

Asymmetry with
a multi-bin approach

Goal

- Improve the neutrino mass ordering sensitivity
- Start by improving the asymmetry
- We increase the number of *pid* bins used in the asymmetry calculation
(Not bound to pid)
- Used Nikhef Neutrino Mass Ordering program:
NNMO
On April MC mass production

Recap: Current asymmetry

- Asymmetry [..] provides an estimation of the significance of the hierarchy measurement [1]

$$A = \frac{N_{NO} - N_{IO}}{\sqrt{N_{NO}}} \quad \chi^2 = \frac{(x_i - f(x_i))^2}{\sigma_i}$$

- Per bin i, j : $A_{ij} = \frac{N_{ij}^{NO} - N_{ij}^{IO}}{\sqrt{N_{ij}^{NO}}}$

$$A^k = \sum_{i,j} (A_{ij}^k)^2, \quad k = \text{shower, track}$$

$$A^{track} = 6.66358$$

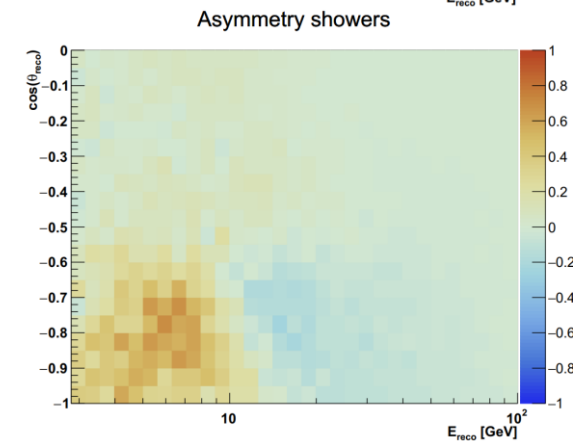
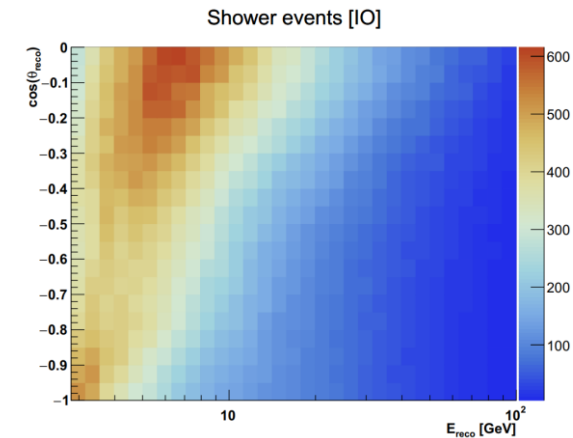
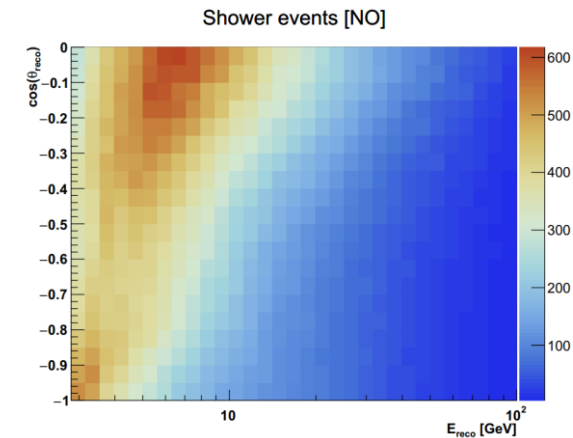
$$A^{shower} = 4.45707$$

Under investigation

$$A = \sqrt{A_{tr}^2 + A_{sh}^2} = 8.0167$$

Track quality	$q < 0.6$	$q > 0.6$
Track reco	X	✓
Shower reco	✓	X

Compare NO with IO



Multi-binned asymmetry

- Currently:

Track quality	$q < 0.6$	$q > 0.6$
Track reco	X	✓
Shower reco	✓	X

- Multi-binned:

Track quality	$0.0 < q < 0.1$	$0.1 < q < 0.2$..	$0.9 < q < 1.0$
Track reco	✓	✓	..	✓
Shower reco	✓	✓	..	✓

- Can't compare the asymmetry: events are double counted

- Change current:

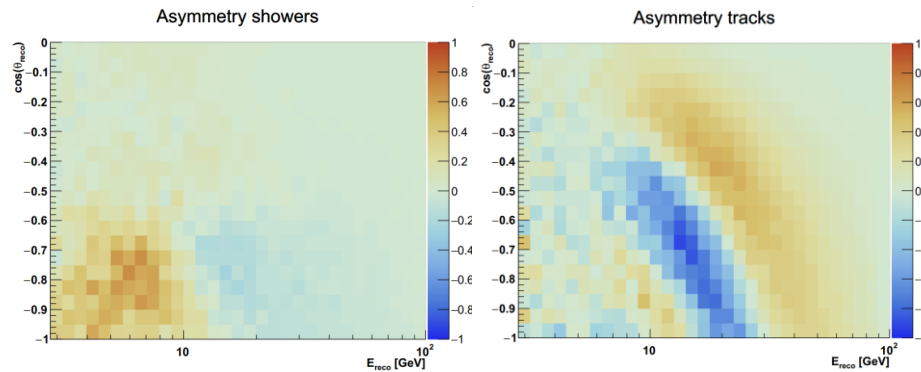
Track quality	$q < 0.6$	$q > 0.6$
Track reco	✓	✓
Shower reco	✓	✓

- Single count with best asymmetry:

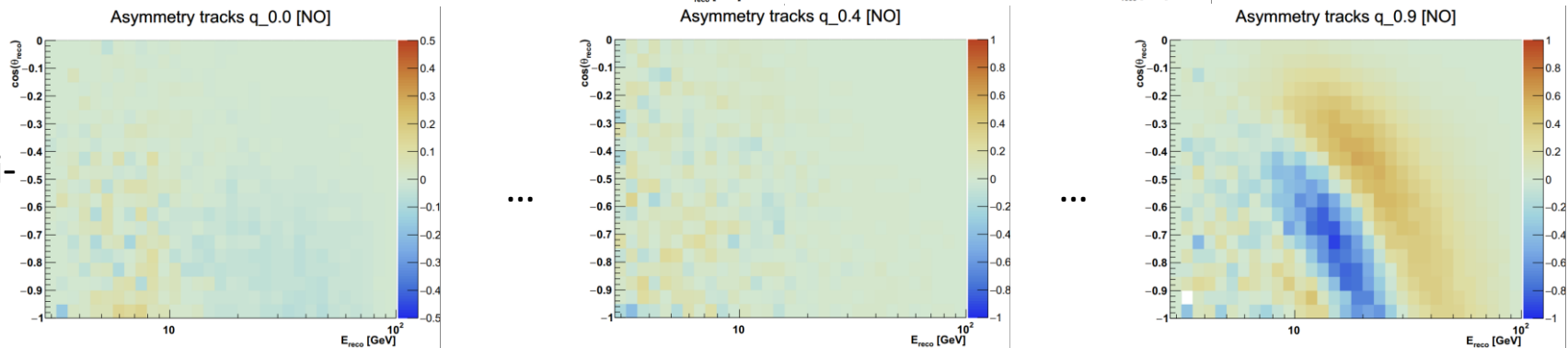
Track quality	$0.0 < q < 0.1$	$0.1 < q < 0.2$..	$0.9 < q < 1.0$
Track reco	X	X	..	✓
Shower reco	✓	✓	..	X

Comparing multi-bin asymmetry

Current:



Multi-bin



Asymmetry	Multi-binned	Current+double counting
Track	8.50658	7.11227
Shower	8.71227	6.52078
Combined	12.1764	9.64909

MB, single count	Current
6.60824	6.66358
7.76154	4.45707
10.19364357	8.01678

Less events per bin -> Is this increase significant?



Energy resolution

E-reso shower

E-reso track

E-reso track;
q=0.0

Under construction

E-reso track;
q=0.4

E-reso track;
q=0.9

E-reso shower;
q=0.0

E-reso shower;
q=0.4

E-reso shower;
q=0.9

Conclusion & next steps

- The combined asymmetry increases by 25%
 - Concern about the MC statistics (10 bins instead of 2)
 - Quantify increase in the sensitivity
- Implement:
 - Uncertainty calculation on asymmetry to find if the difference between methods is significant
 - parameter fit in NNMO using RooFit to find the sensitivity
- Look into:
 - different cuts: parameters to cut on, cut values