Muon reconstruction efficiency studies in the 10kt dual phase geometry in LArSoft

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Introduction

Motivation: validate the implementation of the 10kt dual phase geometry and sim/reco chain in LArSoft

Content:

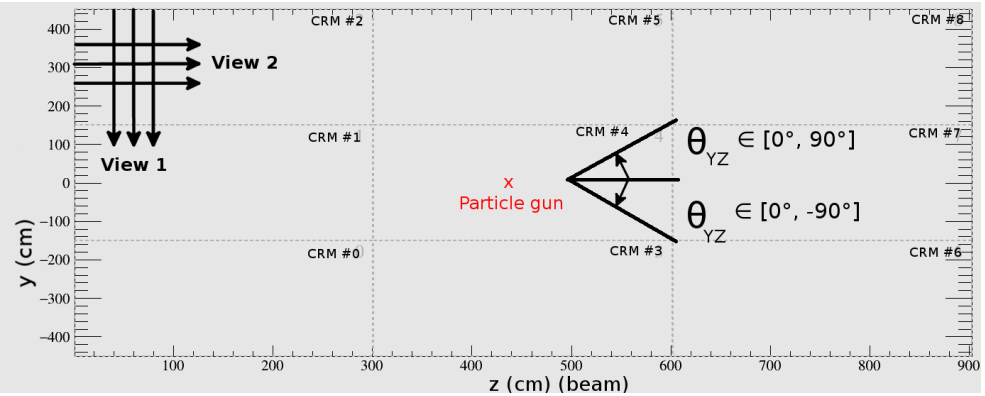
1. Dual phase geometry in LArSoft and efficiency definition
2. Muon reco efficiency for isotropic muons & 'stitching'
3. Muon reco efficiency vs. muon direction
4. Conclusion and outlook

LArSoft config for simulation and reconstruction:

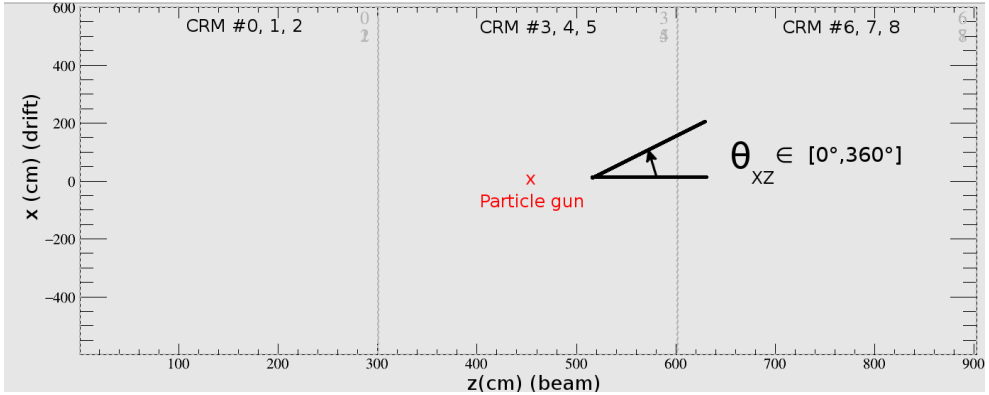
- standard 10kt dual phase .fcl's, including:
- Hits: 'GausHitFinder'
- Cluster: 'linecluster'
- Tracks: 'pmtrack'

Dual phase (workspace) geometry

Top view (anode view)



Side view



- 9 CRMs of 3x3 meters / 960x960 channels each
- Maximum drift: 12 meters

Efficiency definition

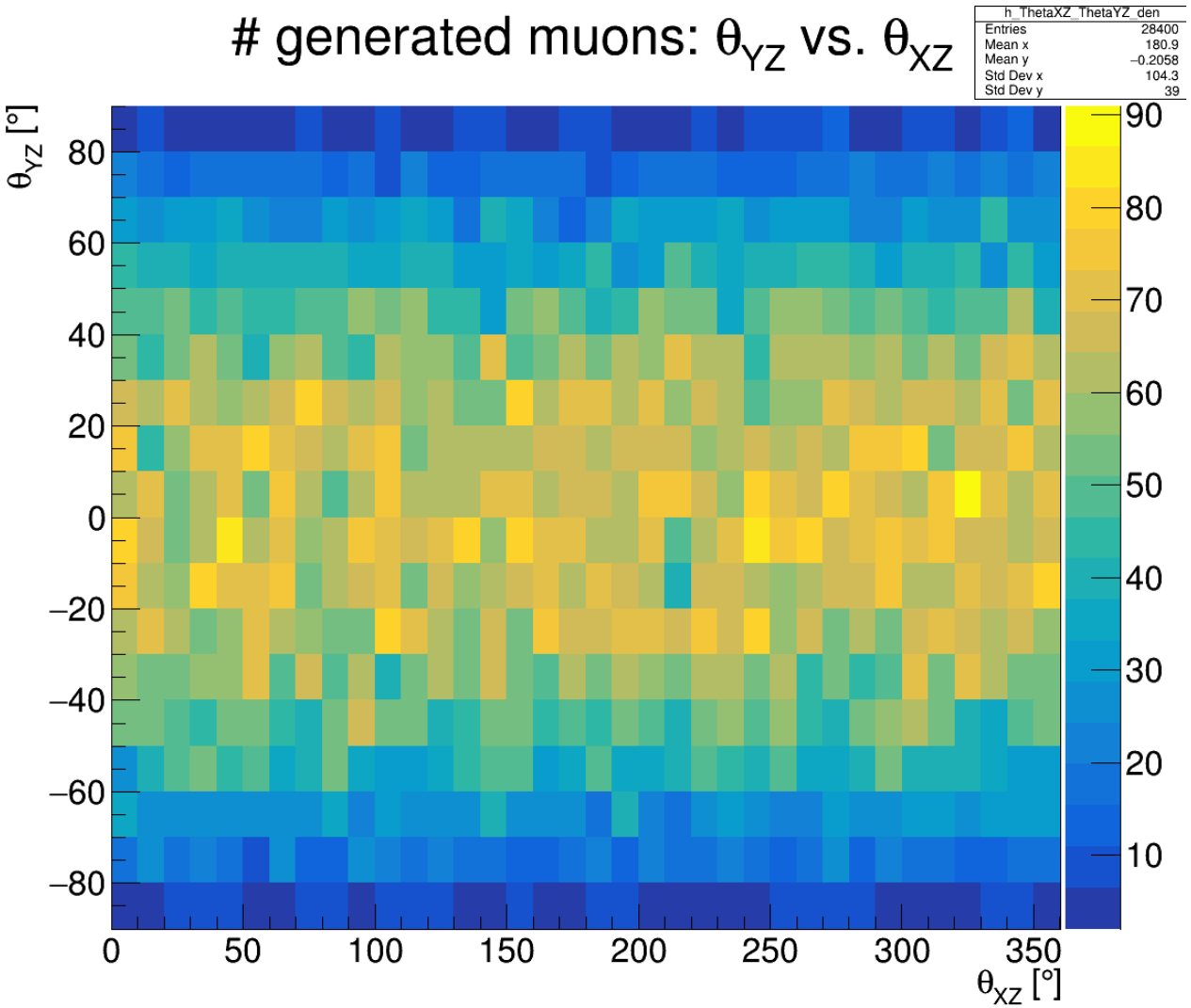
- **Completeness**: energy fraction of the simulated muon that is in a reconstructed track
- **Purity**: energy fraction in a reconstructed track that comes from the simulated muon

- **Reconstructed muon tracks**: largest energy contribution of these tracks come from the simulated muon
- **Leading reco muon track**: Reconstructed muon track with highest Completeness

- **Efficiency criteria** (for leading reco muon track)
  1. Completeness $\geqslant 50\,\%$
  2. Purity $\geqslant 50\,\%$
  3. $75\% \leqslant \frac{L_{reco}}{L_{truth}} \leqslant 125\%$

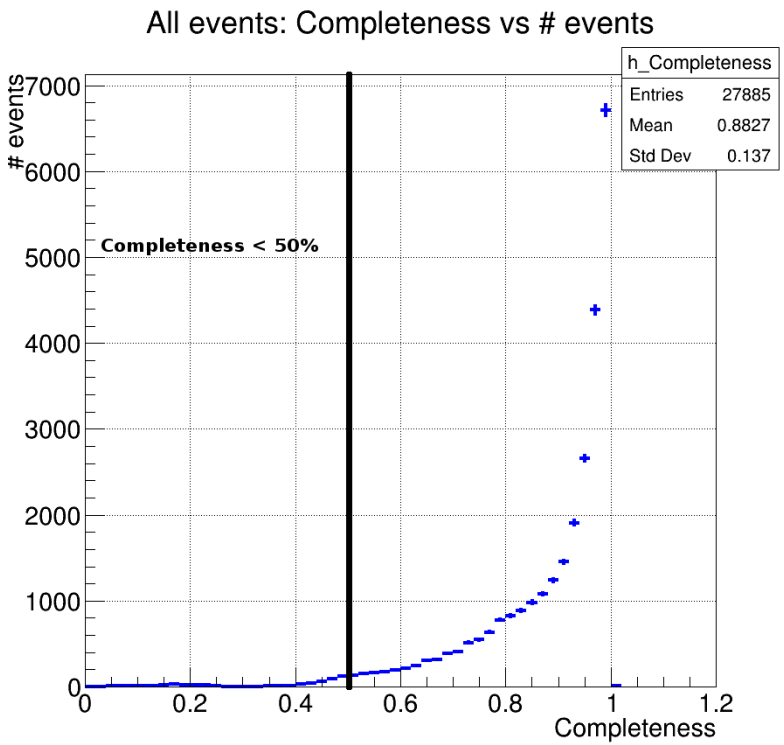
Isotropic muons: data set

- 28400 μ^-, $P_{\mu^-} = 500\,\text{MeV}$, stopping inside
- Low statistics for large $|\,\theta_{YZ}\,|$



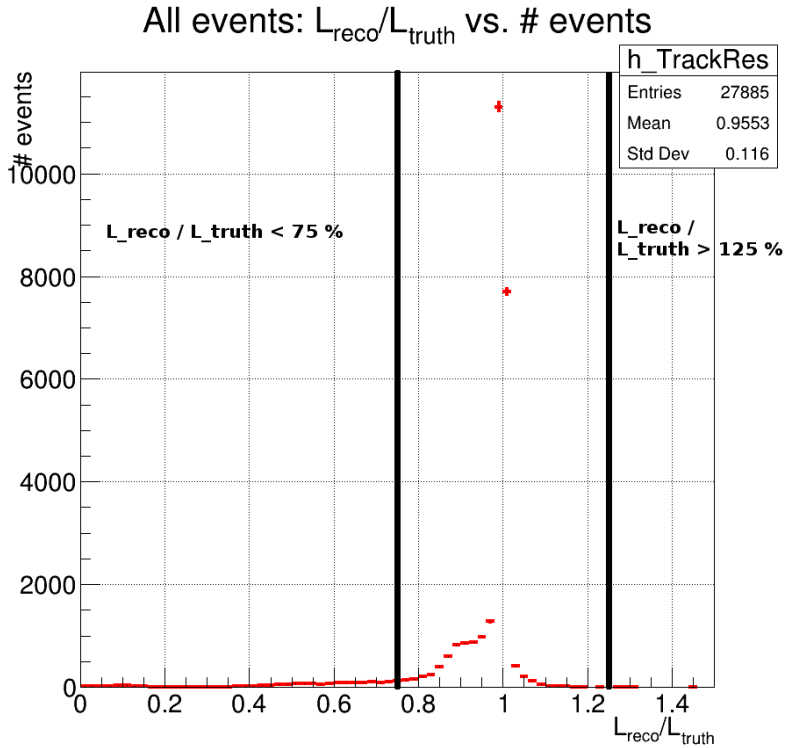
Isotropic muons: Completeness and L_{reco}/L_{truth}

Completeness:



- Completeness peaks at 1 ✔

L_{reco}/L_{truth}:



- L_{reco}/L_{truth} peaks at 1 ✔

Isotropic muons: result

Efficiency: 93 % (26410/28400)

	# events	% total
Total events	28400	100 %
Good events	26410	93 %
Bad events	1990	7 %
No reco (muon) track	515	1.8 %
$L_{reco}/L_{truth} < 75\,\%$	1419	5 %
Completeness $< 50\,\%$	579	2 %
$L_{reco}/L_{truth} > 125\,\%$	13	0.05 %
Purity $< 50\,\%$	6	0.02 %

- Focus on bad events that have a reco muon track (7 % - 1.8 % = 5.2 %)

Isotropic muons: stitching

- pmtrack splits muon into two (ore more) reco muon tracks if there is a kink in the truth track

# reco muon tracks	good events (93 %)	bad events (7 %)
0	0 %	25.9 %
1	75.8 %	11.8 %
2	21.8 %	48.3 %
3	2.2 %	13.2 %
$\geqslant$4	0.2 %	0.8 %

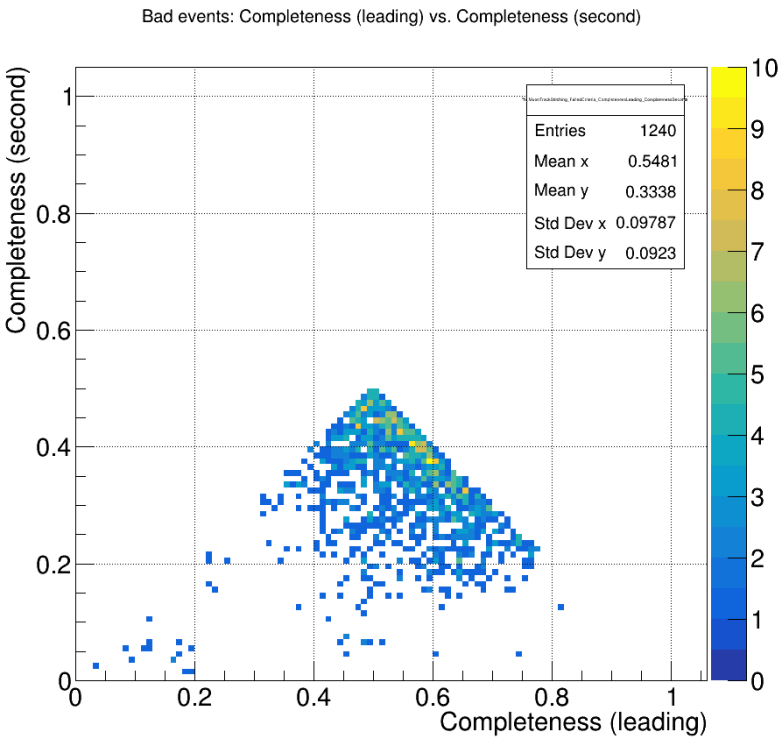
- Solution for bad events: choose second reco muon track (reco muon track with second highest Completeness)

$\rightarrow$ Add up leading + second reco muon track ('stitching')

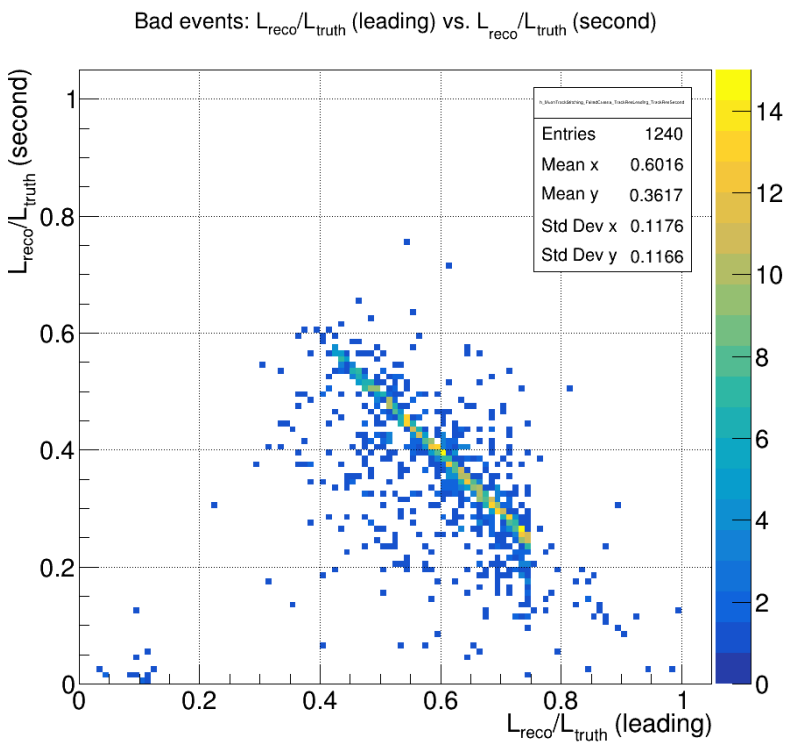
Isotropic muons: stitching

Leading reco muon track vs. second reco muon track (bad events):

Completeness:



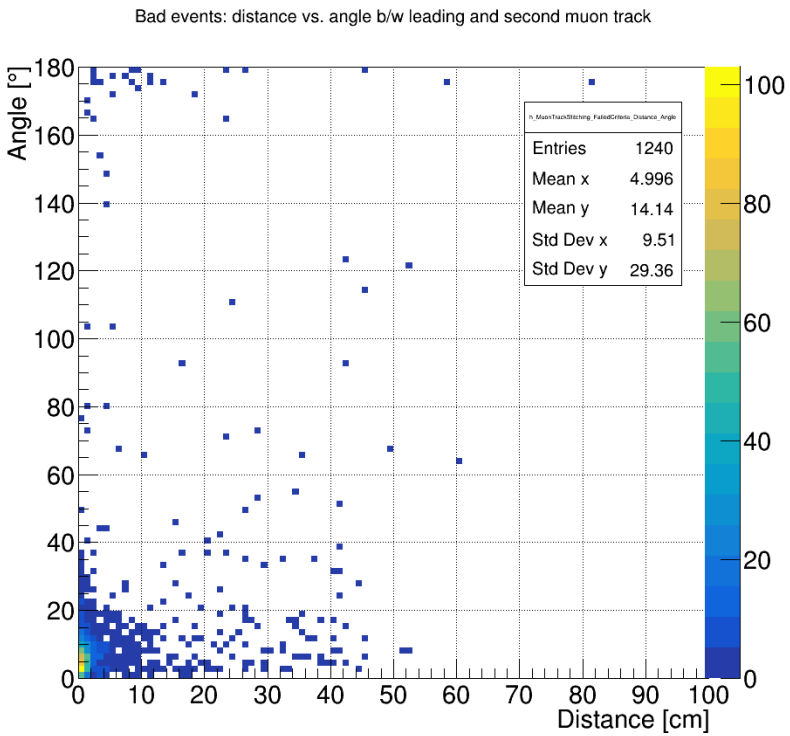
L_{reco}/L_{truth}:



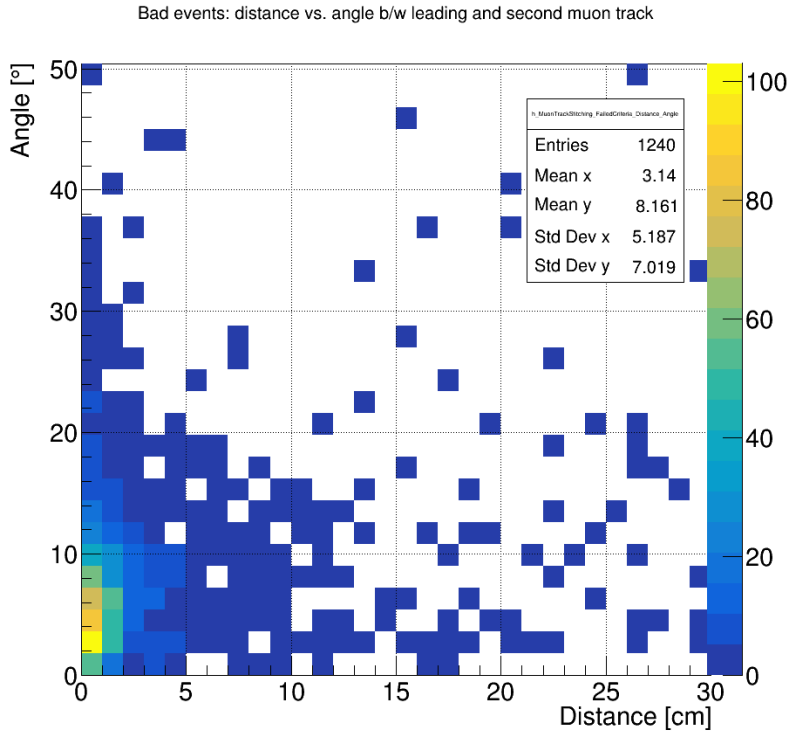
- Completeness: leading + second $\simeq 1$ ✔
- L_{reco}/L_{truth}: leading + second $\simeq 1$ ✔

Isotropic muons: stitching

3D distance vs. 3D angle b/w closest endpoints of leading and second reco muon track (bad events):



Zoom



- Most events have small angle and distance b/w the two tracks ✔
- Cluster at large angles due to $\sim 180^\circ$ kinks in the reco at the end of one track (not understood) ✗

Isotropic muons: results after stitching

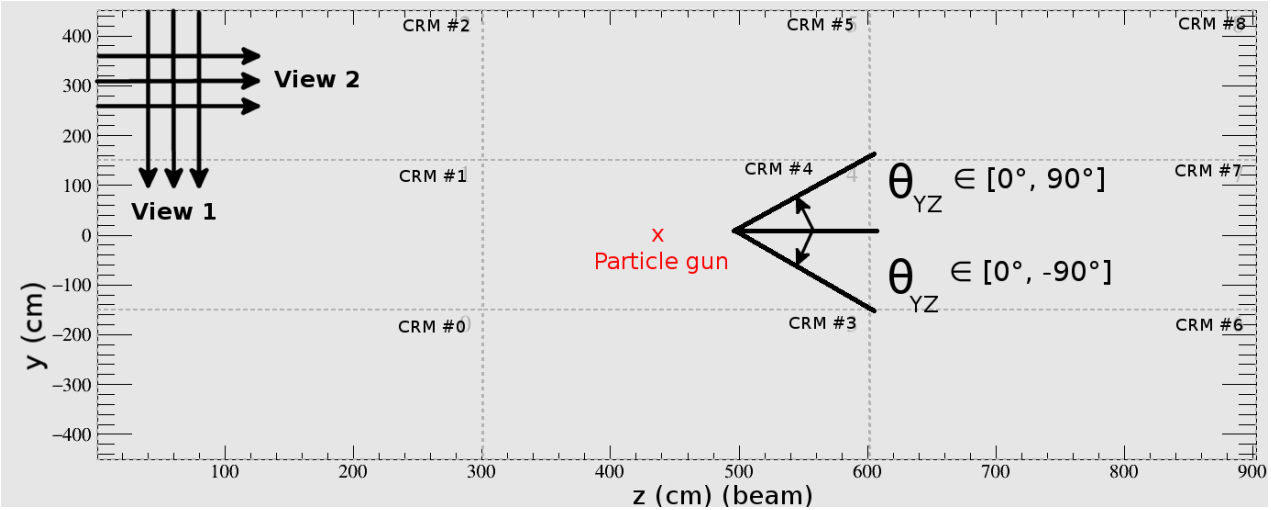
leading reco muon track $\rightarrow$ leading + second reco muon track (stitching)

	# events	% total
Total events	28400	100 %
Good events	26410 $\rightarrow$ 27596	93 % $\rightarrow$ 97.2 %
Bad events	1990 $\rightarrow$ 804	7 % $\rightarrow$ 2.8 %
No (muon) track	515 $\rightarrow$ 515	1.8 % $\rightarrow$ 1.8 %
$L_{reco}/L_{truth} < 75\,\%$	1419 $\rightarrow$ 260	5 % $\rightarrow$ 0.9 %
Completeness $< 50\,\%$	579 $\rightarrow$ 226	2 % $\rightarrow$ 0.8 %
$L_{reco}/L_{truth} > 125\,\%$	13 $\rightarrow$ 16	0.05 % $\rightarrow$ 0.06 %
Purity $< 50\,\%$	6 $\rightarrow$ 6	0.02 % $\rightarrow$ 0.02 %

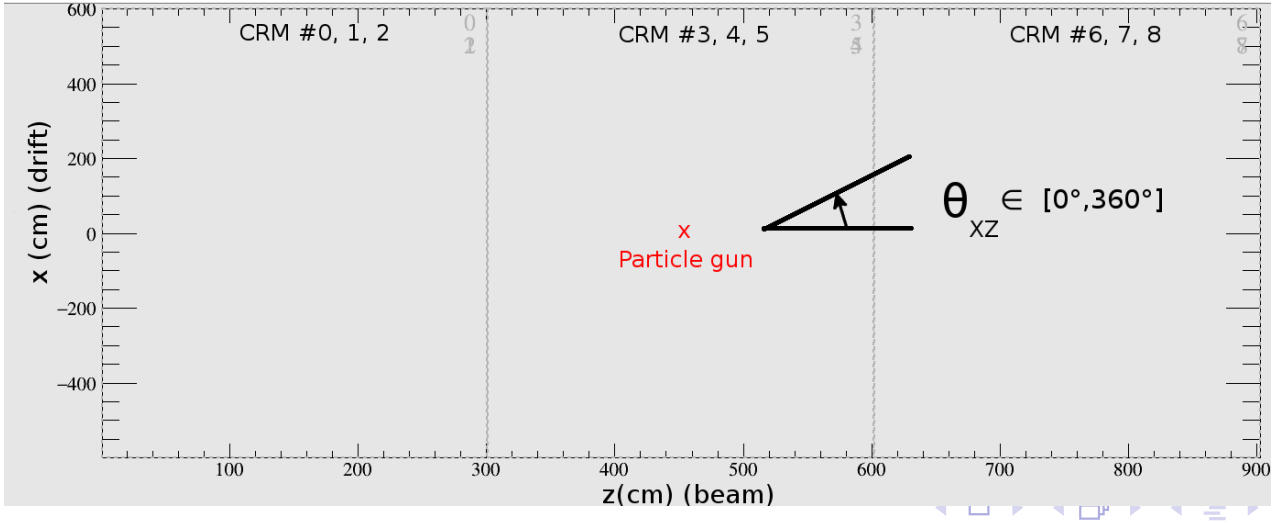
- Stitching increases efficiency by 4.2 %
- 94 % of the 804 bad events left after stitching have 0 or only 1 reco muon track $\rightarrow$ can not be recovered with stitching

Reminder: dual phase workspace geometry

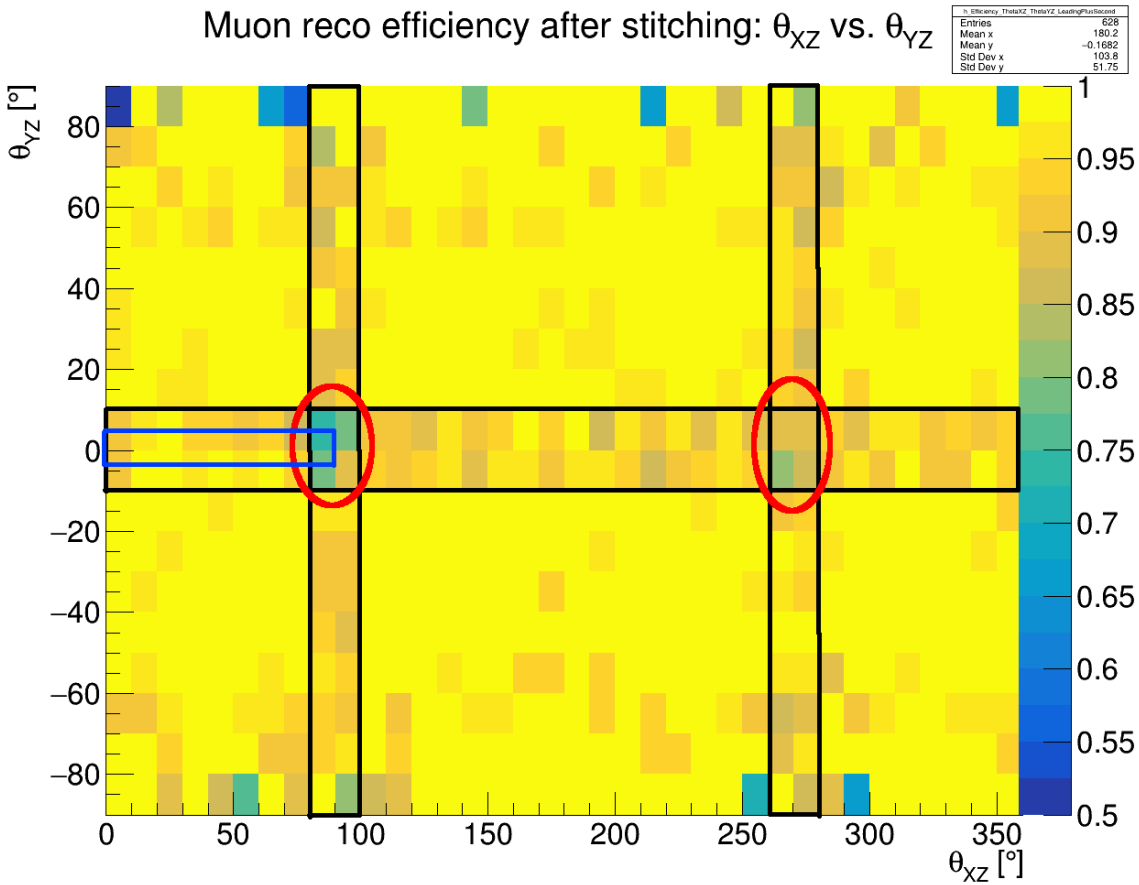
Top view (anode view)



Side view

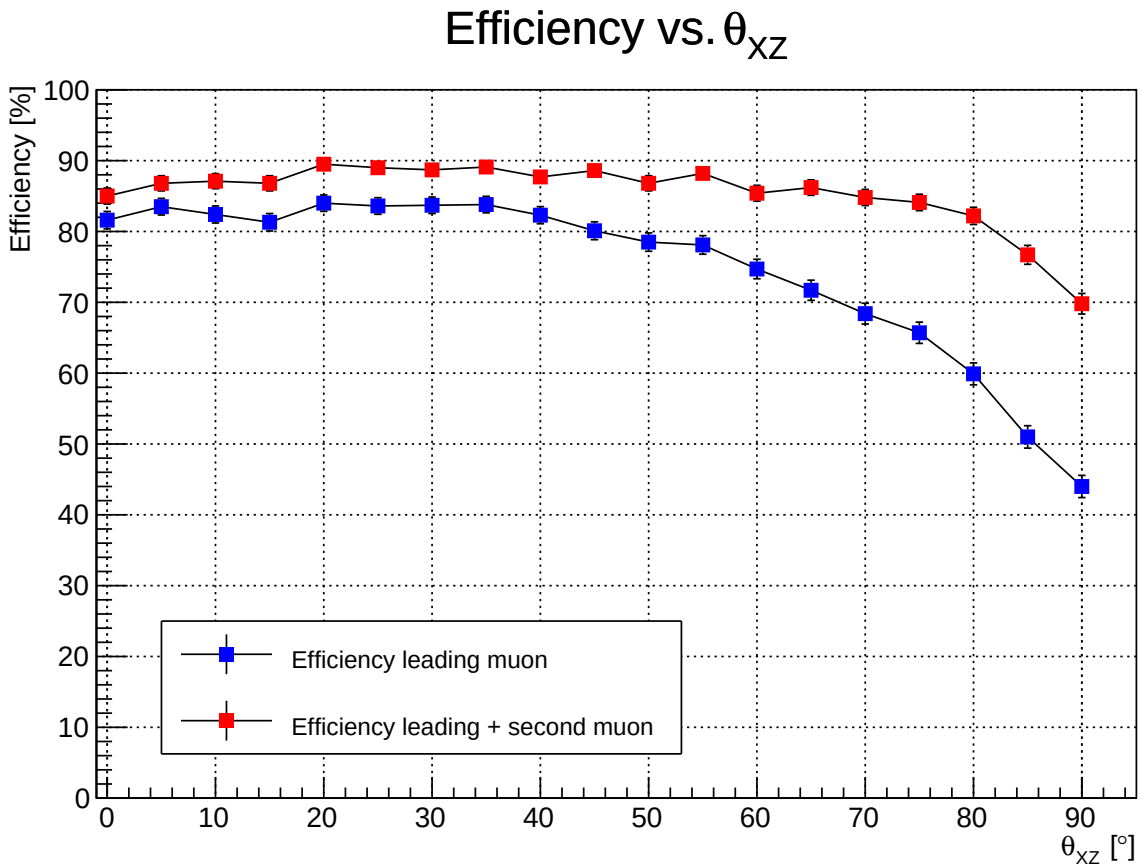


Isotropic muons: efficiency map after stitching



- Large errors for large θ_{YZ} (due to low statistics)
- black boxes: muon is seen only a few wires in one view
- red circles: muon along drift direction
- Focus on blue box: $\theta_{YZ} = 0^\circ \quad , \quad 0^\circ \leqslant \theta_{XZ} \leqslant 90^\circ$

Efficiency vs. muon direction ($\theta_{YZ} = 0°$)

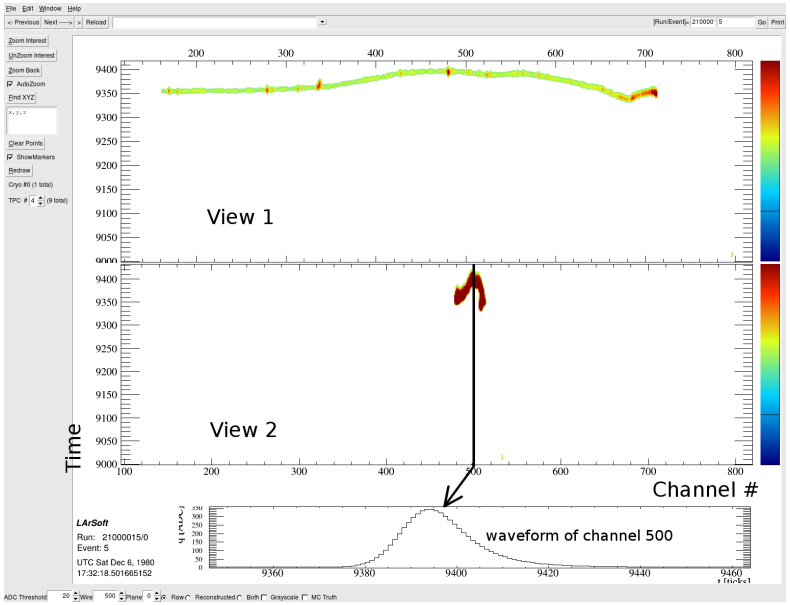


- Each dot: 1000 μ^- with $P_{\mu^-} = 500\,\mathrm{MeV}$
  binomial error: $\sigma_{\mu^-} = \sqrt{\varepsilon \cdot (1-\varepsilon)/1000}$
- Track splitting increased & lower efficiency for $\theta_{XZ} \to 90\,°$
- Pick two example events: $\theta_{XZ} = 0°$ and $\theta_{XZ} = 90°$

Efficiency vs. muon direction

Example events (raw data):

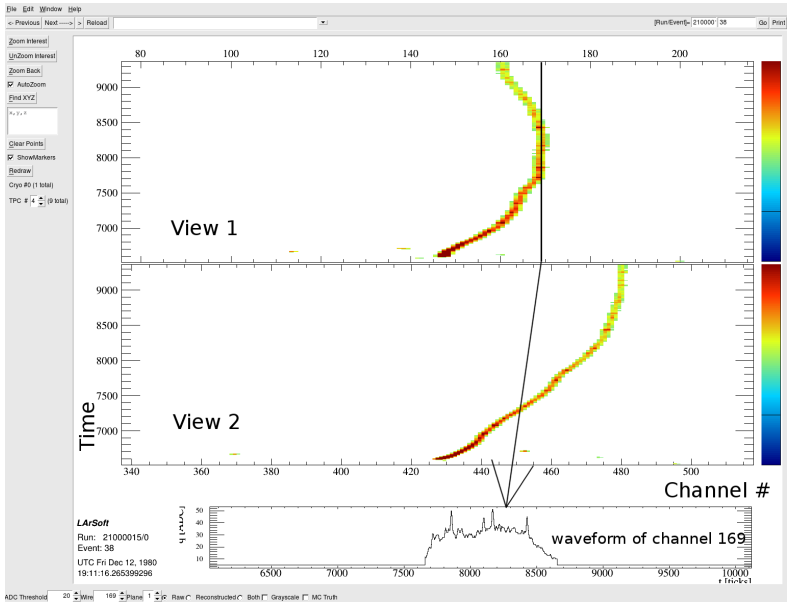
$\theta_{YZ} = 0°$, $\theta_{XZ} = 0°$



- isochronous
- muon is seen by only a few wires in view 2

→ problem for track reco

$\theta_{YZ} = 0°$, $\theta_{XZ} = 90°$



- not isochronous
- muon is seen by only a few wires in both views

→ problem for hit finding

Conclusion and outlook

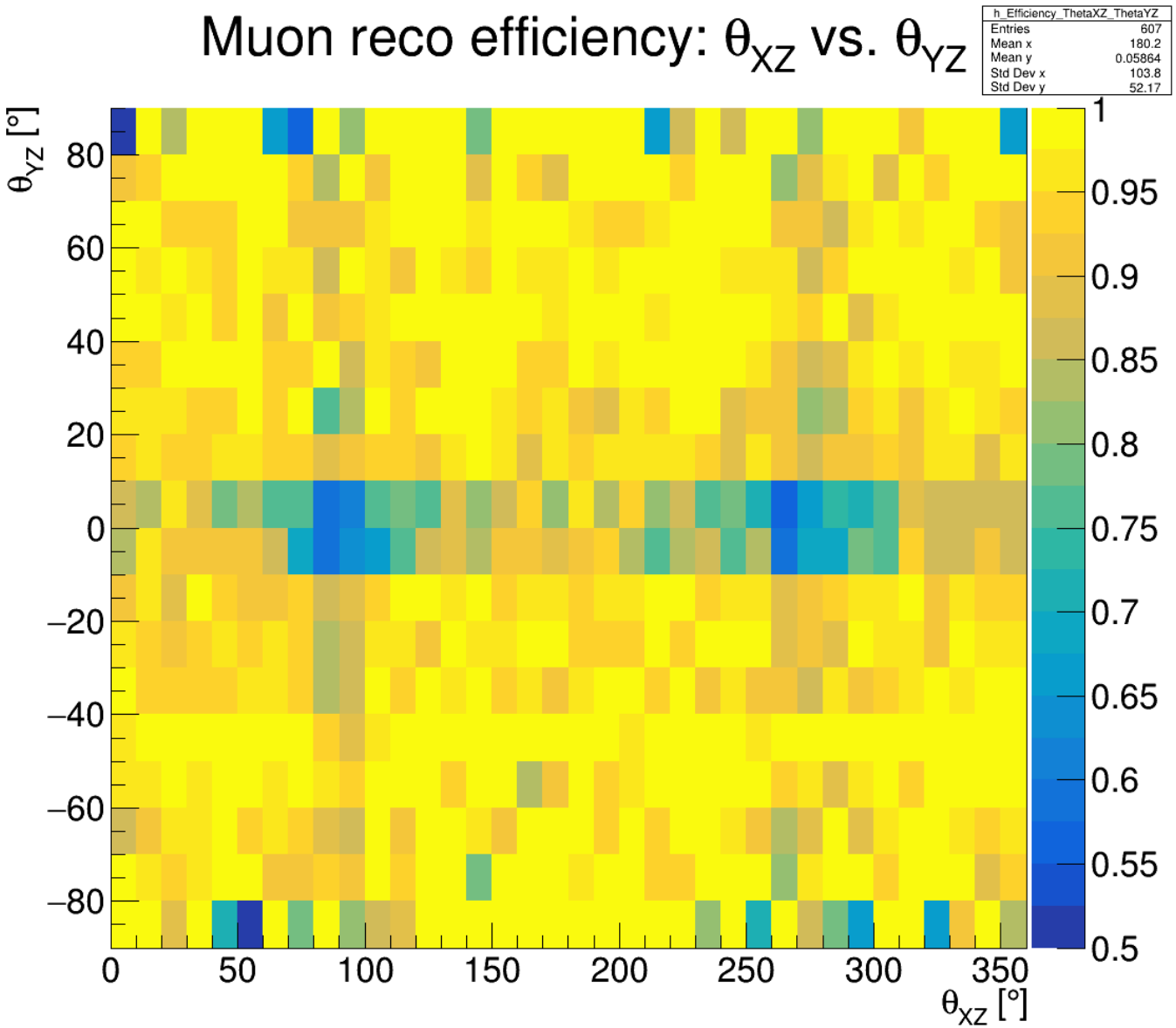
- Efficiency for isotropic muons: 97.2 % (close to 100 % for non-problematic directions)
- Problematic directions: along a few wires in one view (problem: track reco) & along drift direction (problem: hit finding)

$\rightarrow$ start working on hit finding without deconvolution in dual phase

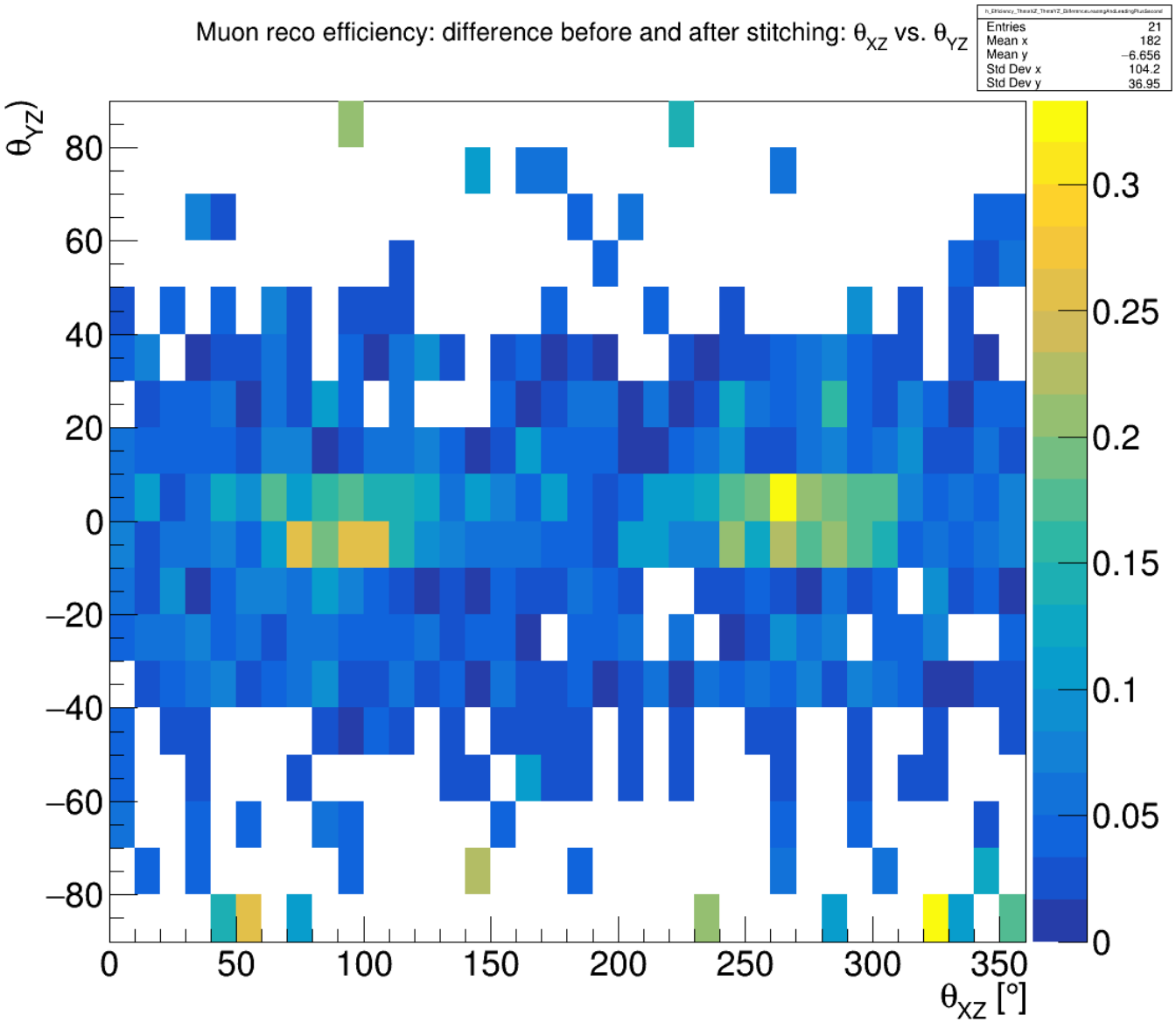
Thanks for your attention!

Backup slides

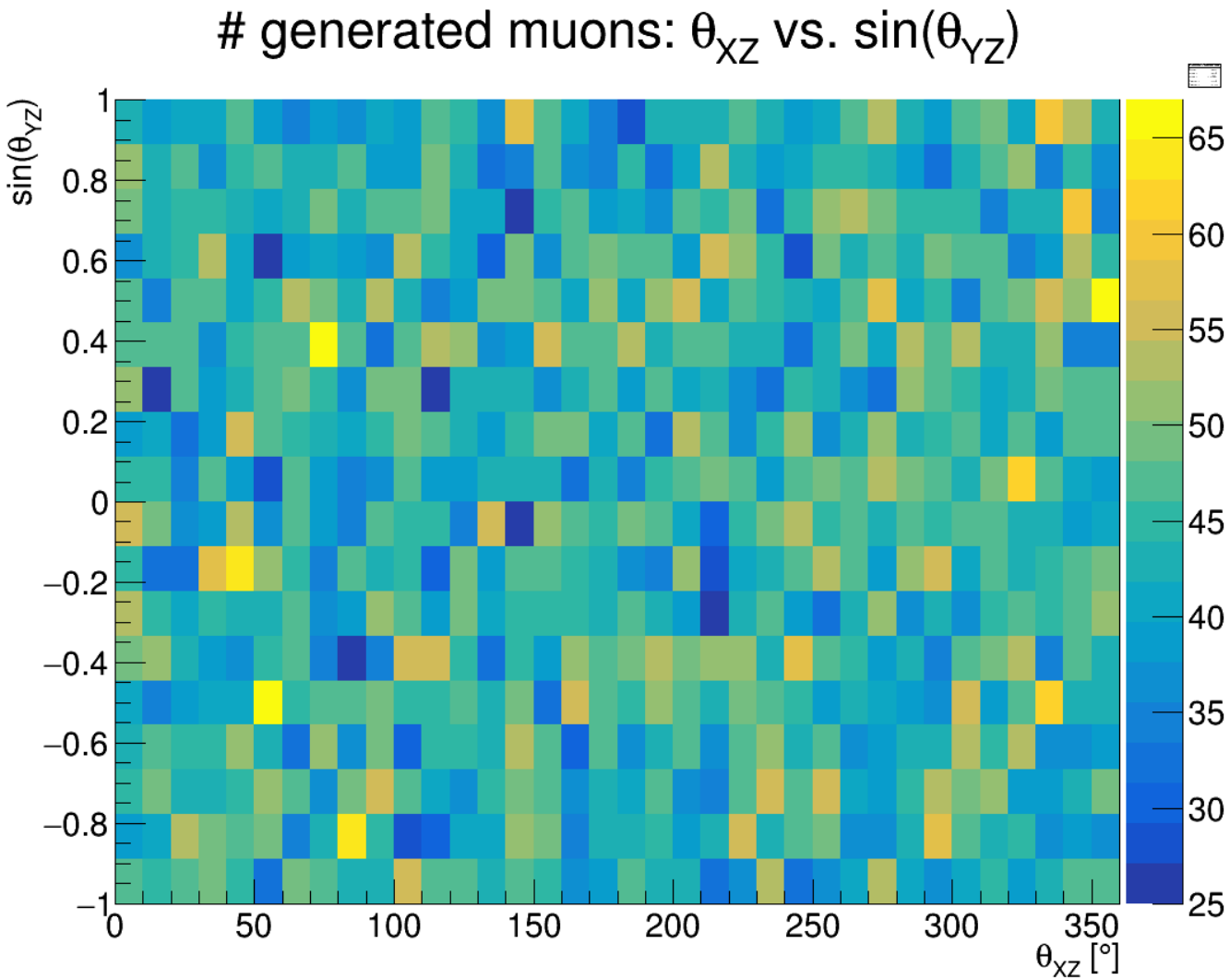
Isotropic muons: efficiency map for leading muon track



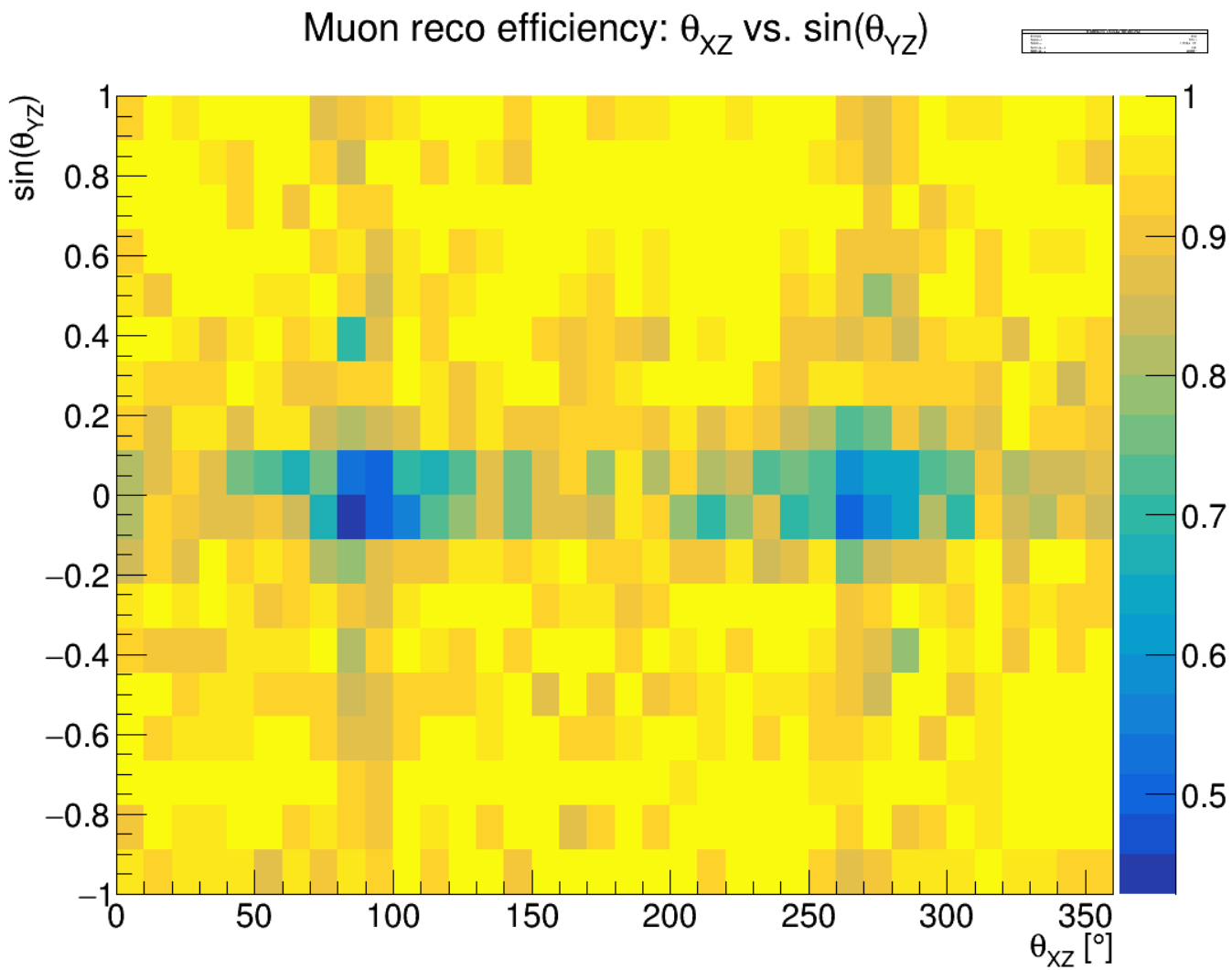
Isotropic muons: Δ efficiency before and after stitching



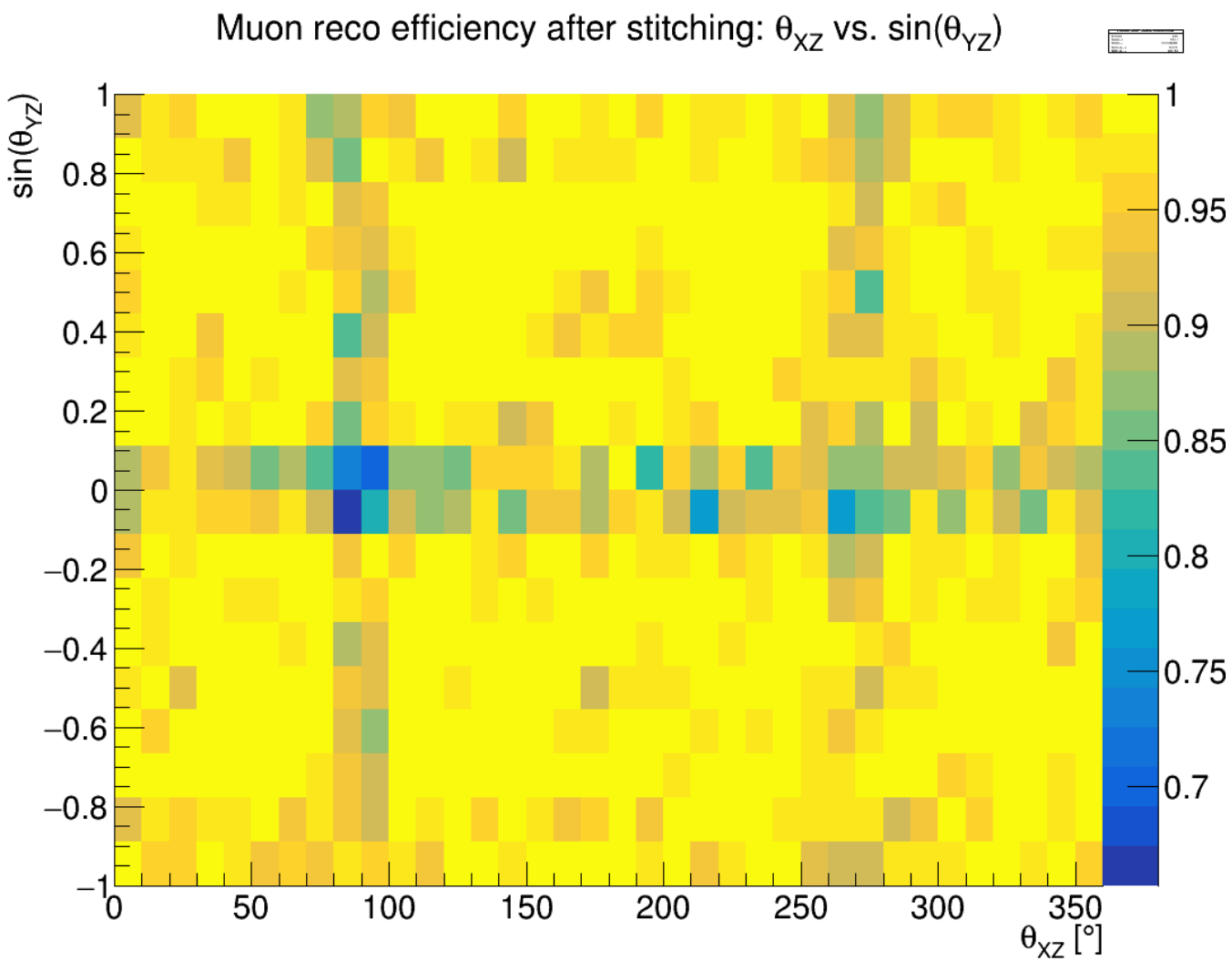
Isotropic muons: generated muons ($sin(\theta_{YZ})$)



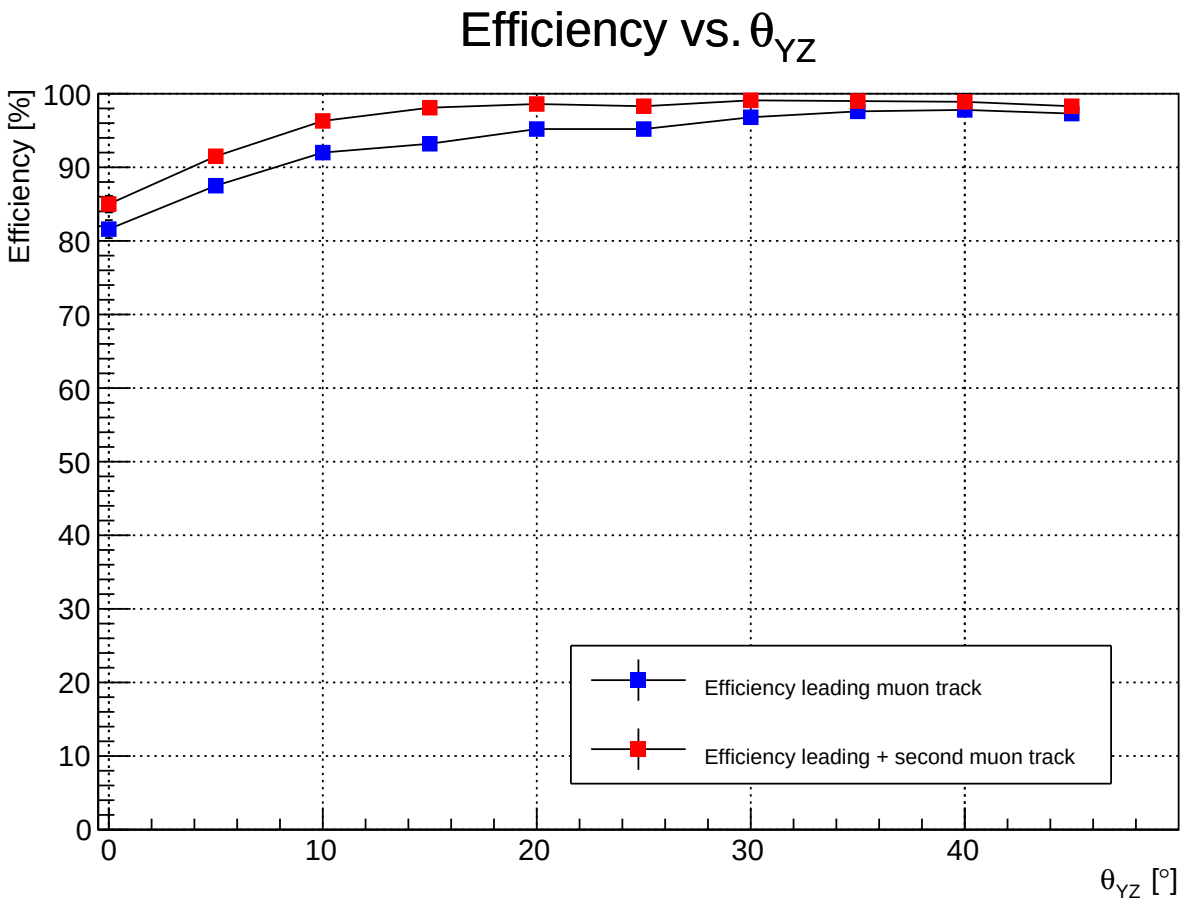
Isotropic muons: efficiency map for leading muon track ($sin(\theta_{YZ})$)



Isotropic muons: efficiency map after stitching ($sin(\theta_{YZ})$)



Efficiency vs. muon direction ($\theta_{XZ} = 0°$)



- Each dot: 1000 μ^- with $P_{\mu^-} = 500\,\mathrm{MeV}$
  $\sigma_{\mu^-} = \sqrt{\varepsilon \cdot (1-\varepsilon)/1000}$
- Track splitting decreased & higher efficiency for $\theta_{YZ} \to 45\,°$