

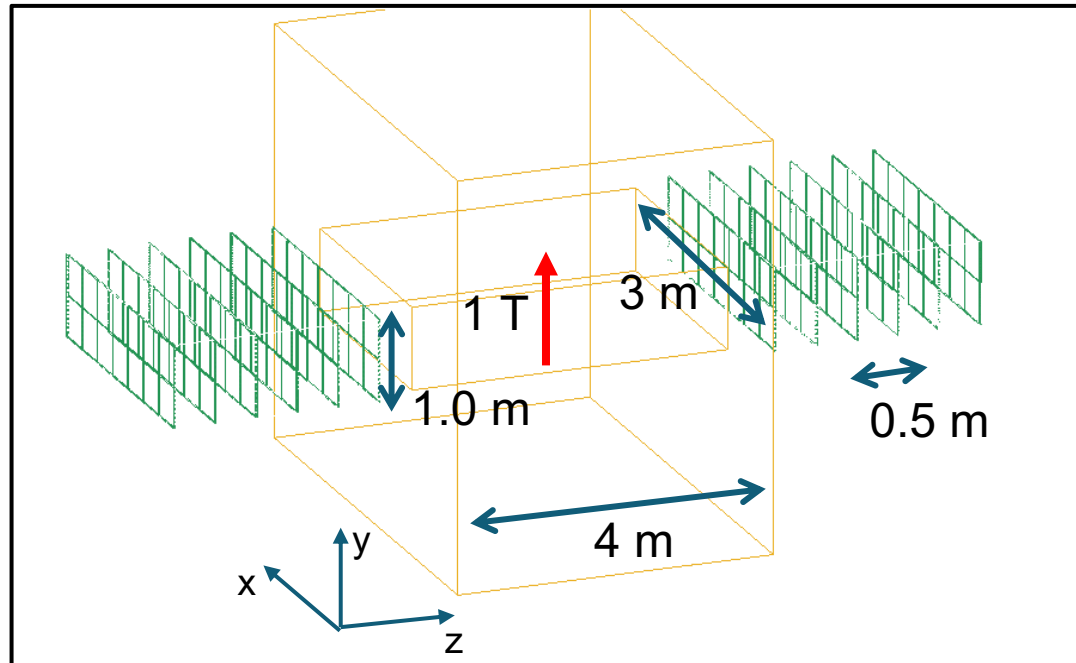
Muon acceptance into FASER2 for different FPF options

Matteo Vicenzi

November 14th, 2023

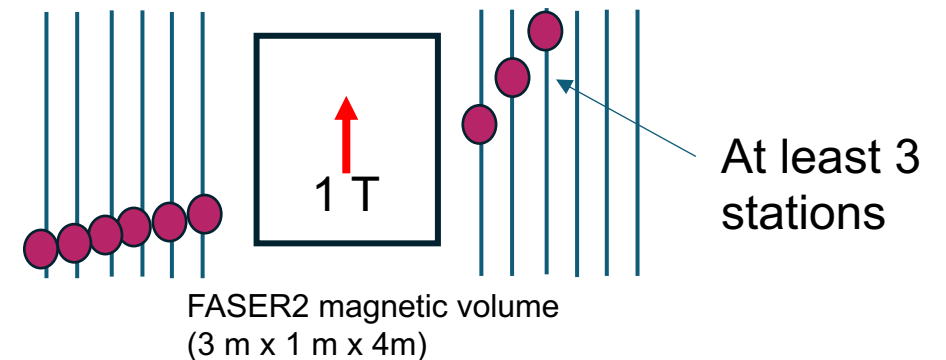
FLArE Technical Meeting

Magnet: SAMURAI



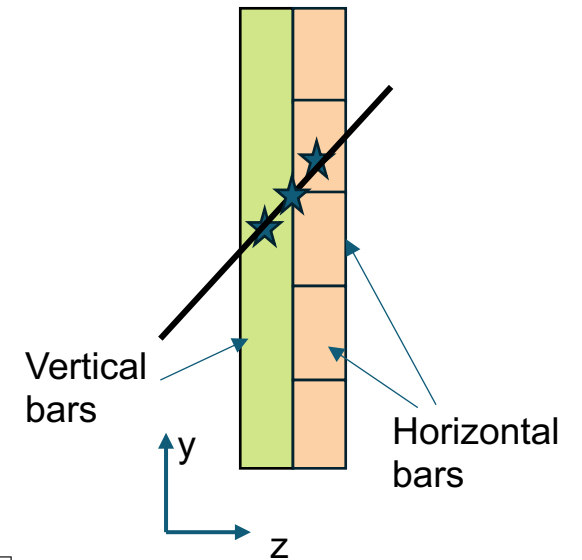
Rectangular window: 3 m x 1 m (4 Tm)
6 tracking stations, 50 cm apart
 $B = 1$ T (fixed)
Yoke X-thickness: 1.5m
Yoke Y-thickness: 2m

- Simple acceptance requirements:
 - **>0 digits** in the pre-magnet tracking stations
 - **>2 digits** in the post-magnet tracking stations

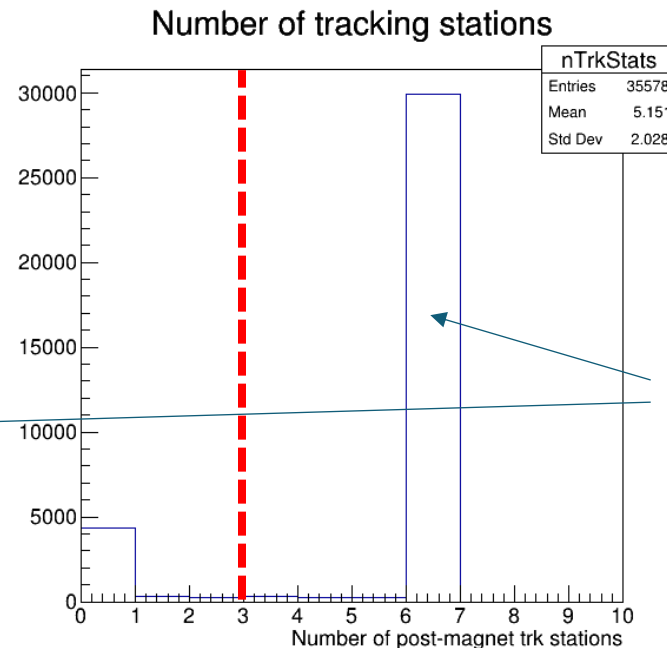
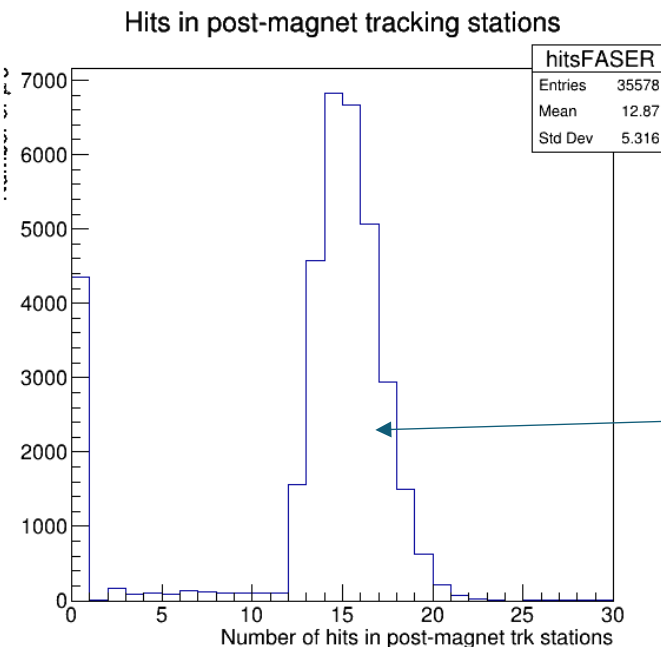


Segmentation

- The segmentation/digitization of the tracking stations is currently ignored.
- In the past studies, I was requesting **>5 hits** assuming each station was yielding only 2 hits (which is not always true).
- Now I'm setting a requirement on the number of tracking station crossed (1 digit = 1 tracking station), rather than the number of hits.



Distributions of hits for the muons that touched the pre-magnet tracking stations:



Crossing all 6 stations:
number of hits is not fixed, due to the stepping of the simulation

Options

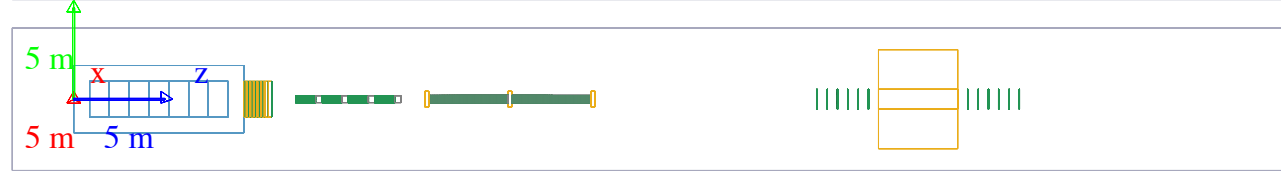
FLArE +
FASER2 only



FLArE to FASER2:
(center to center)

$D = 38336 \text{ mm}$

Option 0:
Reference hall

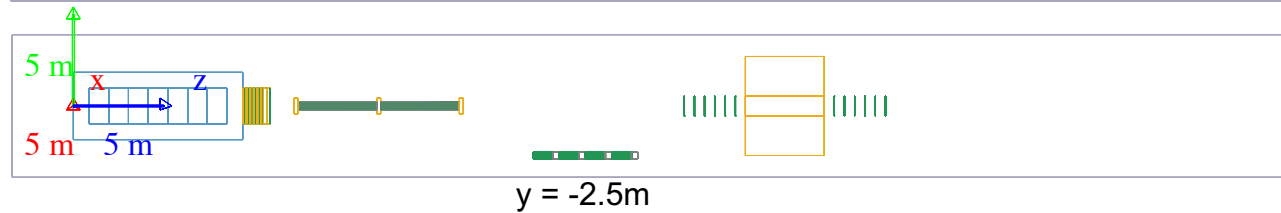


Option 1a:
FORMOSA last

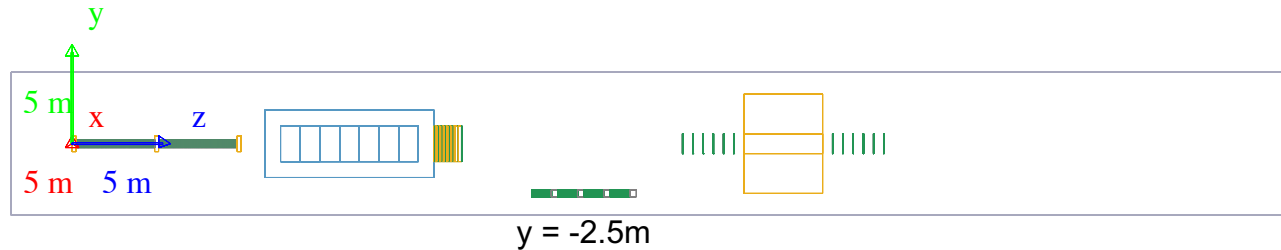


$D = 31816 \text{ mm}$

Option 1b:
FORMOSA under



Option 2:
FASERnu2 first



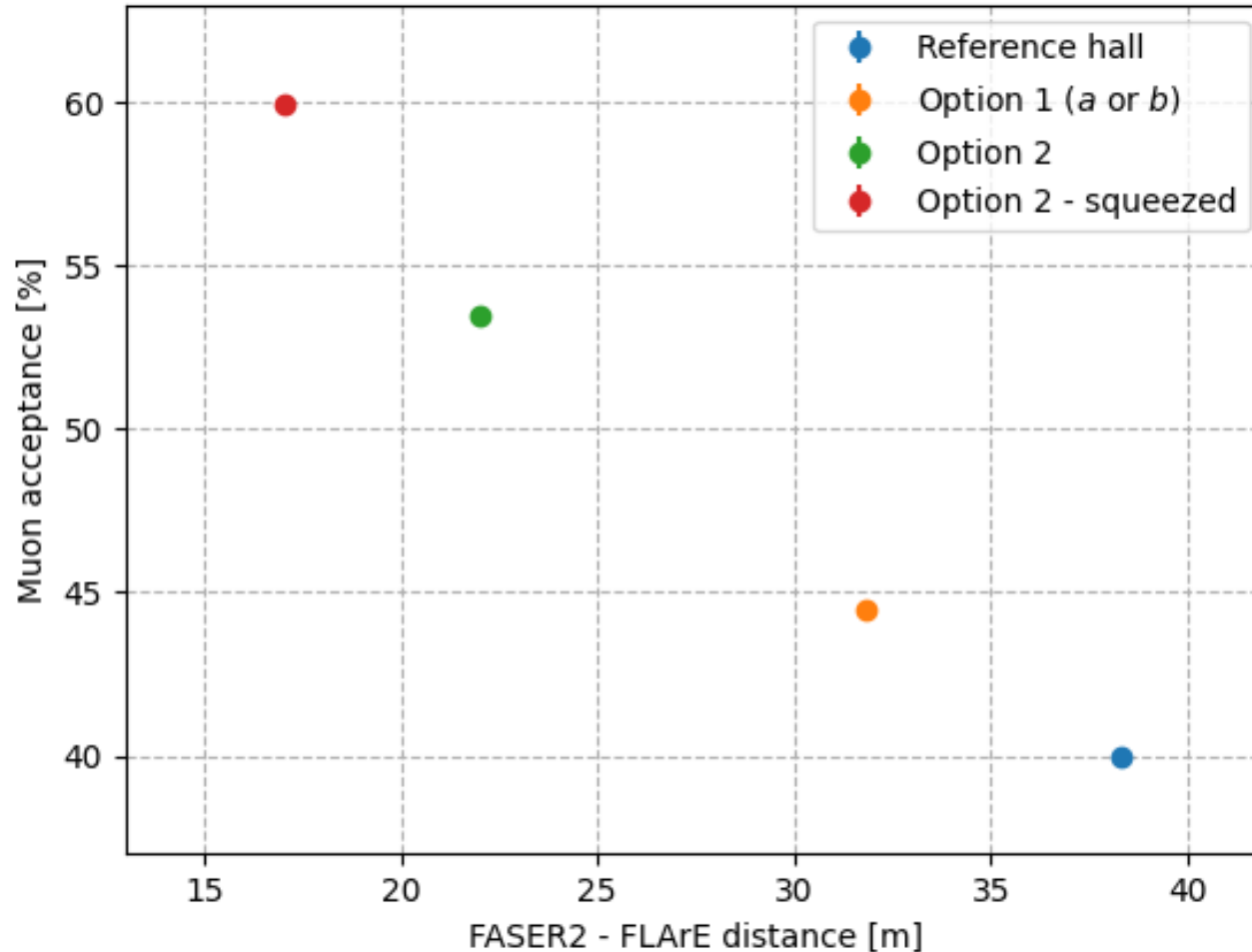
$D = 22030 \text{ mm}$

Muon acceptance

Muons from a sample of 100k ν_μ CC interactions in FLArE.
B-field @ FLArE: 1 T; FLArE fiducial is: 1m x 1m x 7m.

OPTION	Distance to FASER2	FLArE volume	TOT	HadCat + MF	FASER2
FLArE + FASER2 only	38.3 m	All	76699	66899 (87.2%)	23760 (31.0%)
		Fiducial	76699	73486 (95.8%)	30808 (40.2%)
Option 0: Reference hall		Fiducial	76699	73486 (95.8%)	30668 (40.0%)
Option 1a: FORMOSA last	31.6 m	Fiducial	76699	73486 (95.8%)	34118 (44.5%)
Option 1b: FORMOSA under			76699	73486 (95.8%)	34118 (44.5%)
Option 2: FASERnu2 first	22 m	Fiducial	76699	73461 (95.8%)	41027 (53.5%)
Option 2 "squeezed"	17 m	Fiducial	76699	73309 (95.6%)	45952 (59.9%)

Acceptance vs distance



B-field @ FLArE: 1 T

FLArE fiducial is: 1m x 1m x 7m.

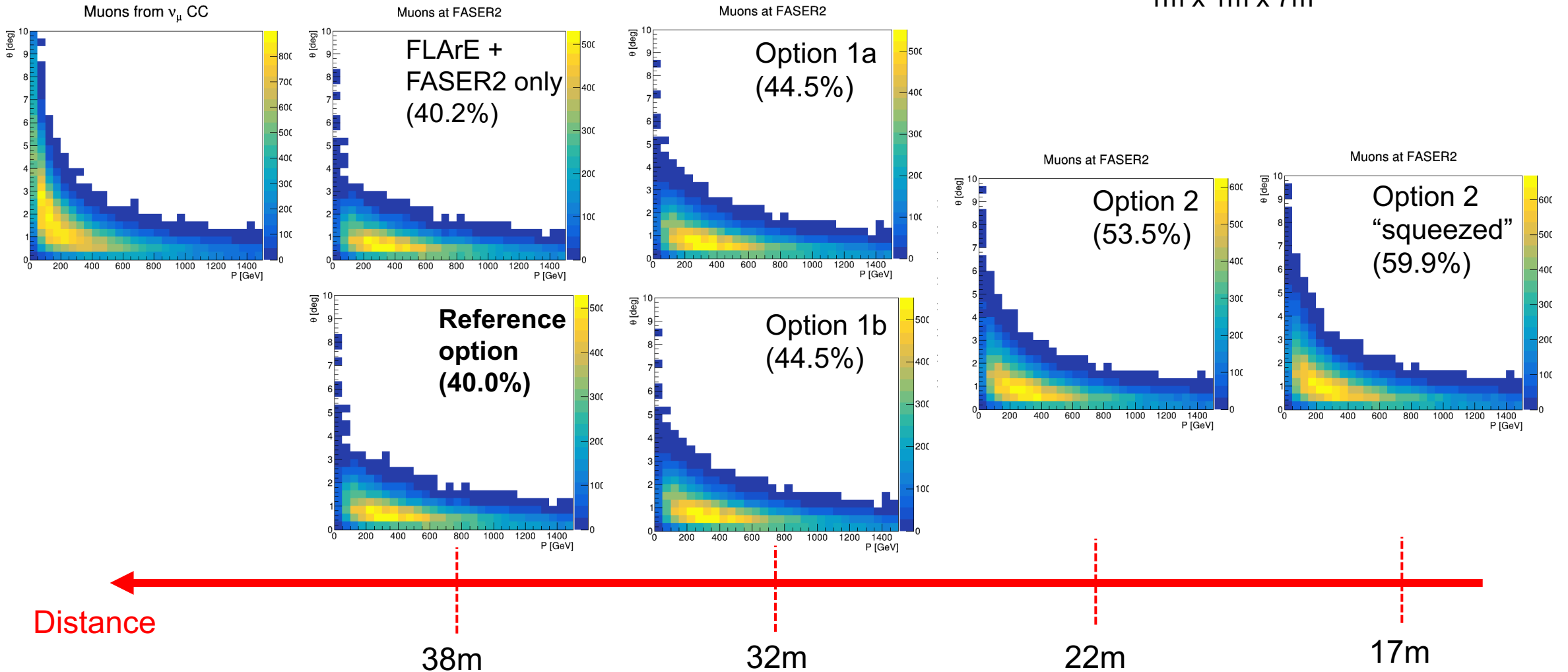
Can we do better than Option 2?

- FASER2 decay volume minimum length is 8m → gaining ~2m meters
- Squeezing tracking stations from 0.5m spacing to 0.2m → gain ~1.8 meters
- No inter-detector buffer → gaining ~1.2 meters

Option 2 “squeezed”: ~17 m

Acceptance phase space

B-field @ FLArE: 1 T
FLArE fiducial is:
1m x 1m x 7m



Fiducial volume

- In the past I reported a 32.8% acceptance using the FLArE fiducial volume.

OPTION	D [m]	FLArE volume	TOT	HadCat + MF	FASER2
FLArE + FASER2 (OLD)	~37	All	15407	13580 (88.1%)	4905 (31.8%)
		1m x 1.8m x 7m	8519	7843 (92.0%)	2793 (32.8%)

Old study [REF]:
Fiducial only with $|x| < 0.5\text{m}$

*past study used >5 hits requirement

- Now I'm getting ~40% in the "same" conditions. This is due to a **difference in the definition of the fiducial volume**: cut along Y dominates the acceptance (due to y-size of magnet window)

OPTION	D [m]	FLArE volume	TOT	HadCat + MF	FASER2
FLArE + FASER2	38.3	All	76699	66898 (87.2%)	23760 (31.0%)
		1m x 1m x 7m	76699	73486 (95.8%)	30808 (40.2%)
		1m x 1.8m x 7m	42554	38885 (91.4%)	13364 (31.4%)
		1.8m x 1m x 7m	42799	39061 (91.3%)	16917 (39.5%)

New study:
Comparing fiducial volumes:

$|x| < 0.5\text{m} \ \&\& \ |y| < 0.5\text{m}$

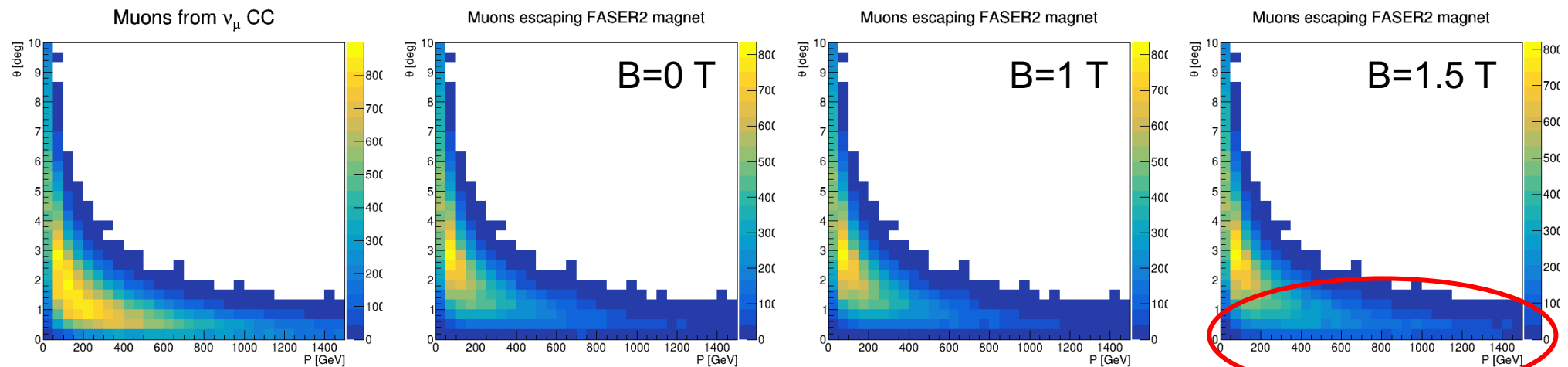
$|x| < 0.5\text{m}$ (only)

$|y| < 0.5\text{m}$ (only)

Dependence on FLArE B-field

- In the past study, the effect of FLArE B-field on the FASER2 acceptance appeared negligible. This is no longer the case, possibly given then newer fiducial volume definition.

OPTION	D [m]	B [T]	FLArE volume	TOT	HadCat + MF	FASER2
FLArE + FASER2 only	38.3	0	Fiducial	76699	73284 (95.5%)	30680 (40.0%)
		1	Fiducial	76699	73486 (95.8%)	30808 (40.2%)
		1.5	Fiducial	76699	69440 (90.5%)	26381 (34.4%)

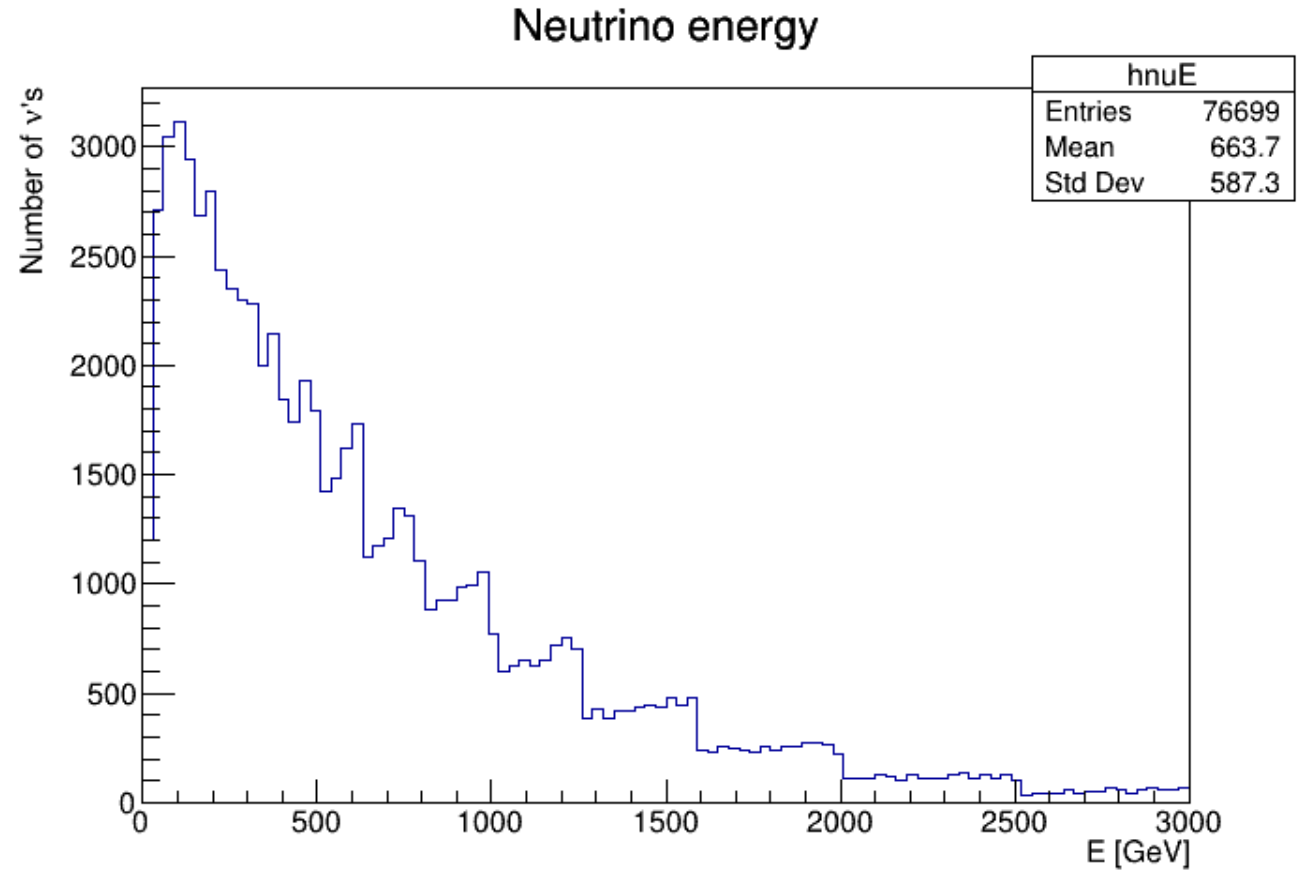
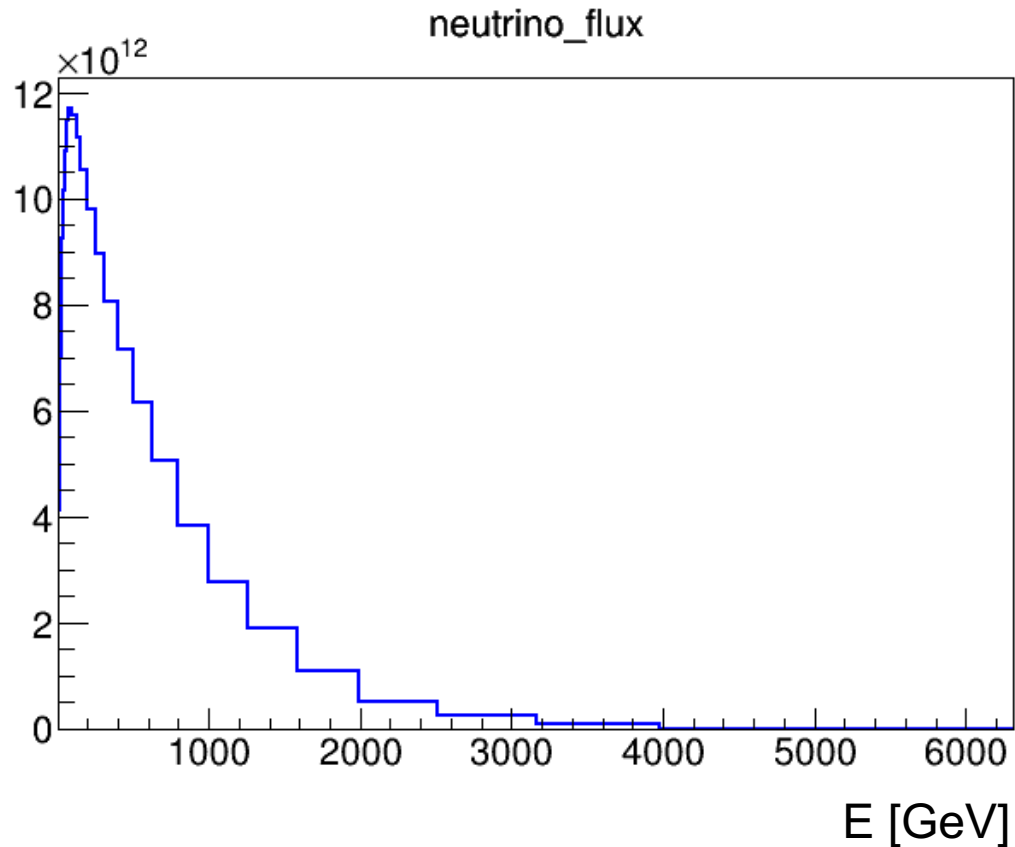


Next steps

- Repeating the same using Crystal-Pulling magnets.
 - Production completed yesterday, looking into it today/tomorrow.
- Revisiting muon momentum reconstruction performance (both magnets).
- Optimize FLArE HadCat+MF for muons escaping FASER2
 - Targeting 20% resolution for ~10 GeV muons
- Summarize these results in the tech note.

Back-up

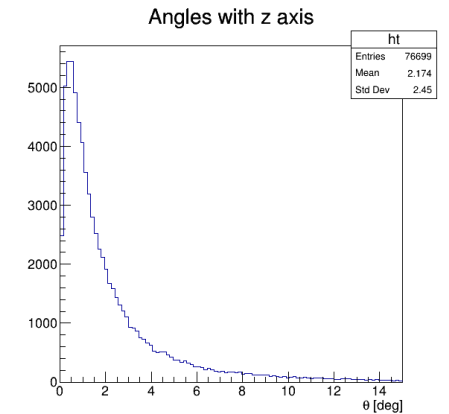
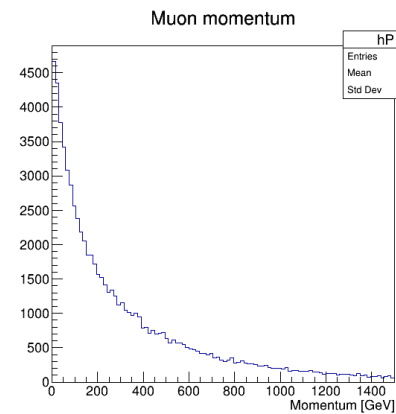
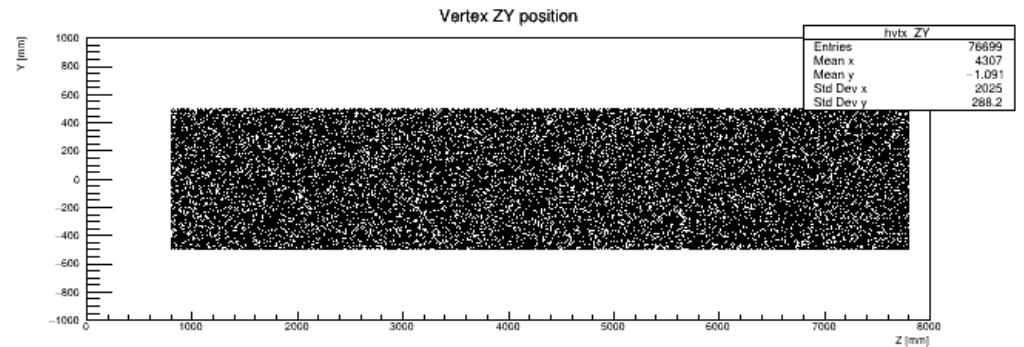
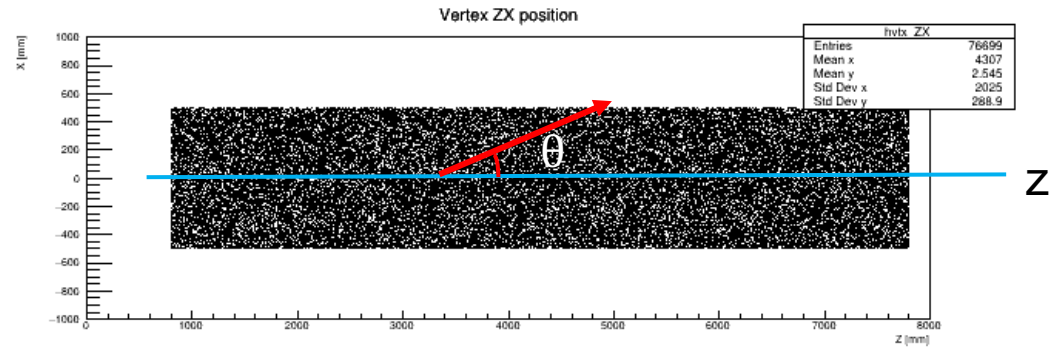
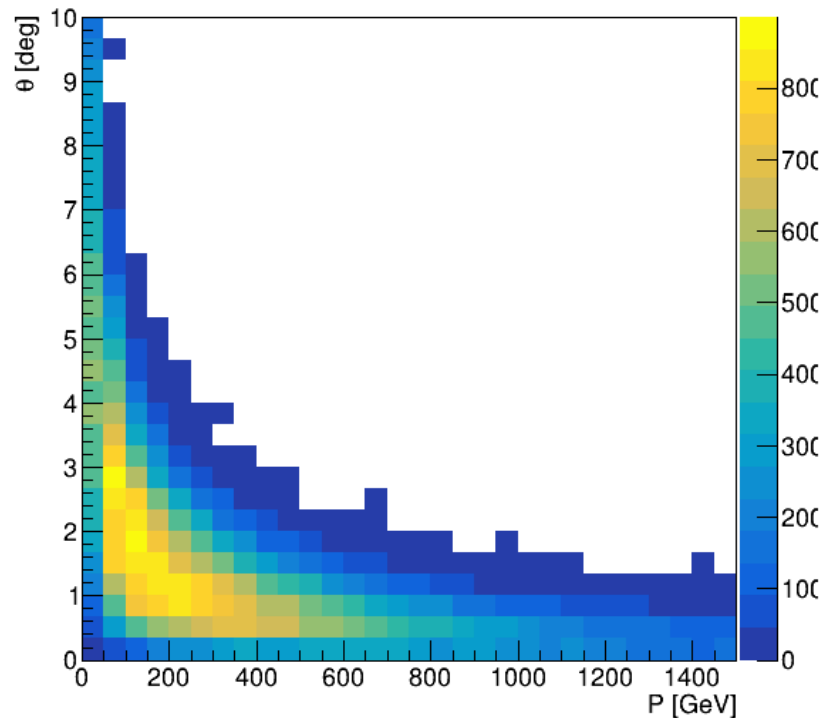
Input ν_μ flux



Muons from ν_μ

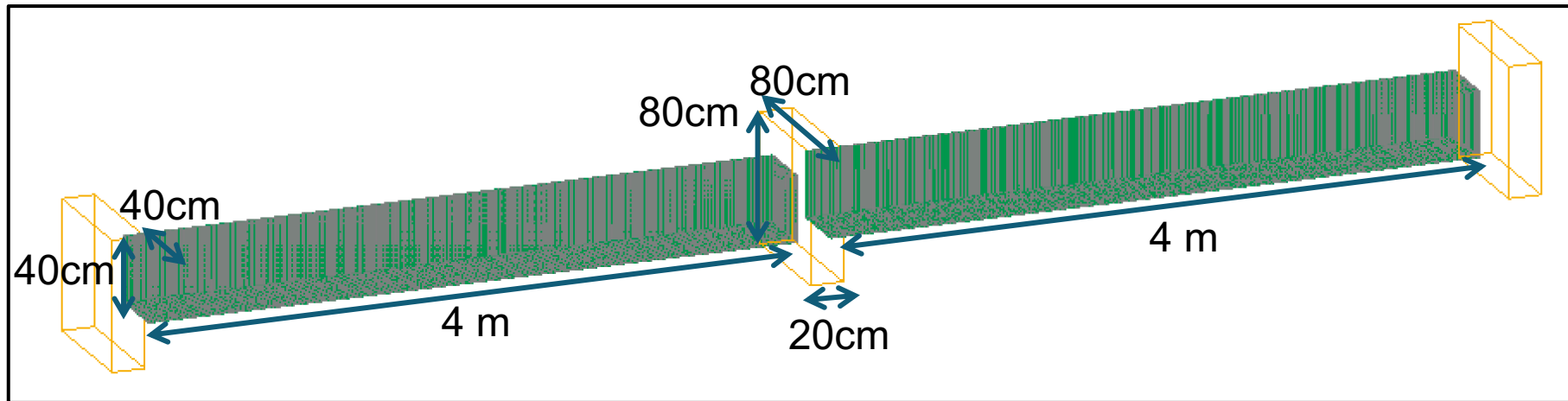
- Picking out muons from ν_μ interactions, uniformly distributed in FLArE. [\[ref\]](#)
- 100k ν_μ sample \rightarrow 76.7k μ (77%)

Muons from ν_μ CC



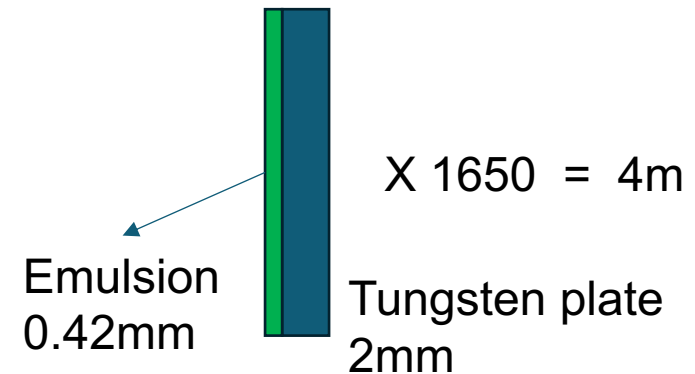
FASERnu2

FASERnu2 geometry according to [\[ref\]](#)



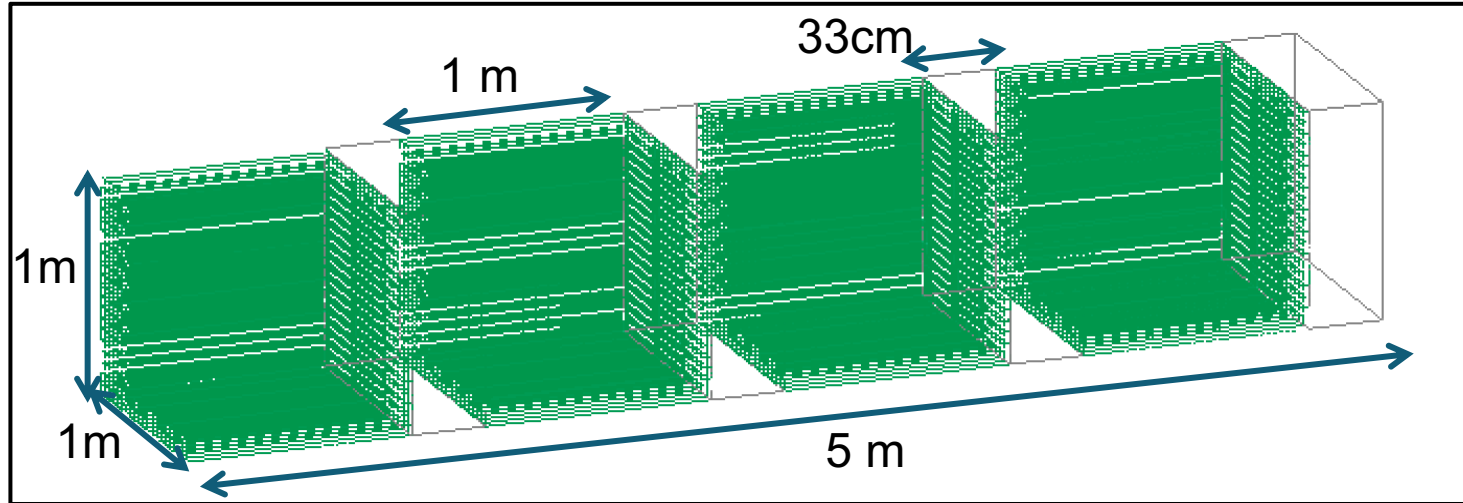
2 emulsion-tungsten modules, 40cm x 40cm x 4m
3300 tungsten plates, 2mm thick
3 veto/interface detectors, 80cm x 80cm x 20cm
(no cooling box for now)

Total length: 8.6m



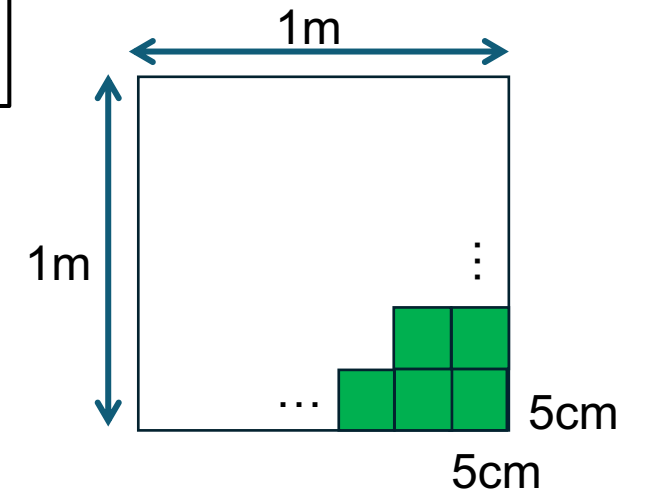
FORMOSA

FORMOSA geometry from FPF P5 paper [\[ref\]](#)



4 scintillator modules, 1m x 1m x 1m
Each made of 400 bars, 20 x 20
Single bar: 5cm x 5cm x 1m
2 veto detectors (not added yet)

Total length: ~5m



Acceptance vs digits requirement

- The nominal requirement is at least 3 tracking stations. Minimum requirement for momentum reconstruction is 2 tracking stations.

OPTION	Req.	TOT	FASER2
Option 0: Reference hall	>1	76699	30924 (40.3%)
	>2	76699	30668 (40.0%)
	>3	76699	30383 (39.6%)
	>4	76699	30143 (39.3%)
	>6	76699	29879 (38.9%)

