WP6-Beamline Design

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ESS neutrino Super Beam plus

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2nd Annual Meeting

Goal: a beamline to monitor leptons from meson decays in the decay tunnel

- ENUBET MONITORED BEAM

See EPJ C 83 (2023) 964

  - Started from: a beamline to monitor e^+ from K_{e3} decays to constrain ν_e flux
    Adding later: monitoring of $K_{\mu 2}$ and π^+ to constrain ν_μ flux

- REQUIREMENTS:
  - keep the total length as short as possible to minimize early decays
  - non-decaying particles should exit the tunnel w/o hitting the tagger
  - Particle rate at the tunnel $\longrightarrow$ a hornless beam
  - Use normal-conducting magnets

Same requirements apply
to essnusb+ beamline

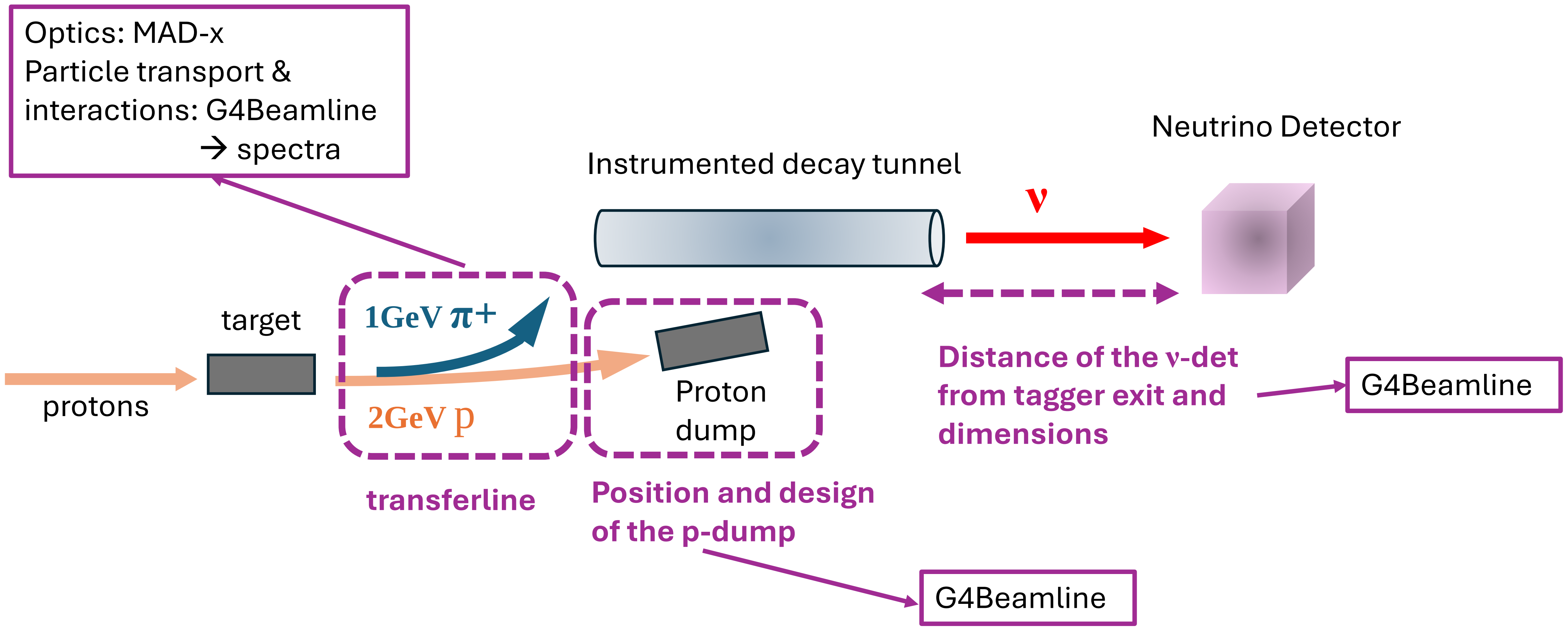
Goal: a beamline to monitor leptons from meson decays in the decay tunnel

	ENUBET	ESSnuSB+
Decay	K+	π+
Particle P	8.5 GeV/c	1 GeV/c
Momentum bite	10%	10%
Primaries	450 GeV protons	2.8 GeV/c protons
Tunnel Length	40m	40m
Tunnel Radius	1m	**0.5m**
Target	Graphite 70 cm length, 3 cm radius	Graphite **20 cm length, 3 cm radius**

Starting assumptions

See next slides

Design of the Beamline



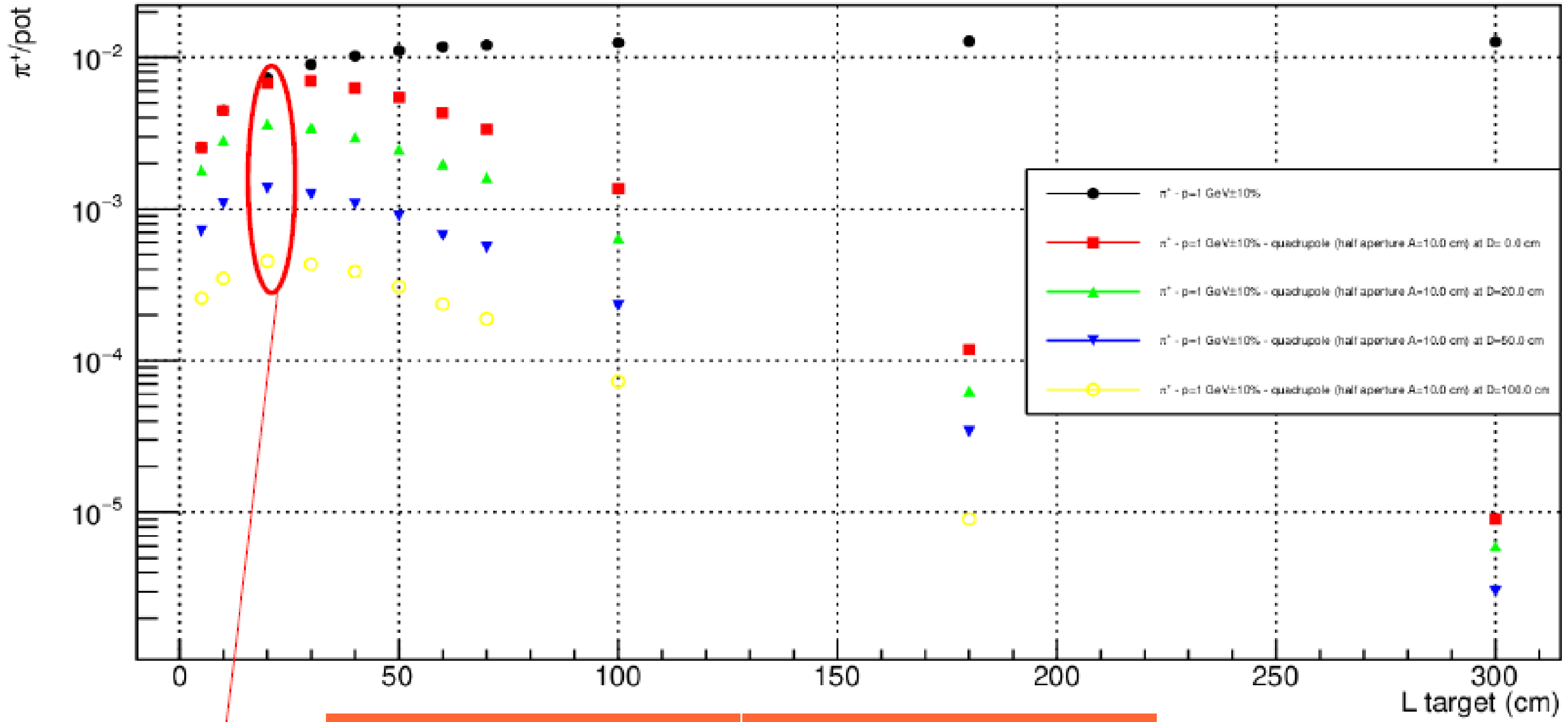
Design of the Beamline – The Target

F. Pupilli

Optimization of Target Length

FOM: pion yield at distance D from first beamline element

→ 20 cm Graphite target (3cm radius)



→ **First element at 50 cm from target**

For L=20 cm:

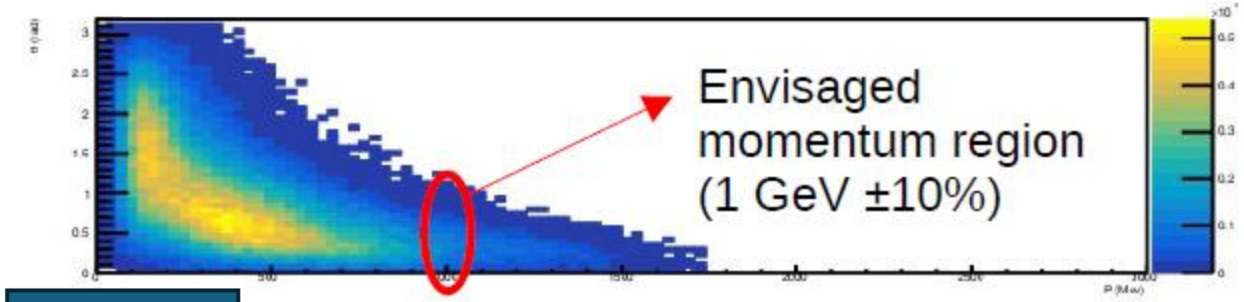
D (cm)	π^+ yield (10^{-3}/pot)
0	6.77
20	3.64
50	1.37
100	0.45

F. Pupilli

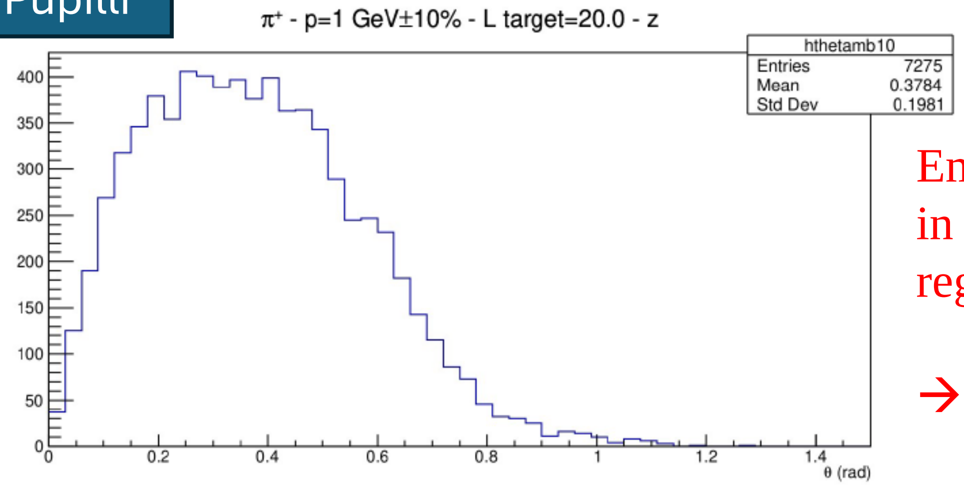
Distributions @

Target exit

π+ **θ vs P**



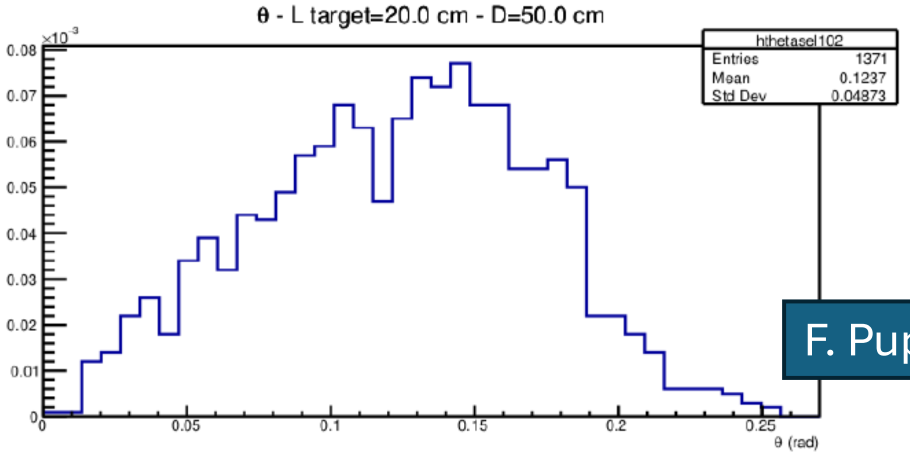
F. Pupilli



Emission angle in the ref. mom. region

→ Large angles

50 cm from target



F. Pupilli

θ for pions with p=1 GeV ± 10% @ 50 cm in a square of **10 cm half-aperture**

Start design of the optics w/ quadrupoles of 20 cm aperture

Design of the Beamline – The Optics

We need:

- **Large aperture magnets**: Using as a reference CERN quad w/ 20 cm apertures and length=1m
- Separation from primary protons → use bending dipoles, also w/ aperture of 20 cm
  - ENUBET case: we used 2 DIPOLES bending in the same direction to have a large angle separation from primary protons TO SUPPRESS NEUTRINOS at the neutrino detector coming FROM THE PROTON DUMP -- BUT we had 450 GeV protons and 8.5 GeV K+
  - ESSnuSB+:
    - **we need to separate 1GeV pions from 2GeV protons → we need enough drift distance after a dipole**
    - **consider a tunnel with 50 cm radius (VS 1m radius in ENUBET)**

→ Started exploring a design with two dipoles w/ opposite bending:

- First one for separation
- Second one to have a collimated parallel beam
- Studying optimal drift distance after 1^{st} dipole
- Using 50 cm separation between the other elements to **keep the transferline as short as possible**

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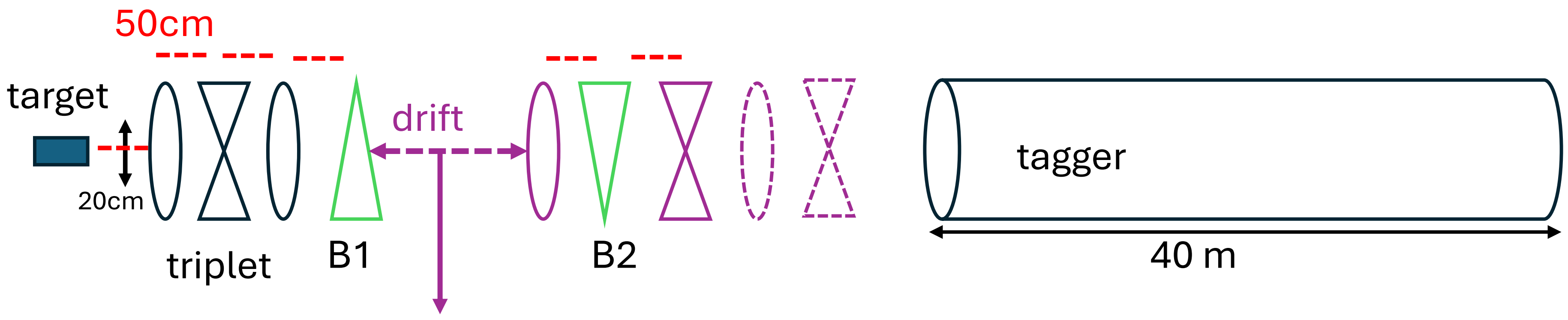
•**MAD-x** Tentatively something like:



•**G4Beamlime**

Check
what
protons do

We have the target files, FLUKA simulation on the optimized target (10 GPOT)
(Assumed 3x10^22 pot/y, i.e. 300 kW →6% of the ESS overall beam power at 2 GeV(5 MW), thanks Fabio!)

Design of the Beamline

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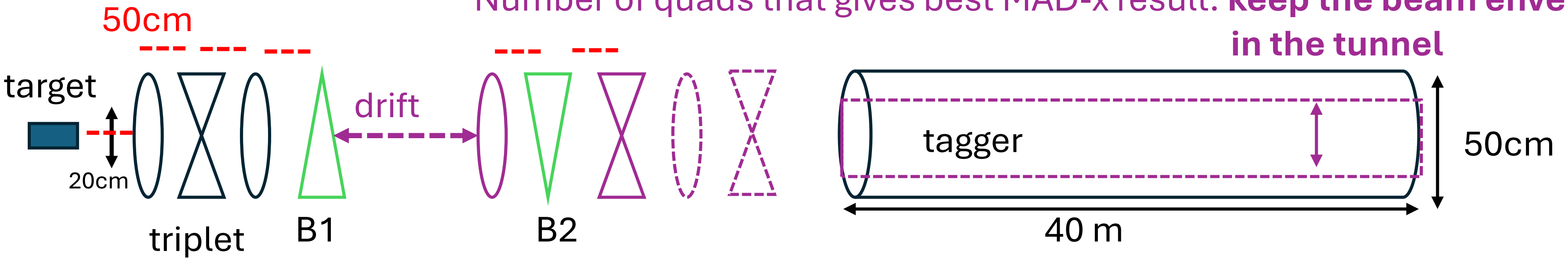
Number of quads that gives best MAD-x result: **keep the beam envelope well contained in the tunnel**



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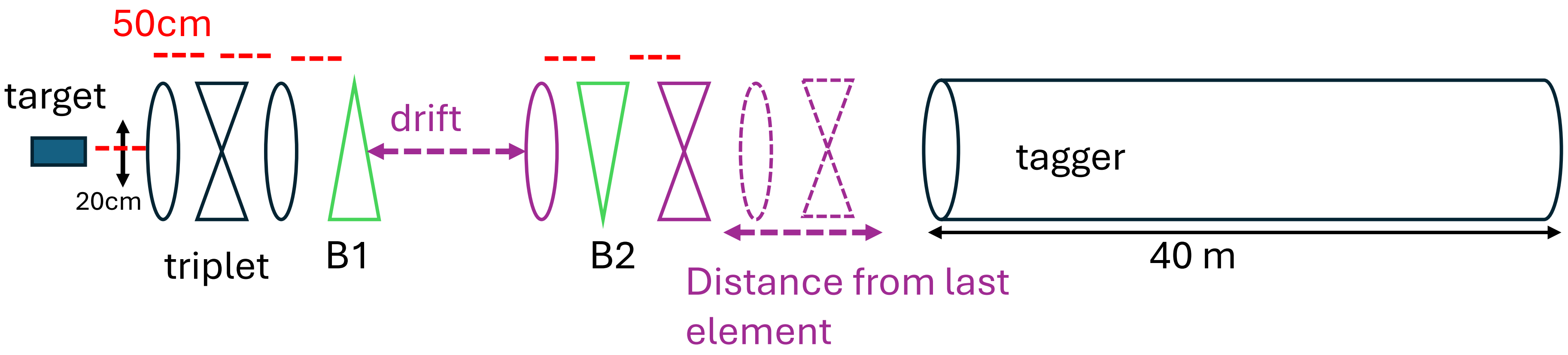

After complete sim. w/ G4BL we'll see if we need space for background suppression

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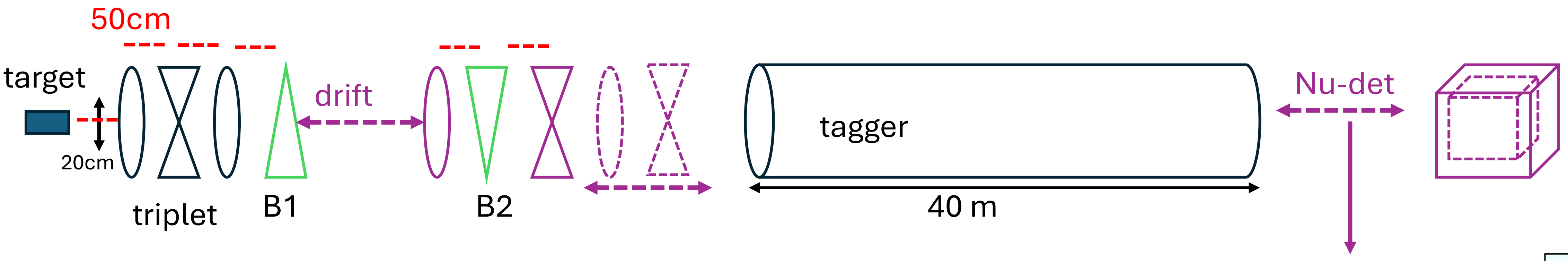

Neutrino spectra w/ G4BL VirtualDetectors: will try **different distances** from the tagger exit and **different front-face sizes**

ENUBET
$6x6m^2$
50 m from tagger exit

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Design of the Beamline: the background

The next steps after the first acceptable design:

- We’ll run a complete **G4Beamline** simulation when the first acceptable optics is defined, then it’s good to start as soon as possible thinking about:
  - Collimators
  - What arrives at the tagger entrance that we don’t want
  - Optimization of the proton dump (→ and check if we are good w/ neutrinos)
- We’ll need to have an estimated of the doses at the magnets and in the tagger… → FLUKA

Conclusions

Plan at the moment

1. MAD-x optics (re-)optimization (kind of) in parallel with a complete G4Beamline (re-) simulation (input = FLUKA target files)

2. Flux at the tunnel entrance is good enough (BOTH in terms of number of pions* and collimation) → move on to check neutrinos and background in the tunnel

reiterate

3. Updates! → Stay tuned!

* For starters: at least 0.1×10^{-3} π/pot