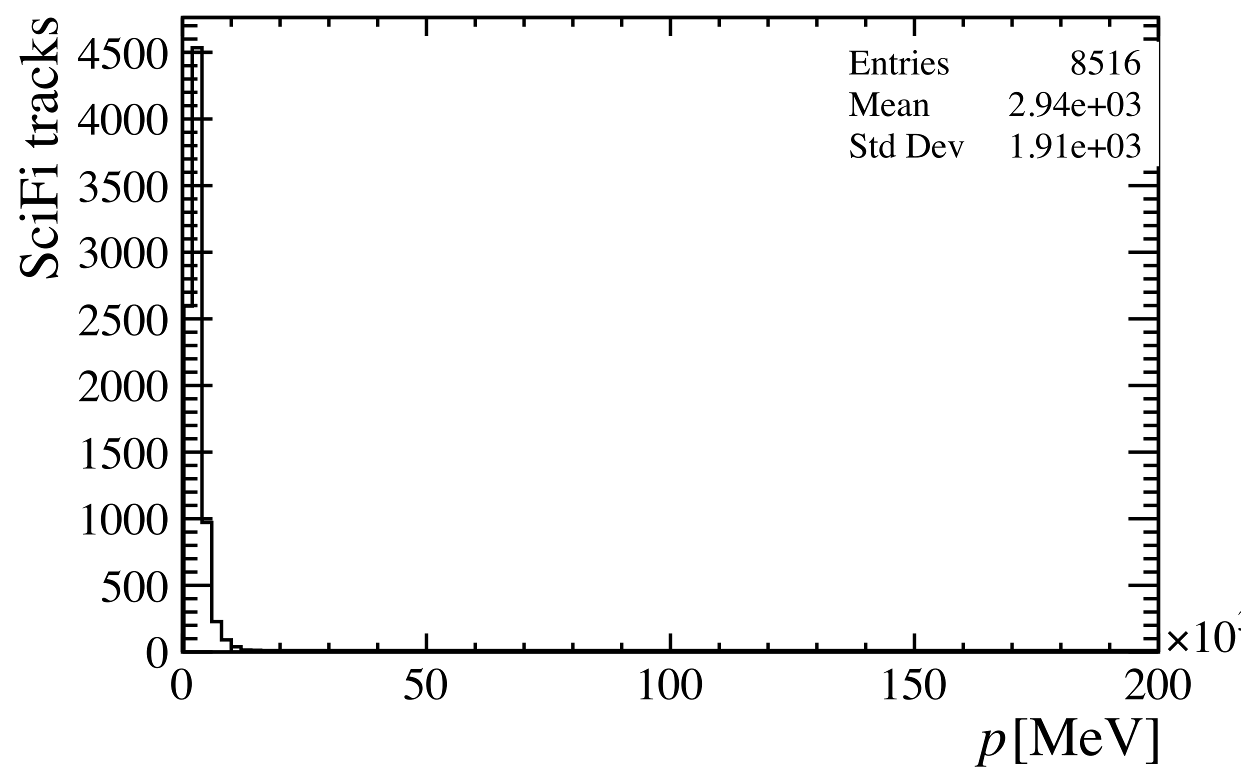
- spacings like 40mm looks preferred
- To-do: evaluate the impact of this

MOMENTUM DISTRIBUTION IN IT, MT, SCIFI REGIONS

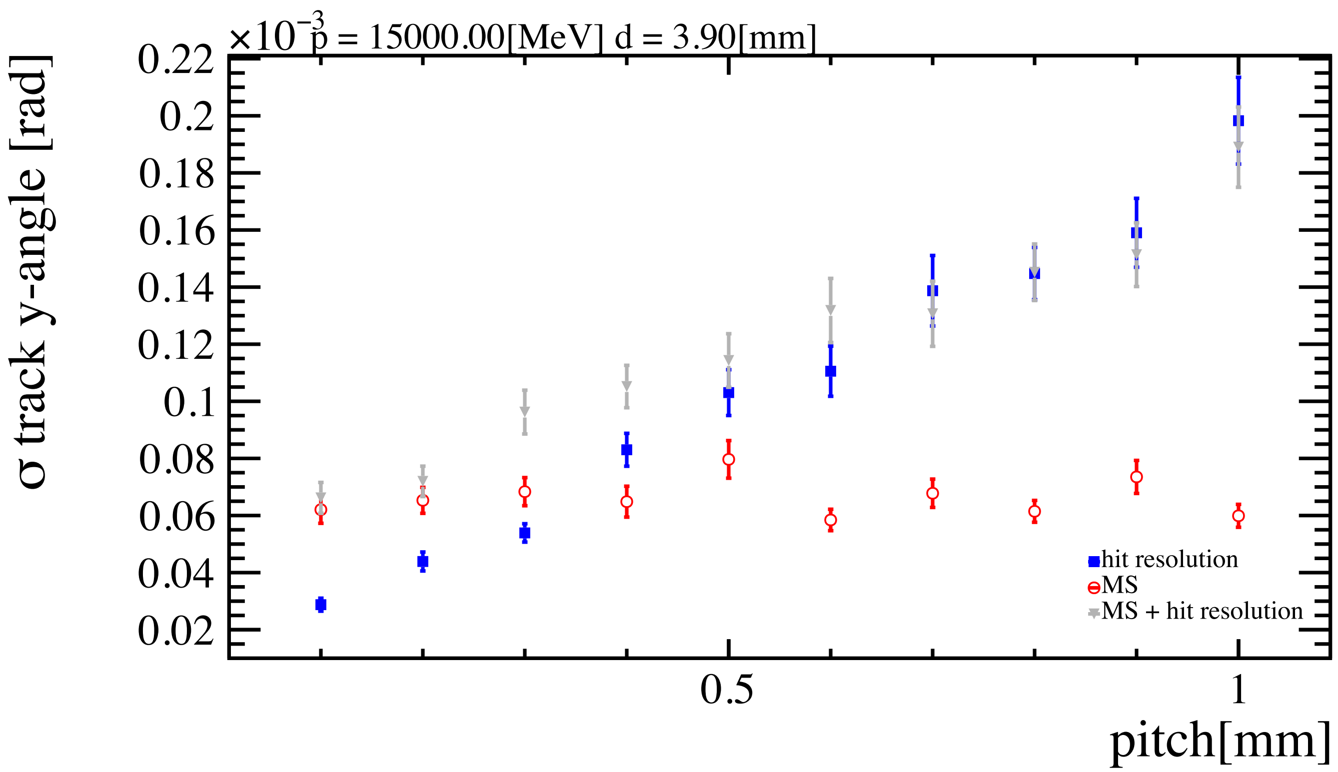


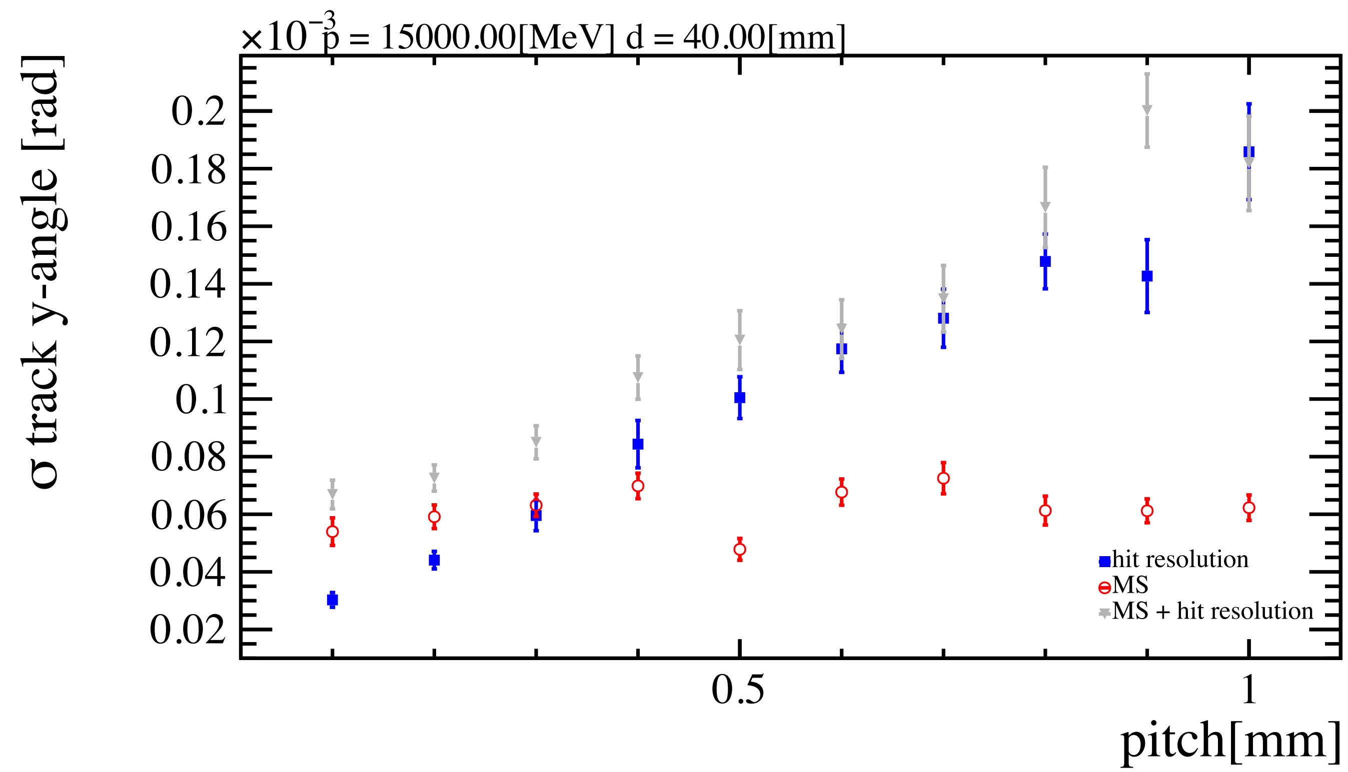


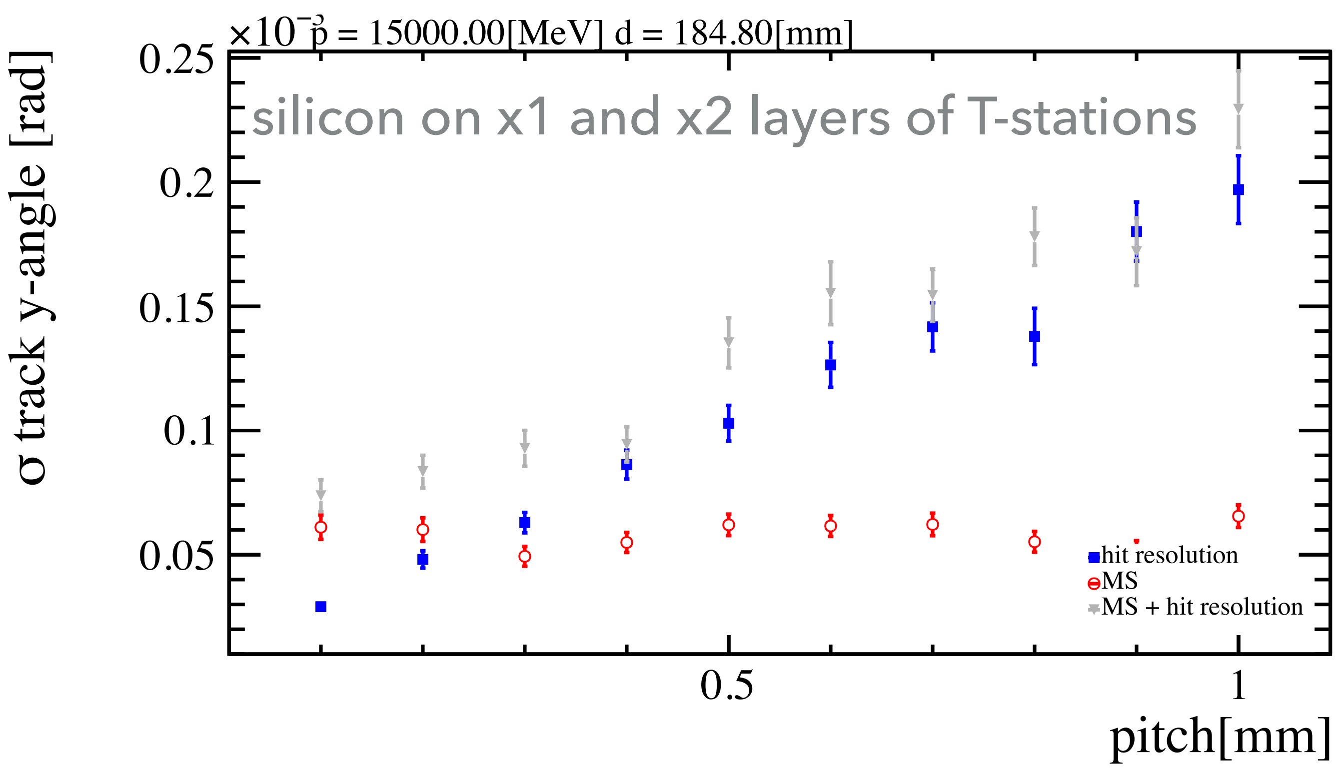
- Inclusive-b MC sample, 1.5x10^34, Long tracks, at first layer of first station



DIFFERENT CONFIGURATIONS [15GEV- MEAN P IN MT ACCEPTANCE]

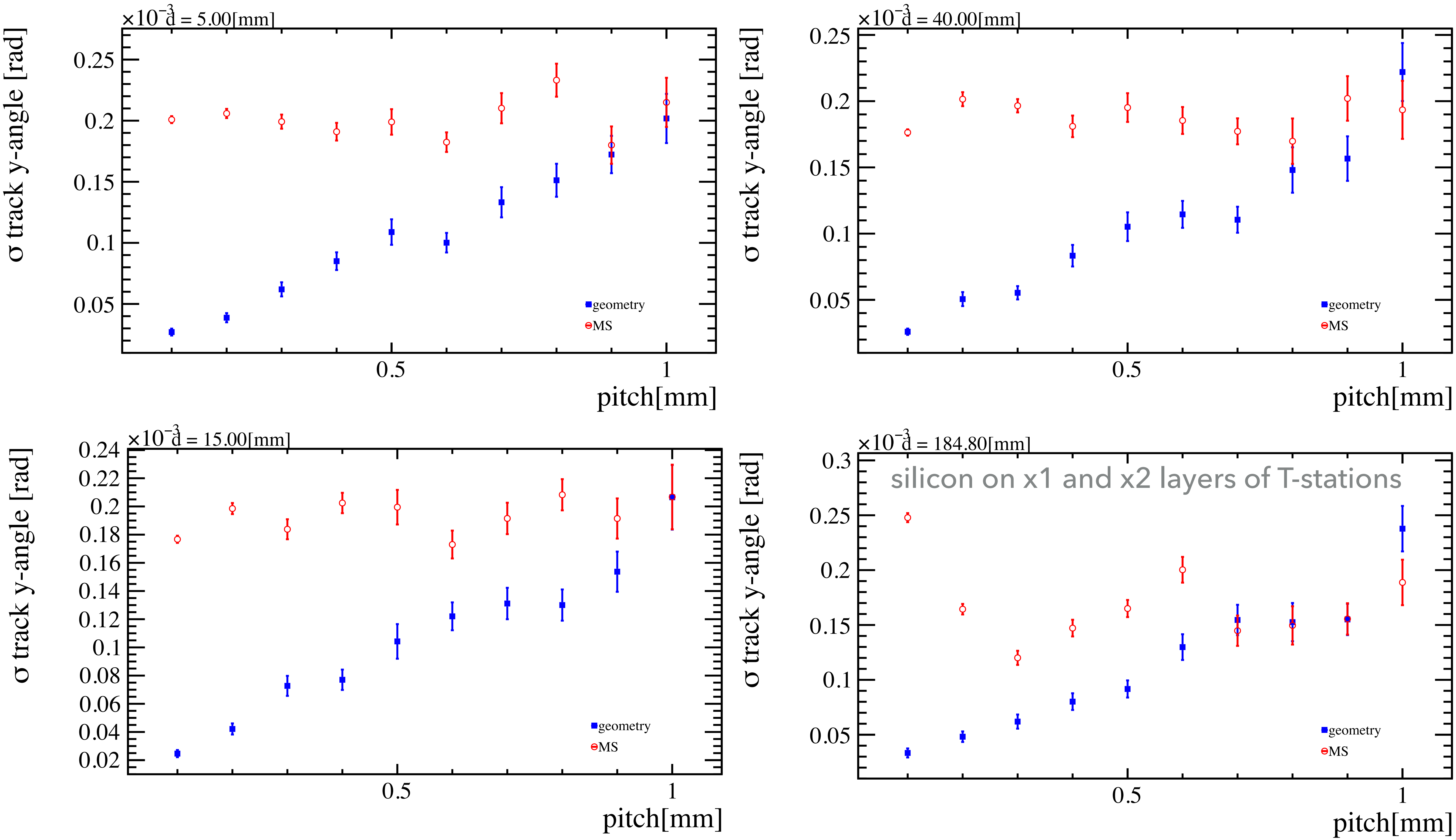




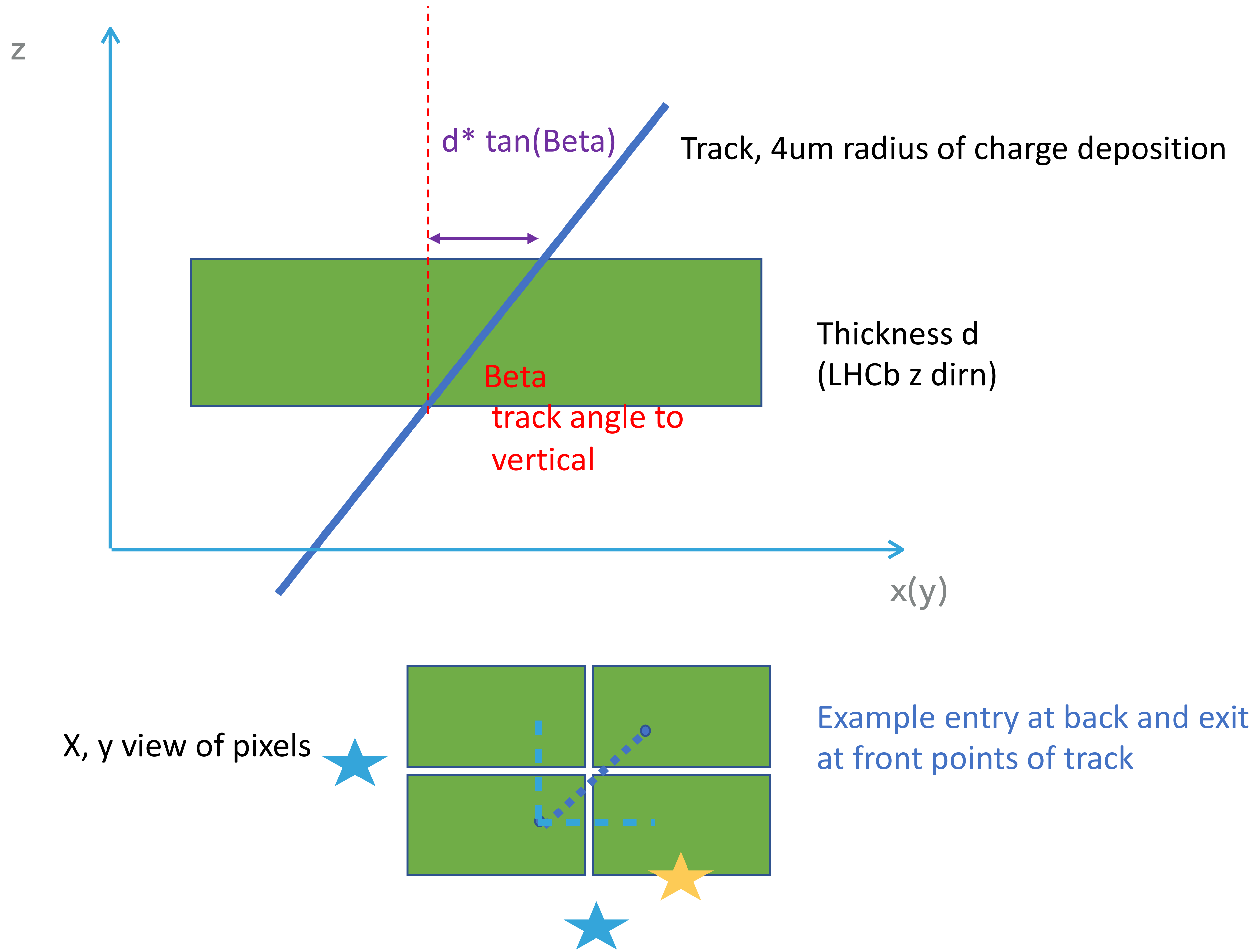


- Small dependence on the layers positions. For doublets (3.9-40mm) no gain for < 200μm

DIFFERENT CONFIGURATIONS [5GEV]

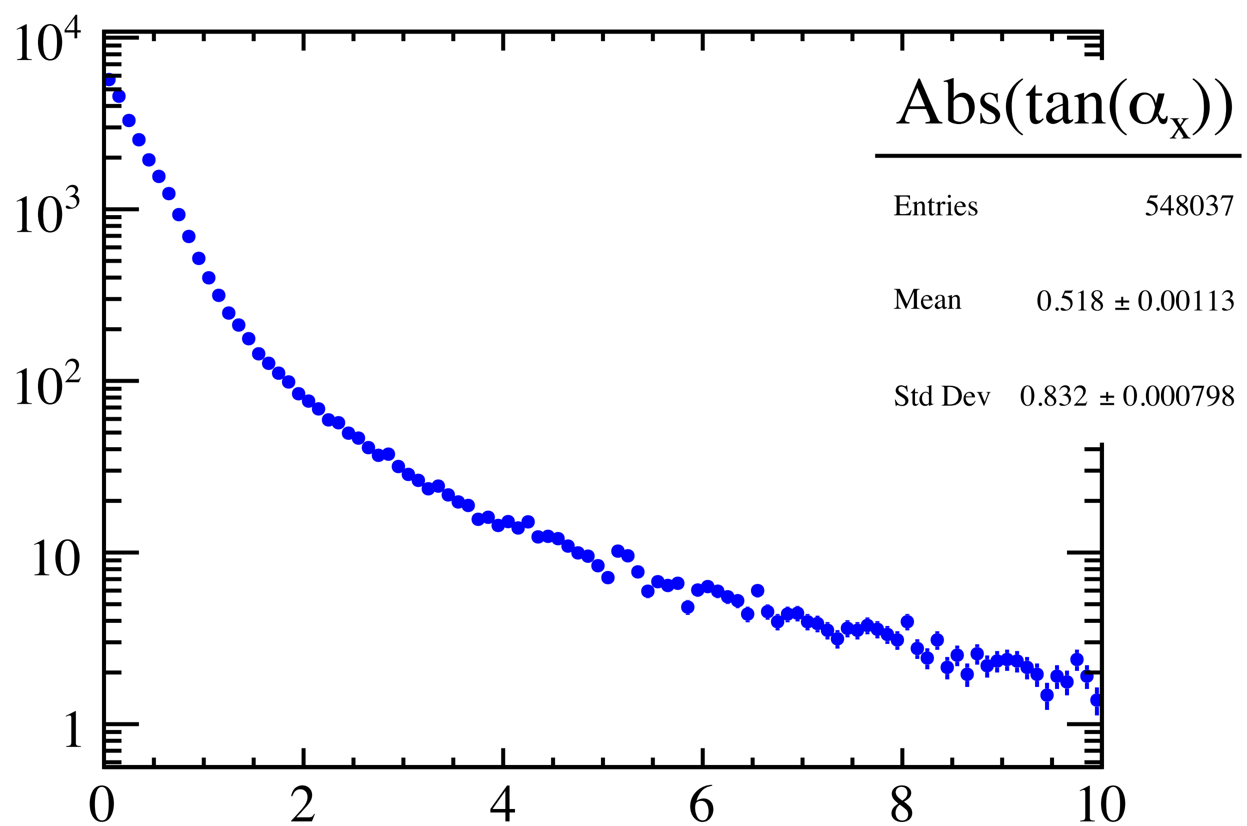


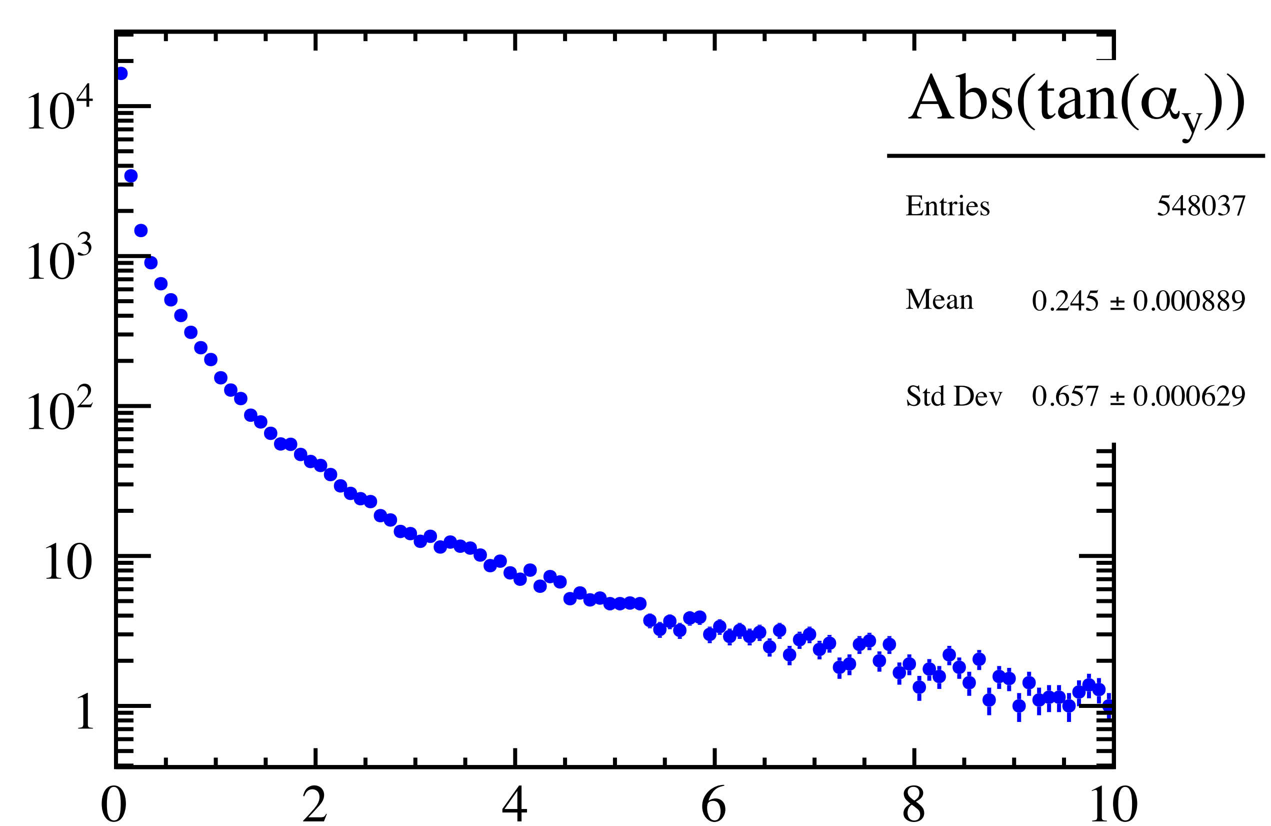
SIZE OF THE CLUSTER (IN #PIXEL)?



SIZE OF THE CLUSTER (IN #PIXEL)?

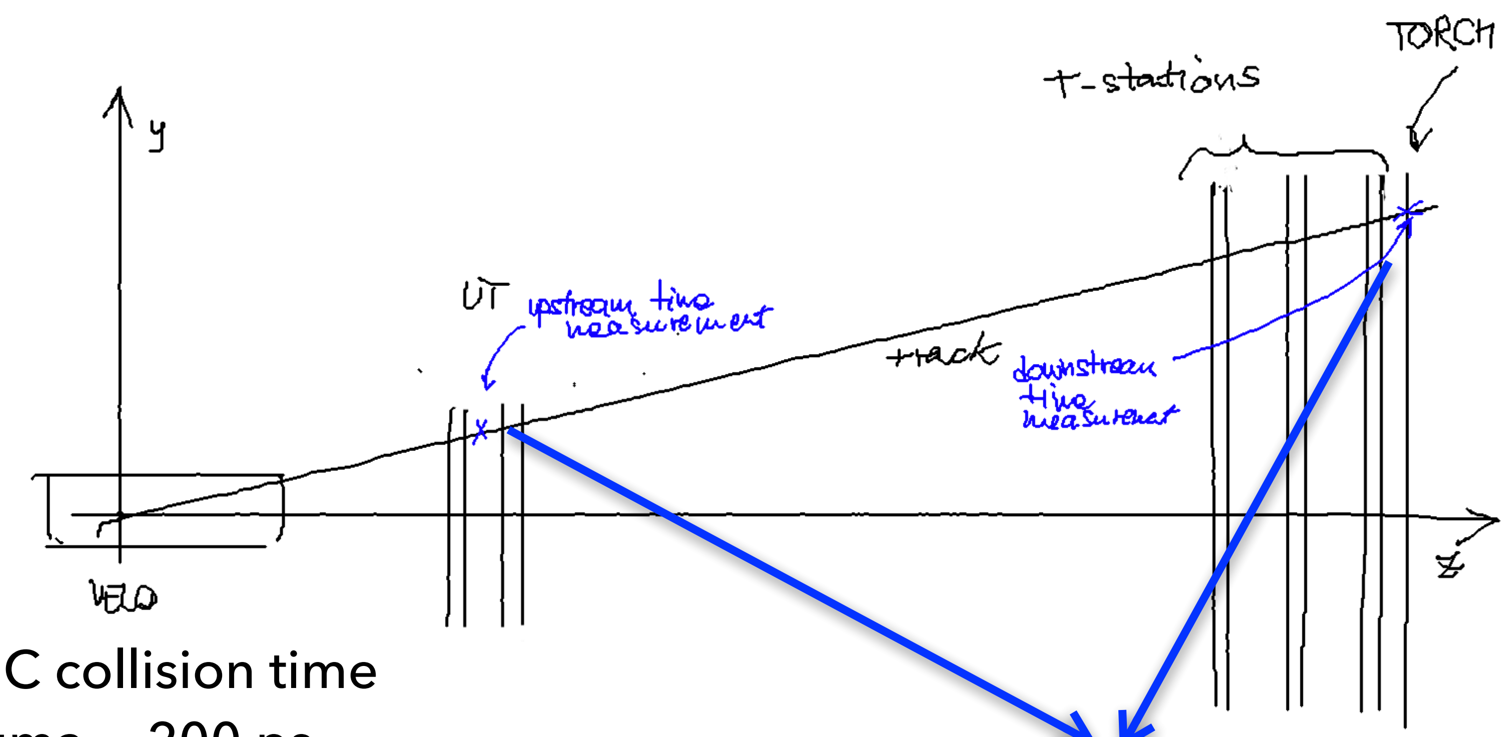
- MCHits in the T-stations (i.e. secondaries etc included)
- Slope between exit and entry points of the MCHits along x and y directions (in plots: average over the events of the sample)



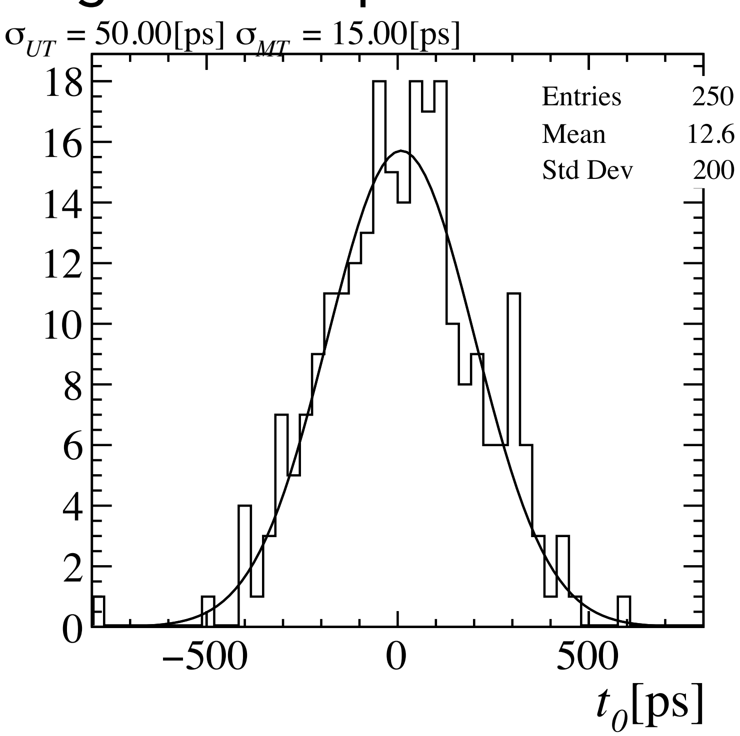


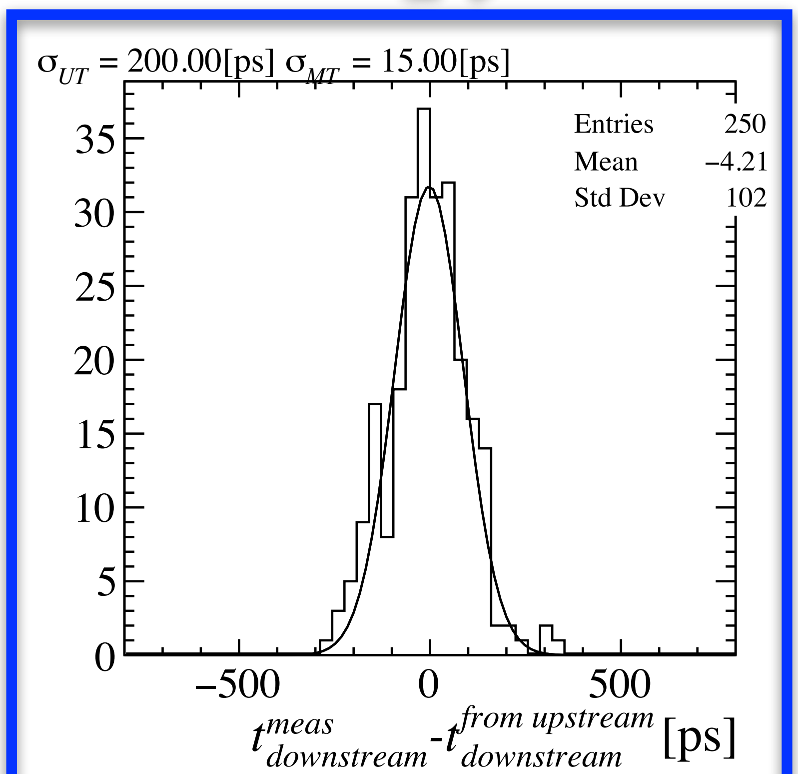
- d = 30microns, baseline pixels 100microns x 300microns
- 97.5% of the hits has cluster size 1, 2.5% of the hits has cluster size 2… Cluster size should be ~1.02 pixels

TIME RESOLUTION AND TRACK MATCHING/PV ASSOCIATION



LHC collision time sigma ~ 200 ps





- Example: use TORCH time measurement (~15ps per-track resolution) for downstream and UT (layer or sensors - 25-200ps per-track resolution)
- To be studied impact on full matching upstream/downstream and rate of mis-association (fakes)