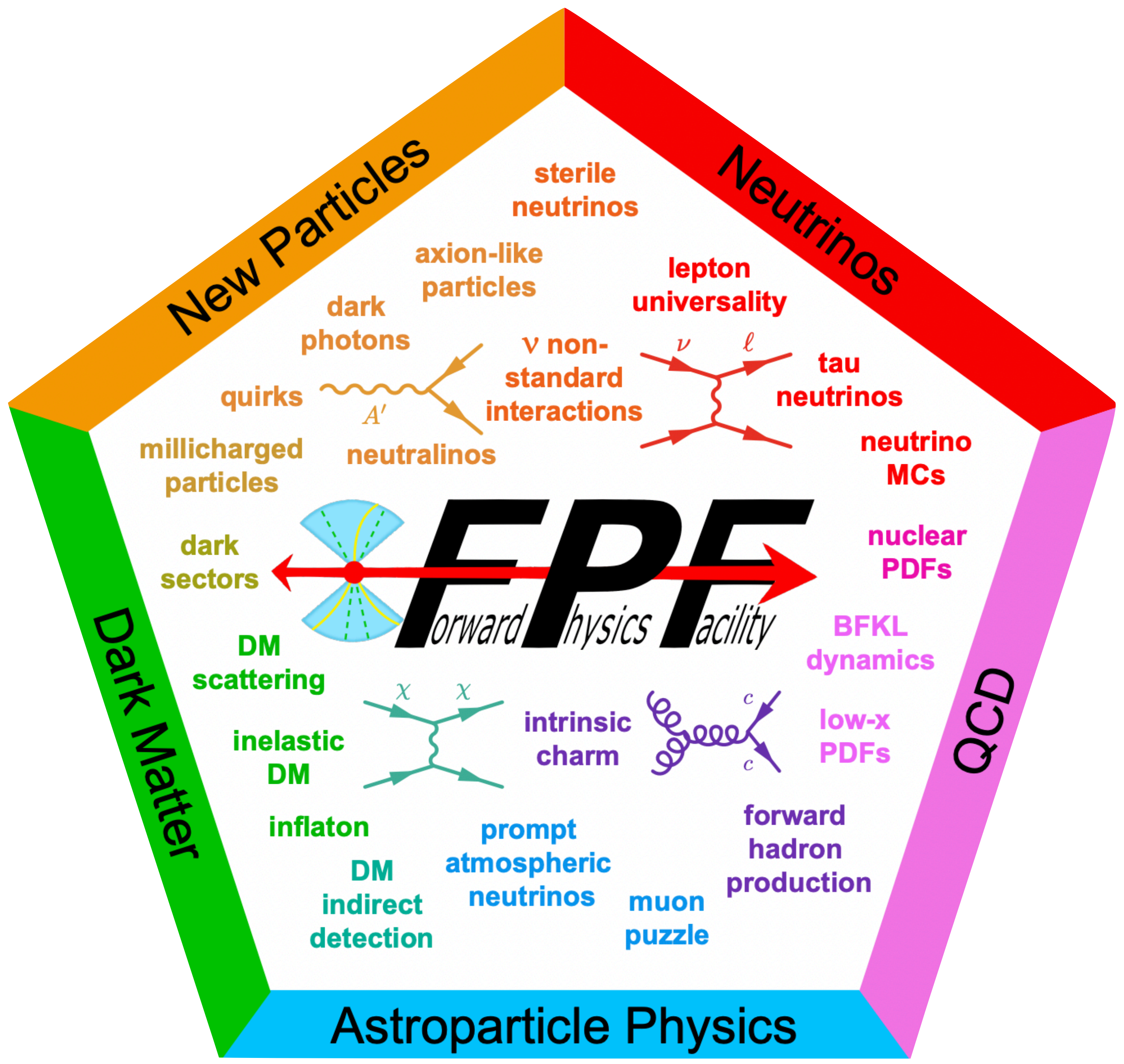

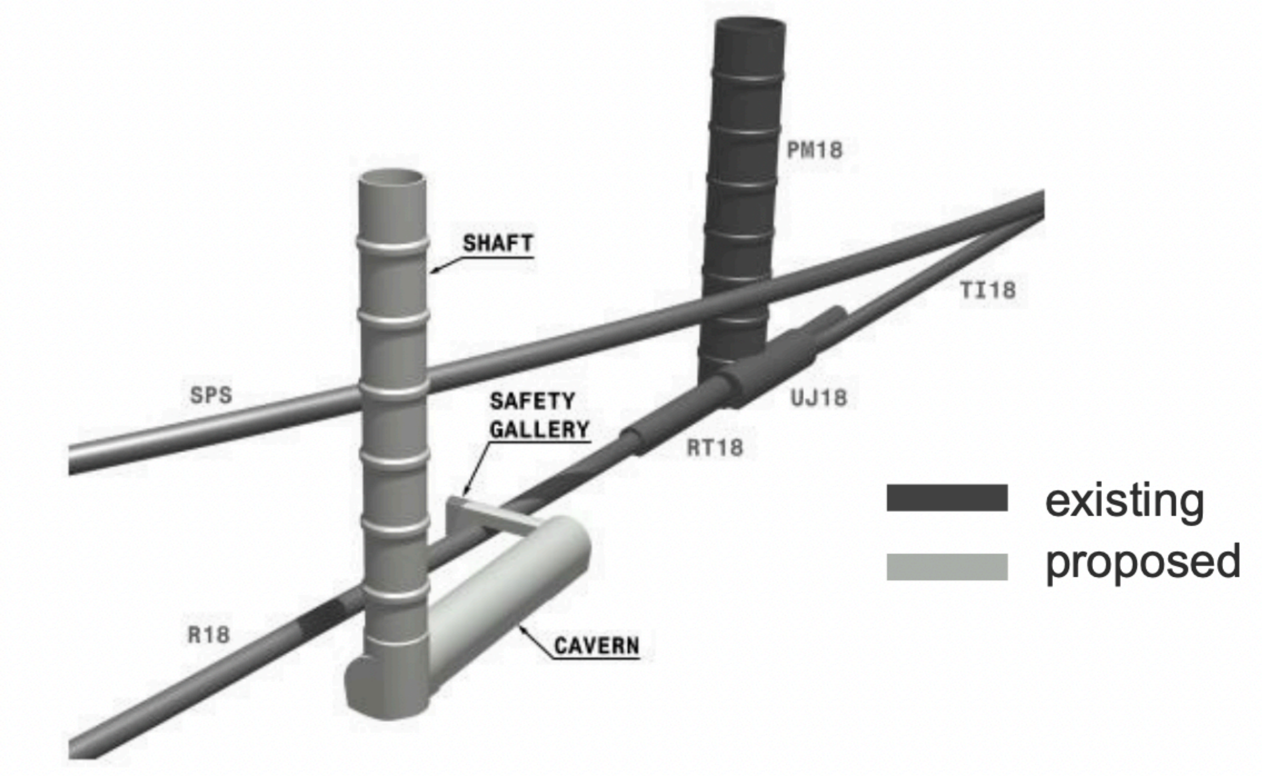

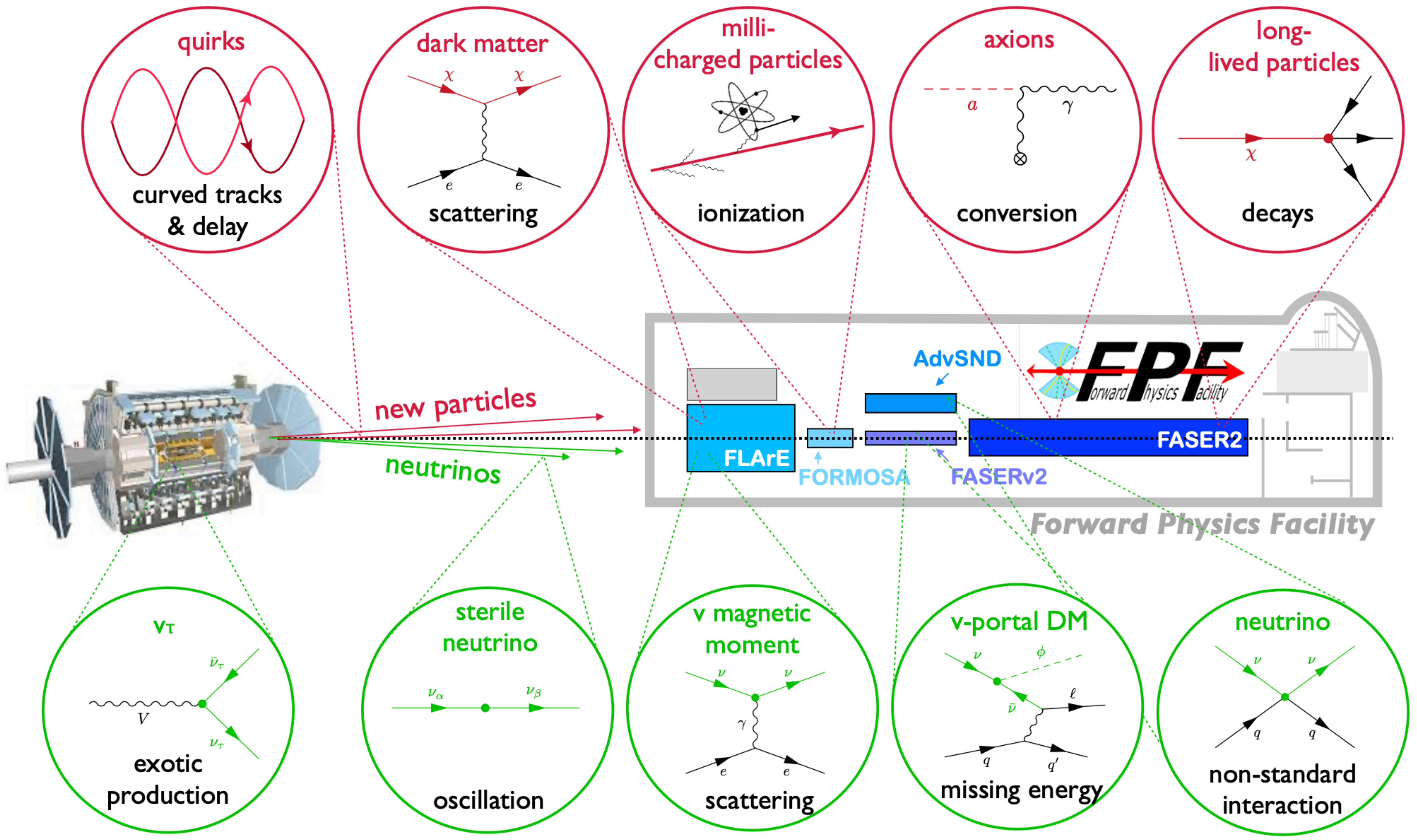

Electron (anti)neutrino detector

FPF7

1/3/2024

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CERN

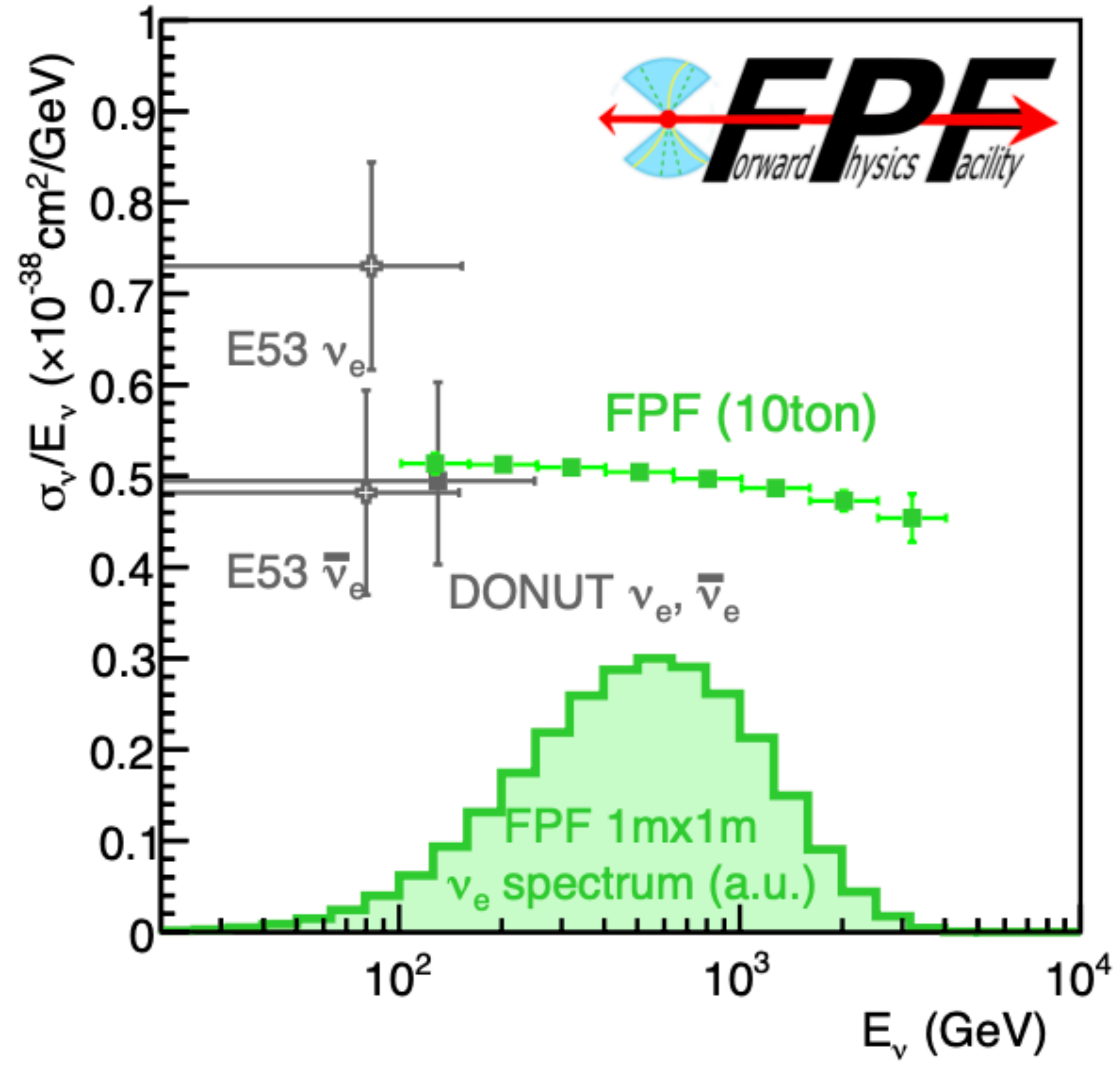
UNIVERSITY OF SUSSEX

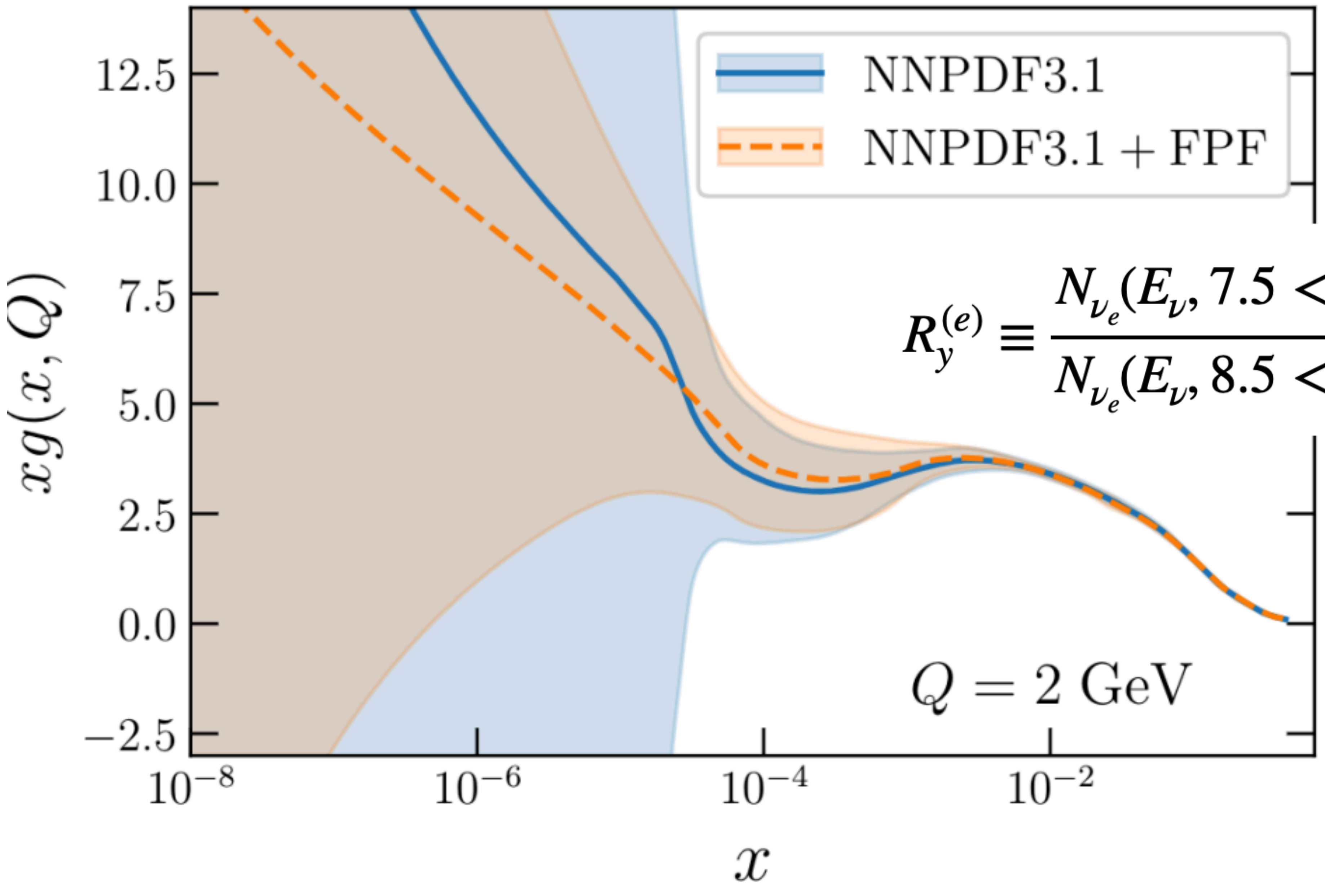
DESY.

Introduction

- Electron neutrinos are to be measured with large statistics at FPF
  - The access they give to charm production making them especially interesting
  - Measurements in different rapidity regions can be especially powerful
  - Currently no separation between neutrino and anti-neutrino possible

- Motivation to have a simple electron neutrino detector that can do this



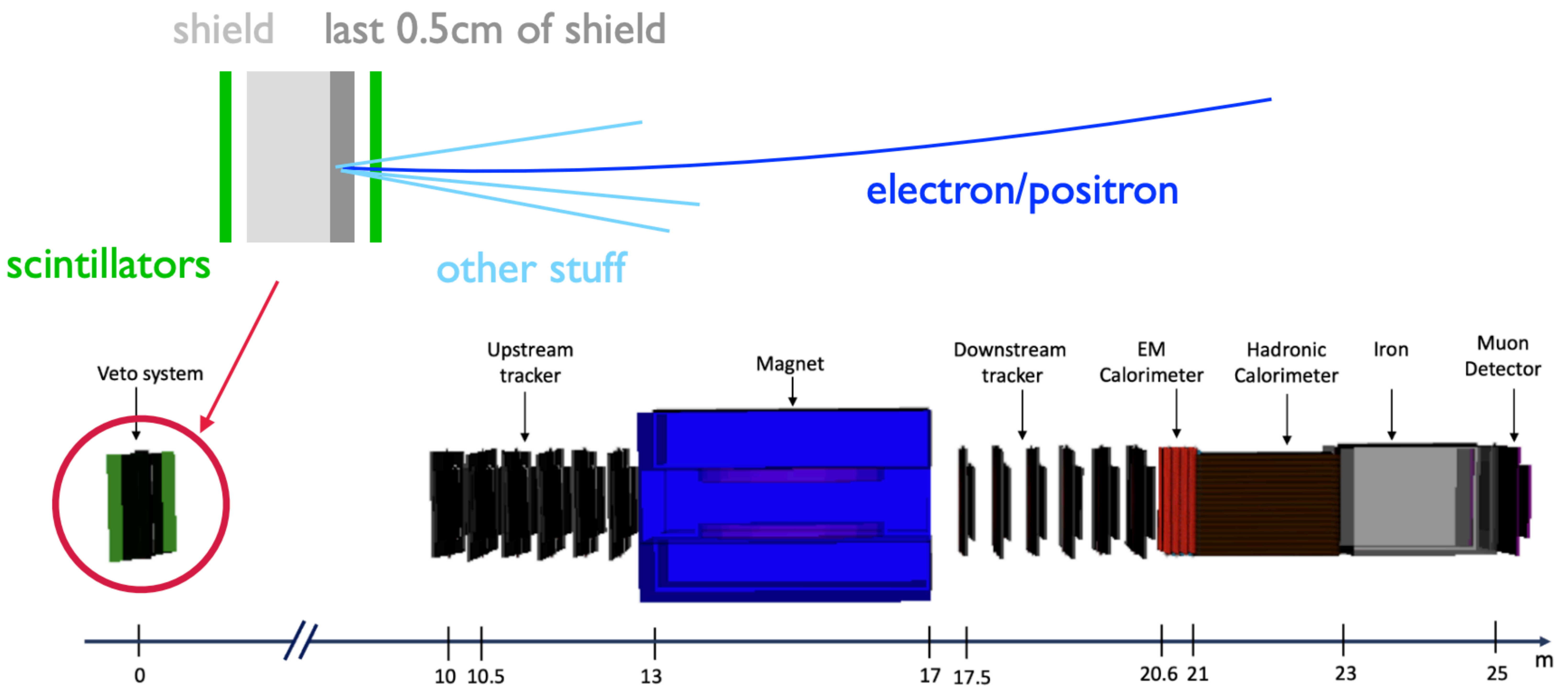


$$R_y^{(e)} \equiv \frac{N_{\nu_e}(E_\nu, 7.5 < y_\nu < 8.0)}{N_{\nu_e}(E_\nu, 8.5 < y_\nu < 9.0)}$$

Introduction

- Can potentially be done with simple detector
  - Electrons from ν_e will not leave FASERν2 so charge measurement is not possible.
  - Studies coming from ideas/discussions with Felix and Jamie
  - Possible use of LHCb SPD detectors

- Distinguishing electron neutrinos and anti-neutrinos is essentially impossible with the FPF neutrino detectors since electrons interact very quickly (within X0=0.56cm in lead), so they don't enter any spectrometer
- Idea: use the neutrinos that interact in the last X0 of veto before FASER2 spectrometer:



Slide from Felix

Inputs and assumptions

- Estimate of neutrino interactions
  - Extrapolate from FASERv2 estimates just scaling by mass
  - Account for interaction rate change as function of radius.

[FPF Short Paper]

Detector			Interactions at FPF			
Name	Mass	Coverage	CC $\nu_e+\bar{\nu}_e$	CC $\nu_\mu+\bar{\nu}_\mu$	CC $\nu_\tau+\bar{\nu}_\tau$	NC
FASERν2	20 tonnes	$\eta \gtrsim 8.5$	178k / 668k	943k / 1.4M	2.3k / 20k	408k / 857k
FLArE	10 tonnes	$\eta \gtrsim 7.5$	36k / 113k	203k / 268k	1.5k / 4k	89k / 157k
AdvSND1	2 tonnes	$7.2 \lesssim \eta \lesssim 9.2$	6.5k / 20k	41k / 53k	190 / 754	17k / 29k
AdvSND2	2 tonnes	$\eta \sim 5$	29 / 14	48 / 29	2.6 / 0.9	32 / 17

Inputs and assumptions

- Estimate of neutrino interactions
  - Extrapolate from FASERv2 estimates just scaling by mass
  - Account for interaction rate change as function of radius.
    - Correct change in transverse area with corresponding different in flux
      - Will check results with dedicated calculation using e.g. FastNeutrinoFluxSimulation)

[FPF Short Paper]

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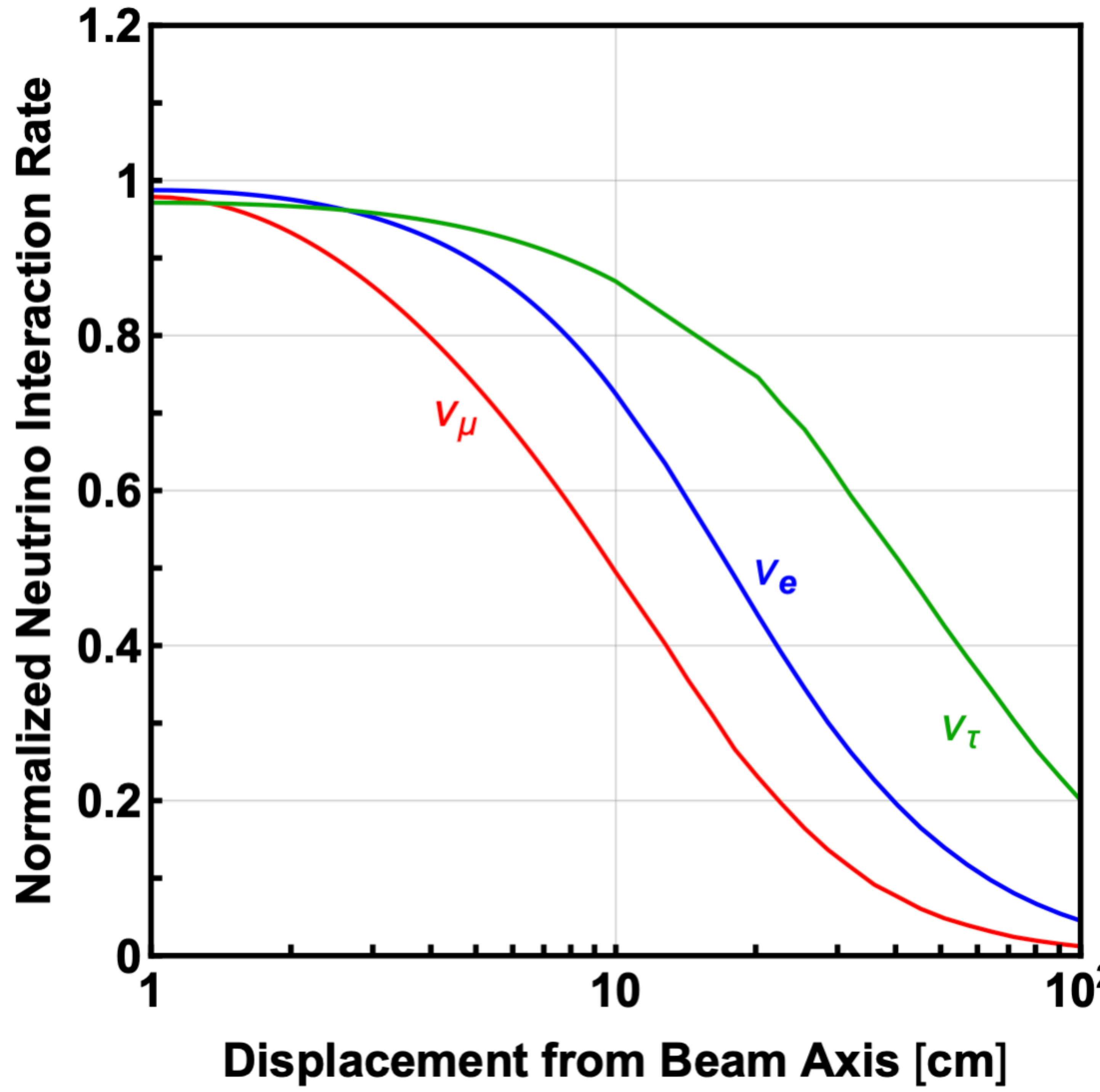
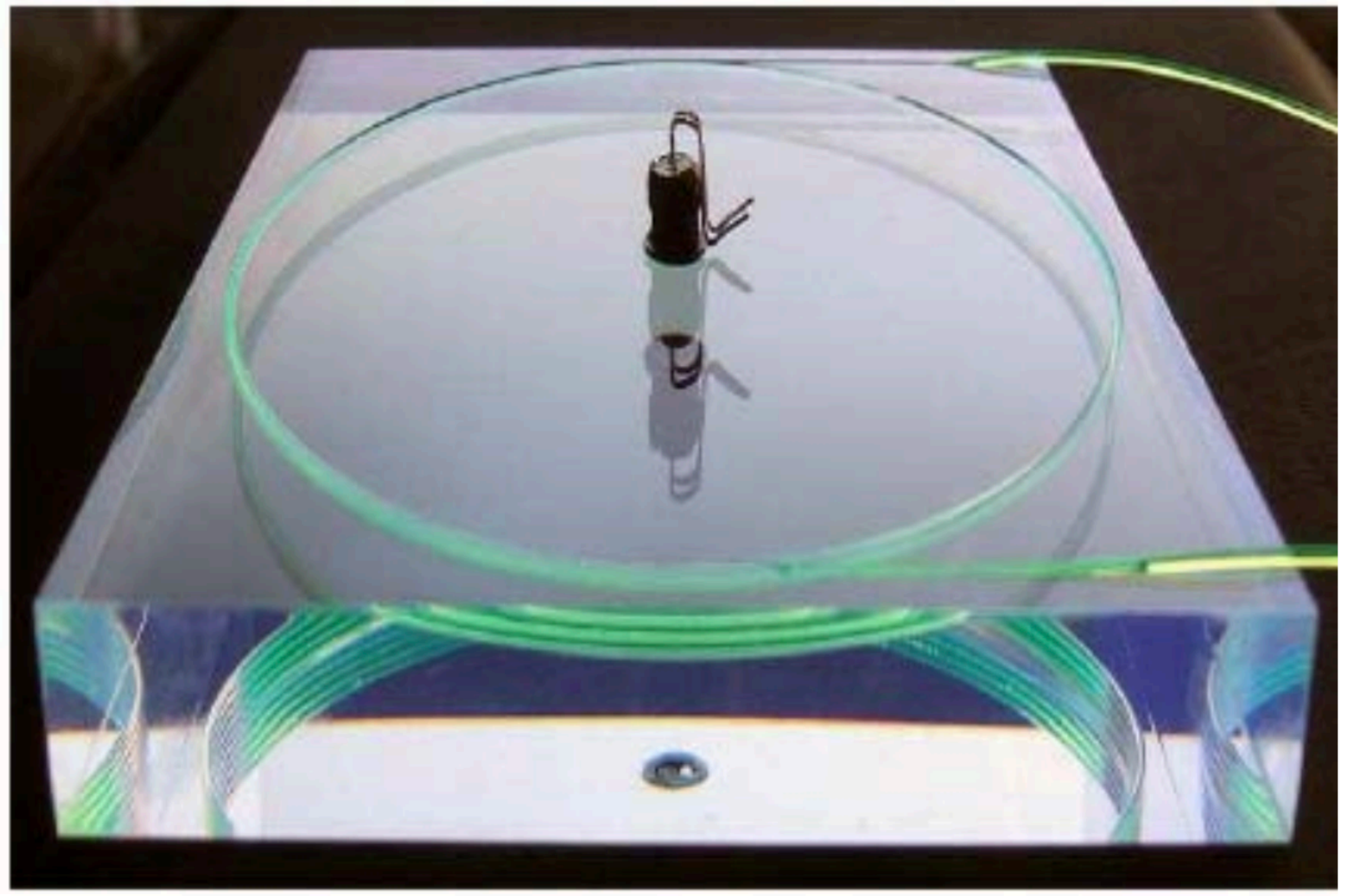
	FASERv2 3 ab^{-1}	Flux-Area correction
ν_e	500k	0.28
ν_μ	1.2M	0.18
ν_τ	10k	0.60



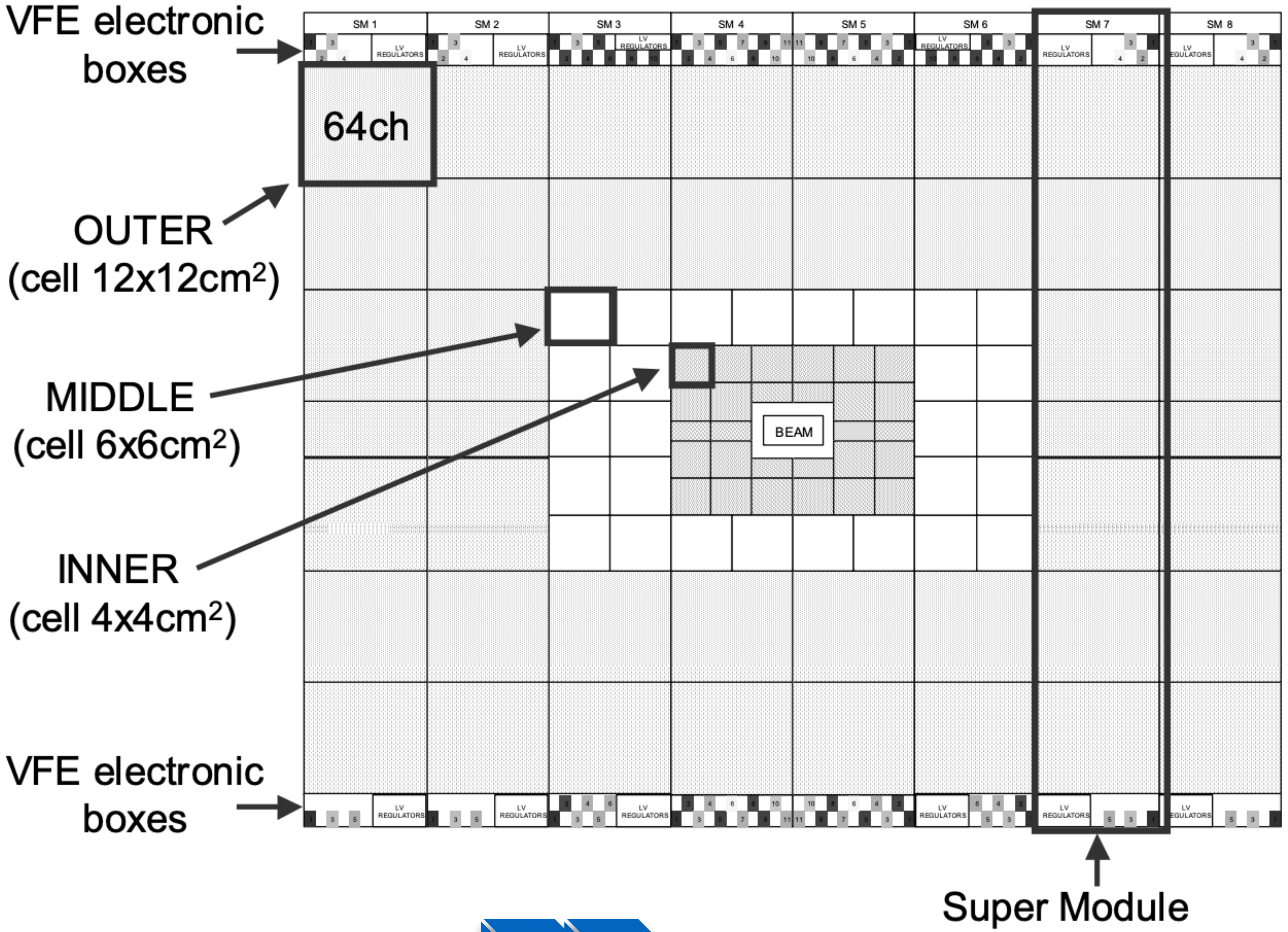
Detector requirements

- Electron neutrino detector requirements
  - Need a material with high enough density to have significant number of neutrino interactions
  - Need low enough number of radiation lengths for electron from ν_e interaction to escape and be detected.
  - Plastic scintillator is a good candidate for this
    - EJ-200 = polyvinyltoluene → X_0 = 42.5 cm
  - Such as LHCb SPD/Preshower detector…

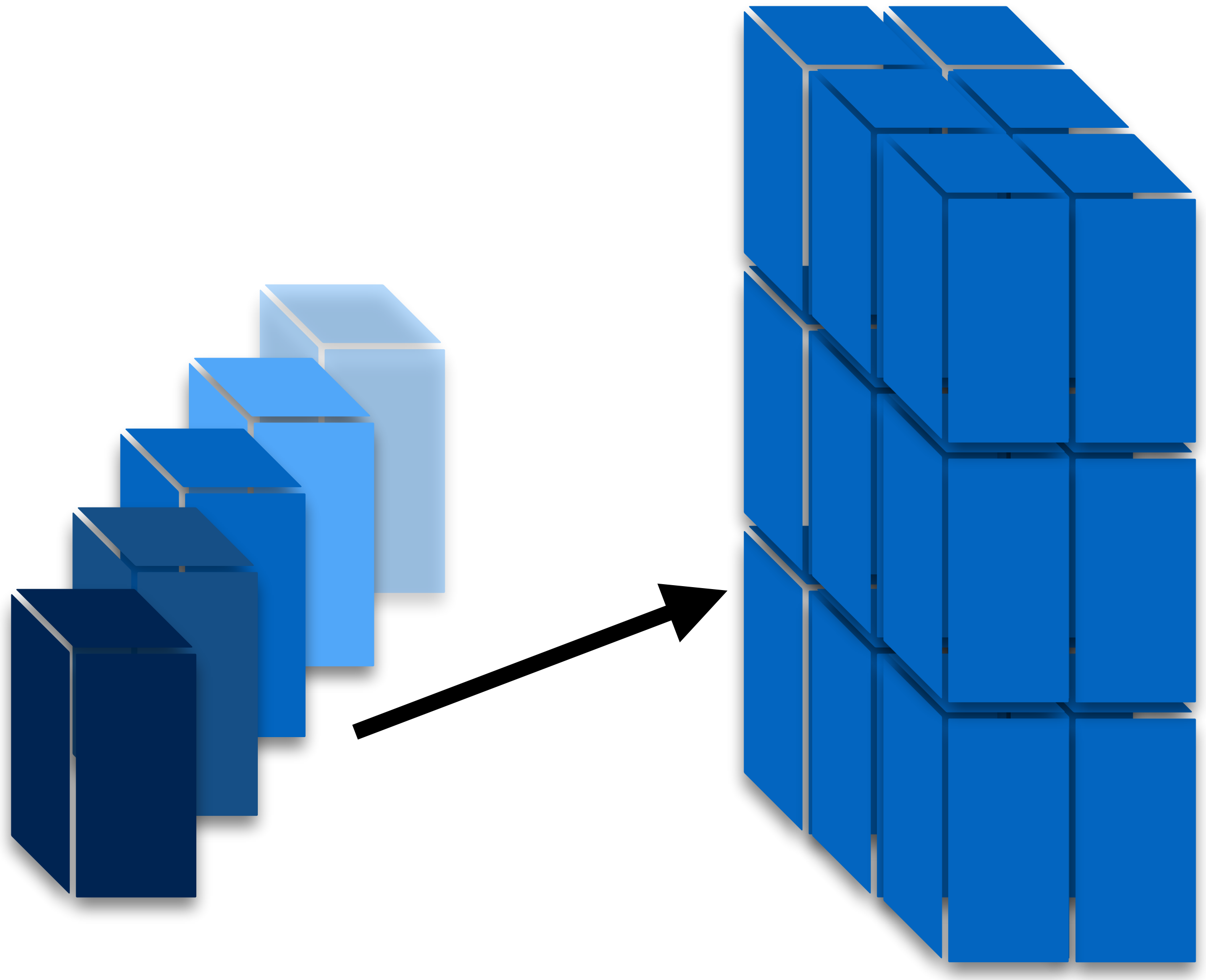


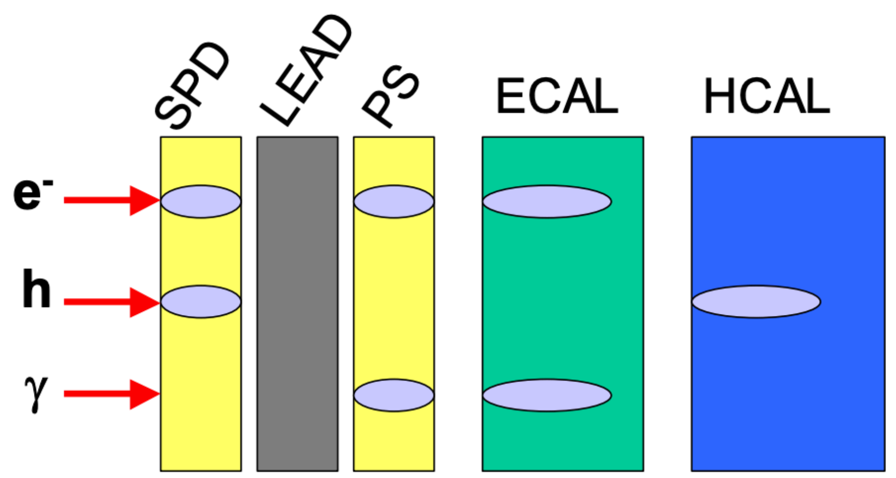
LHCb SPD/PS Detector

- Old LHCb SPD/PS detector (now removed and being held for us) is potentially available
  - Dimensions:
    - 7.68 x 6.24 m transverse size
    - ~50 m^2 area



- If re-arranged for dimensions of FASER2:
  - ~24 cm depth possible from 1 SPD layer
  - 2 x for SPD and PS = **~0.5 m depth ~ 1 X_0**





SPD Neutrino Detector?

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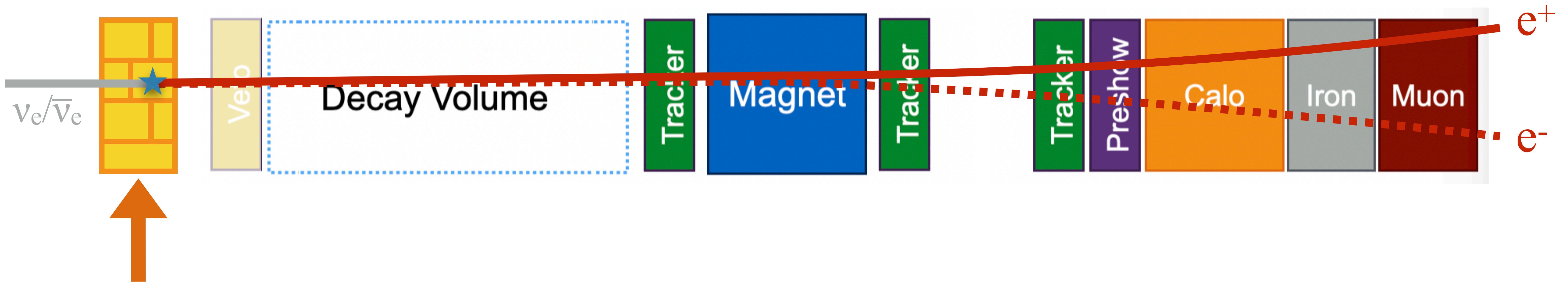
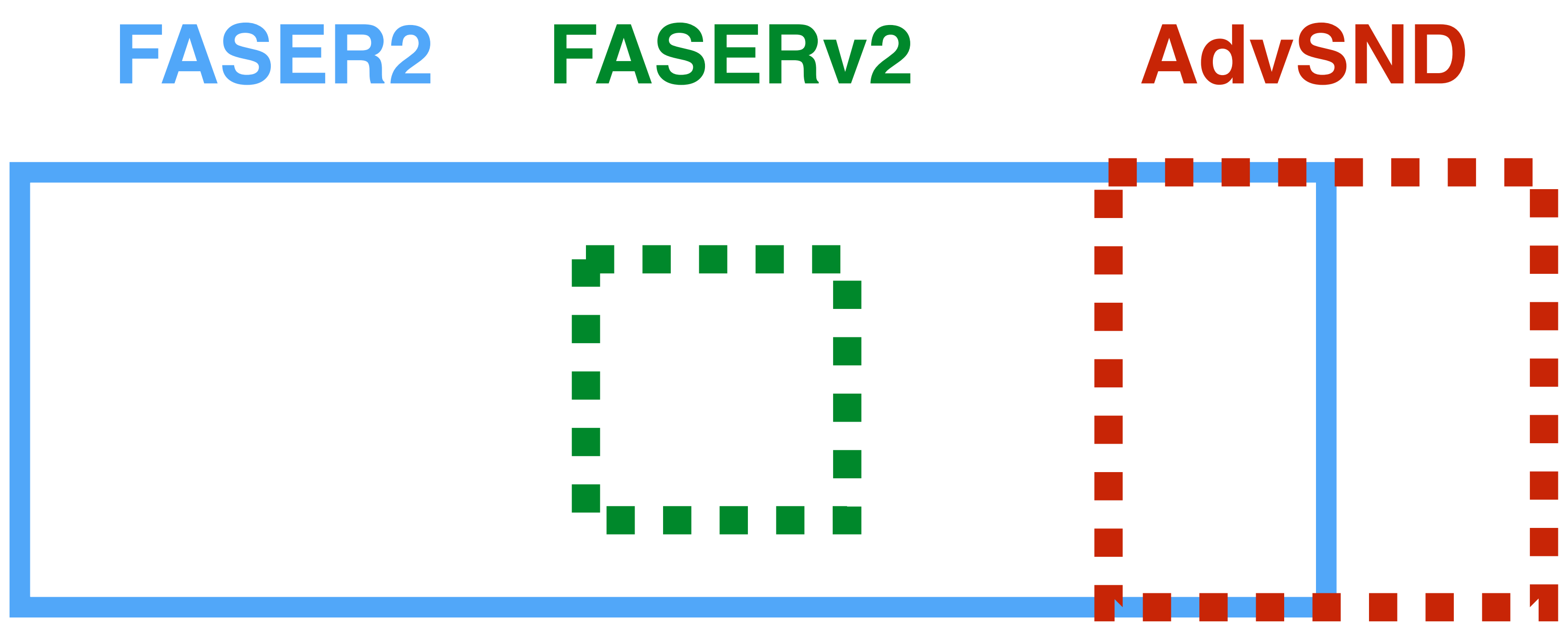
- EJ-200 plastic scintillator density: 1023.0 kg/m^3
- FASER2 "SPD Neutrino Wall":
  - Volume: 3 x 1 x 0.5m = 1.5 m^3
  - Mass: 1534.5 kg
  - m(SPD)/m(Fv2): 0.077



- Significant number of neutrino interactions even with ~1 ab^{-1}

	FASERv2 3 ab^{-1}	FASER2 SPD 3 ab^{-1}	FASER2 SPD 1 ab^{-1}
ν_e	500k	**~10k**	~3k
ν_μ	1.2M	**~160k**	~50k
ν_τ	10k	**~450**	~150

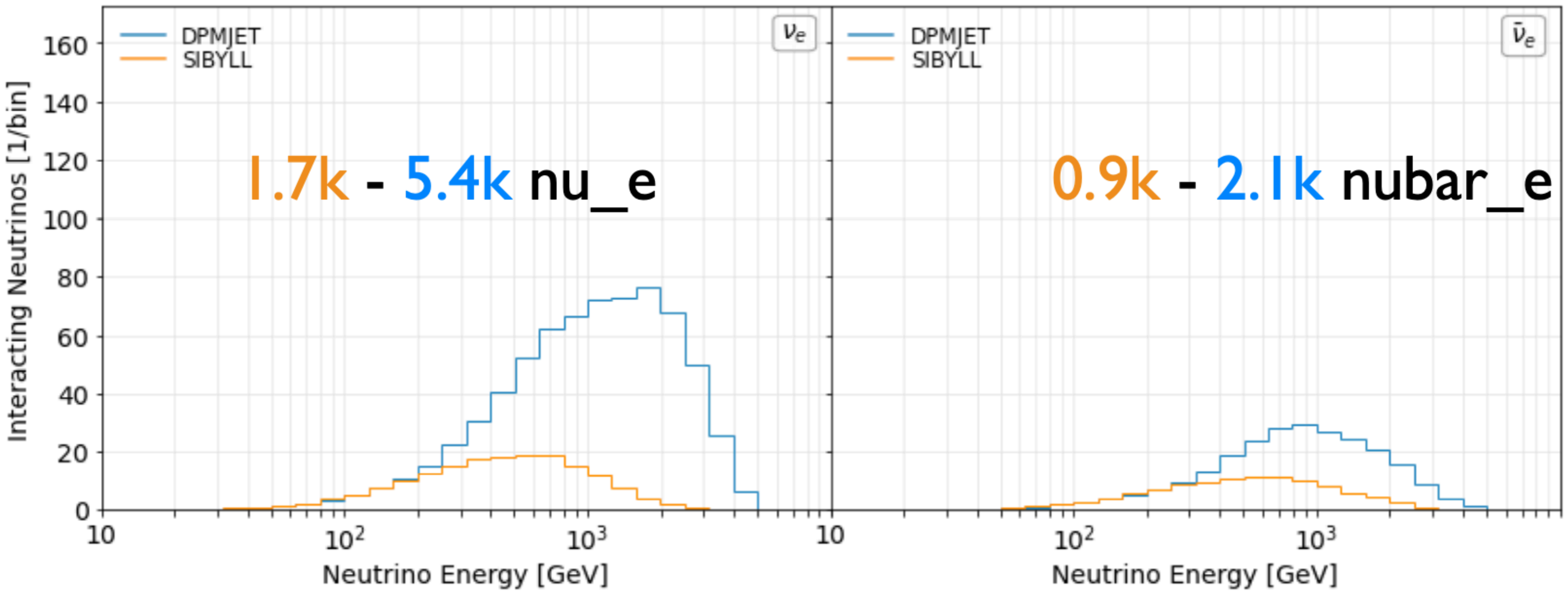


SPD Neutrino Detector?

- In good agreement with previous studies from Felix for **carbon** target:

NEW

- Run3 Setup, 13.6TeV
- 3m x 1m around LOS
- Carbon Target
- ρ(C) = 2.2 g/cm3
- X0(C) = 19.3cm
- target mass = 1275kg
- 3000/fb



- Probes TeV energy scale

Summary

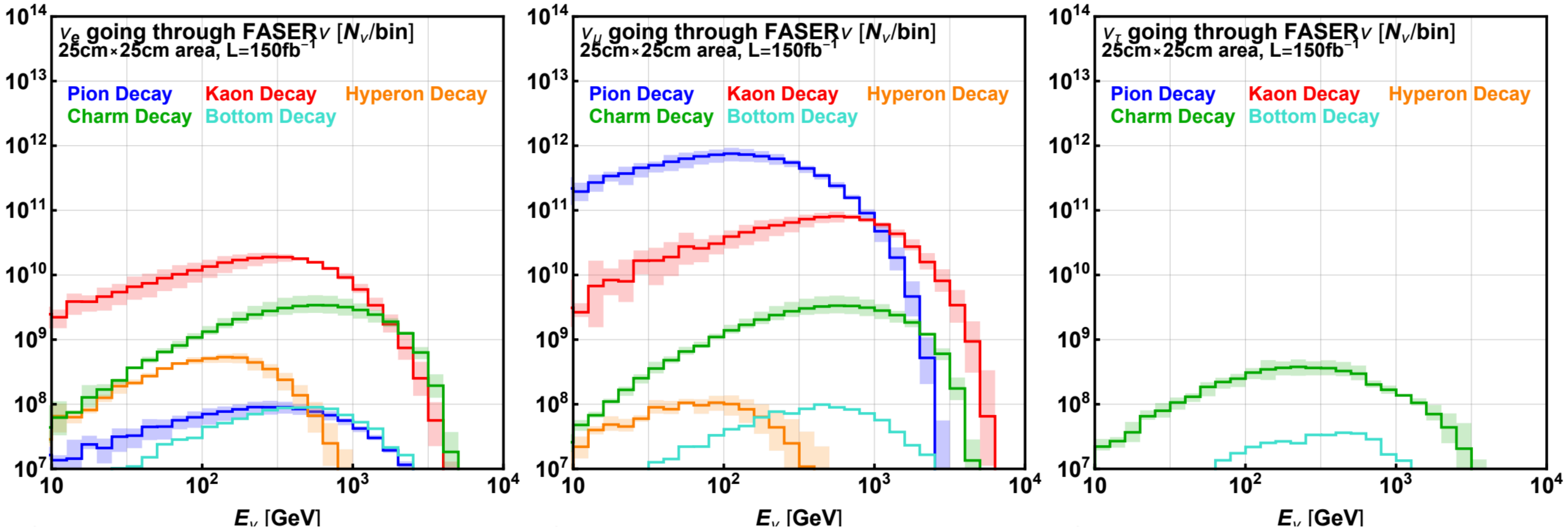
- Estimation of possible neutrino interaction rates in “simple” FASER2 electron neutrino detector.
- Could offer ability to measure electron neutrino/anti-neutrino rates with significant numbers of events at ~TeV energy scale and across relatively wide rapidity range
- Reusing LHCb SPD/PS-based detector for this makes it an even more attractive possibility.
- Requires additional space in cavern, but not a huge amount.
- Next step is to make proper calculations with e.g. FastNeutrinoFluxSimulation

Back-ups

Neutrino analysis

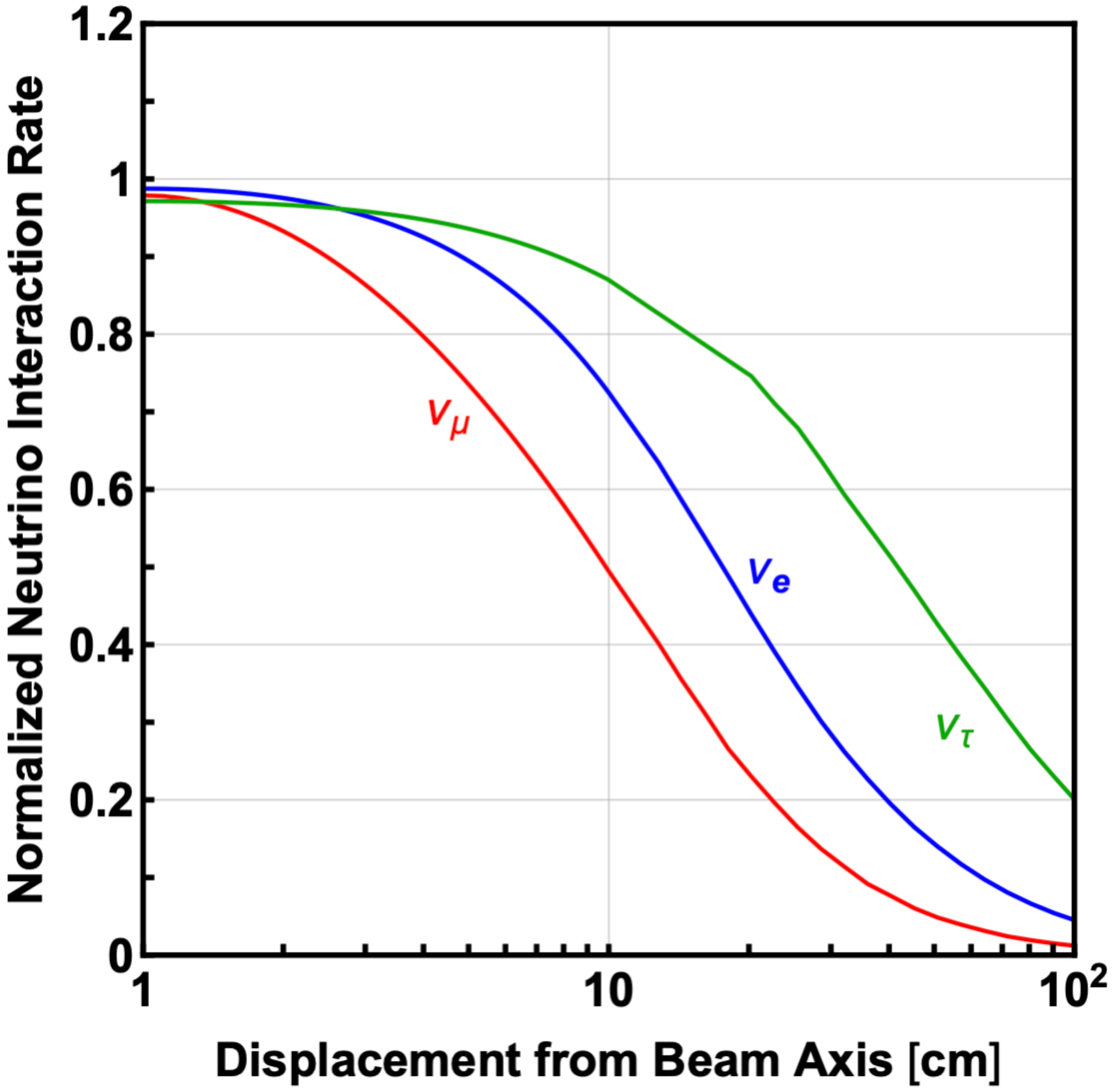
[arXiv:1908.02310]

Type	Particles	Main Decays	E	Q	S	P
Pions	π^+	$\pi^+ \to \mu\nu$	$\surd$	$\surd$	$\surd$	—
Kaons	K^+, K_S, K_L	$K^+ \to \mu\nu,\ K \to \pi\ell\nu$	$\surd$	$\surd$	$\surd$	—
Hyperons	$\Lambda, \Sigma^+, \Sigma^-, \Xi^0, \Xi^-, \Omega^-$	$\Lambda \to p\ell\nu$	$\surd$	$\surd$	$\surd$	—
Charm	$D^+, D^0, D_s, \Lambda_c, \Xi_c^0, \Xi_c^+$	$D \to K\ell\nu,\ D_s \to \tau\nu,\ \Lambda_c \to \Lambda\ell\nu$	—	—	$\surd$	$\surd$
Bottom	$B^+, B^0, B_s, \Lambda_b, \ldots$	$B \to D\ell\nu,\ \Lambda_b \to \Lambda_c\ell\nu$	—	—	—	$\surd$



Inputs and assumptions

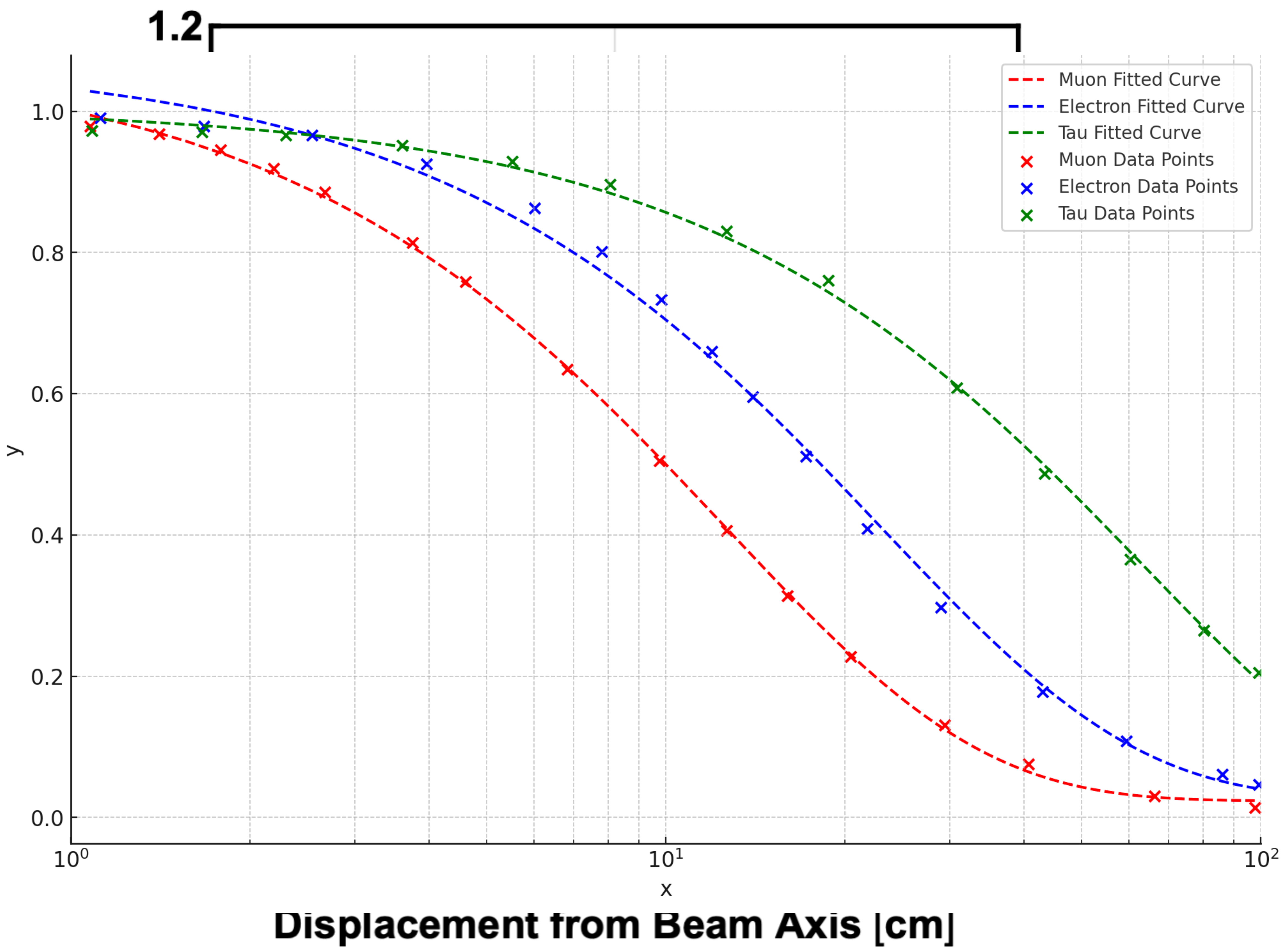
- Assumed numbers from



	FASERν2 3 ab^{-1}
ν_e	500k
ν_μ	1.2M
ν_τ	10k

FASER2 Decay Volume

- Assumed numbers
- Calculating flux for orrecting for rate change as a function of distance from



	FASERv2 3 ab^{-1}	∫(r) FASER	Flux FASER2/ FASERv2	Flux/ Area
ν_e	500k	**1.28**	**5.16**	**0.28**
ν_μ	1.2M	**1.15**	**3.39**	**0.18**
ν_τ	10k	**1.70**	**11.22**	**0.60**