SHiP
Search for Hidden Particles

THE SHiP EXPERIMENT AT CERN

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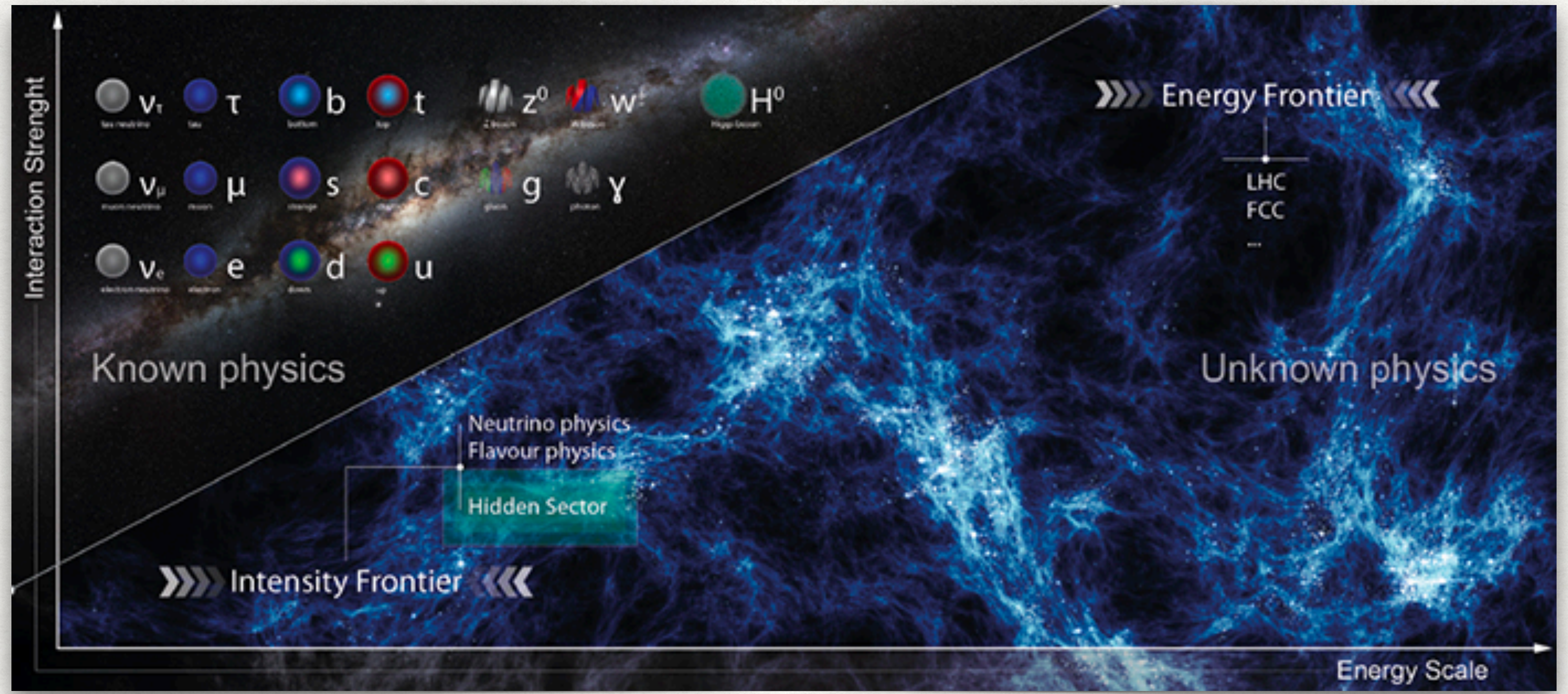
Università Federico II and INFN

Vacuum Fluctuations at Nanoscale and Gravitation: theory and experiments
1 May 2019

MOTIVATION

Many evidences suggest that there is unknown physics **Beyond Standard Model** (BSM)

- Dark Matter
- Neutrino Oscillation and masses
- Matter/antimatter asymmetry in the Universe

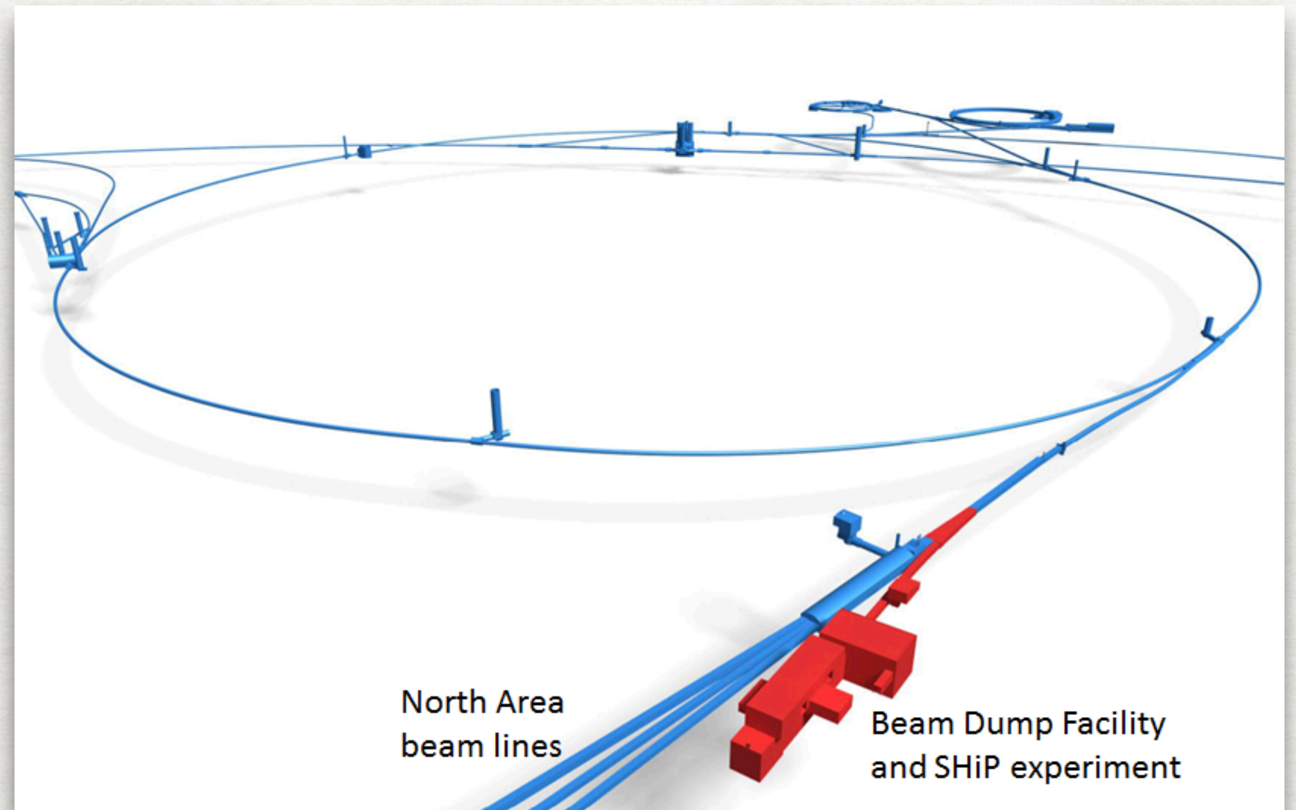


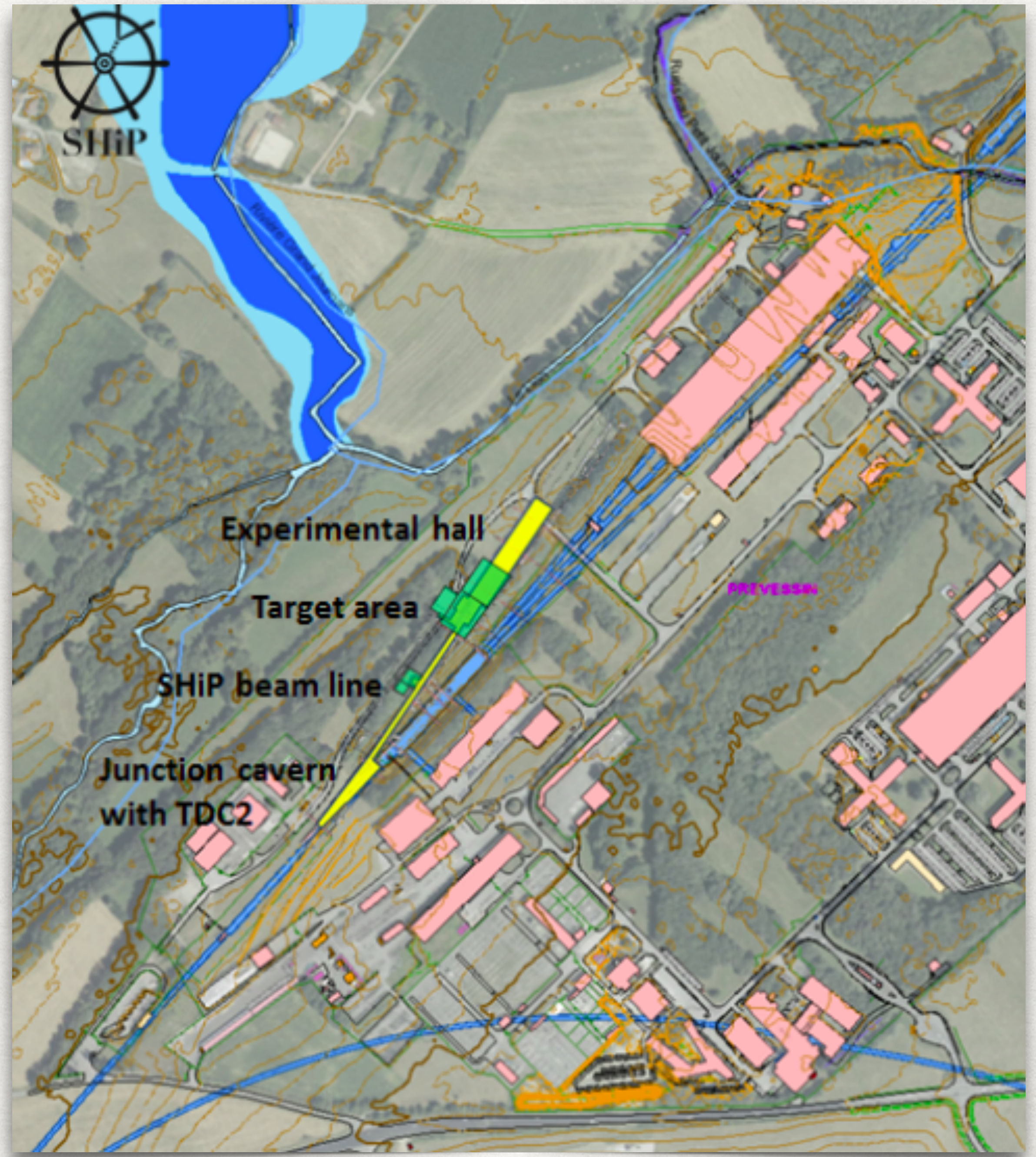
Energy Frontier:
Heavy particles
→ high energy collisions needed

Intensity Frontier:
Very weakly interacting particles
→ beam dump needed

THE SHiP FACILITY

- Fixed target experiment at the **CERN SPS**
- Beam: **400 GeV protons** (4×10^{13} protons per spill)
  → 2×10^{20} pot in 5 years



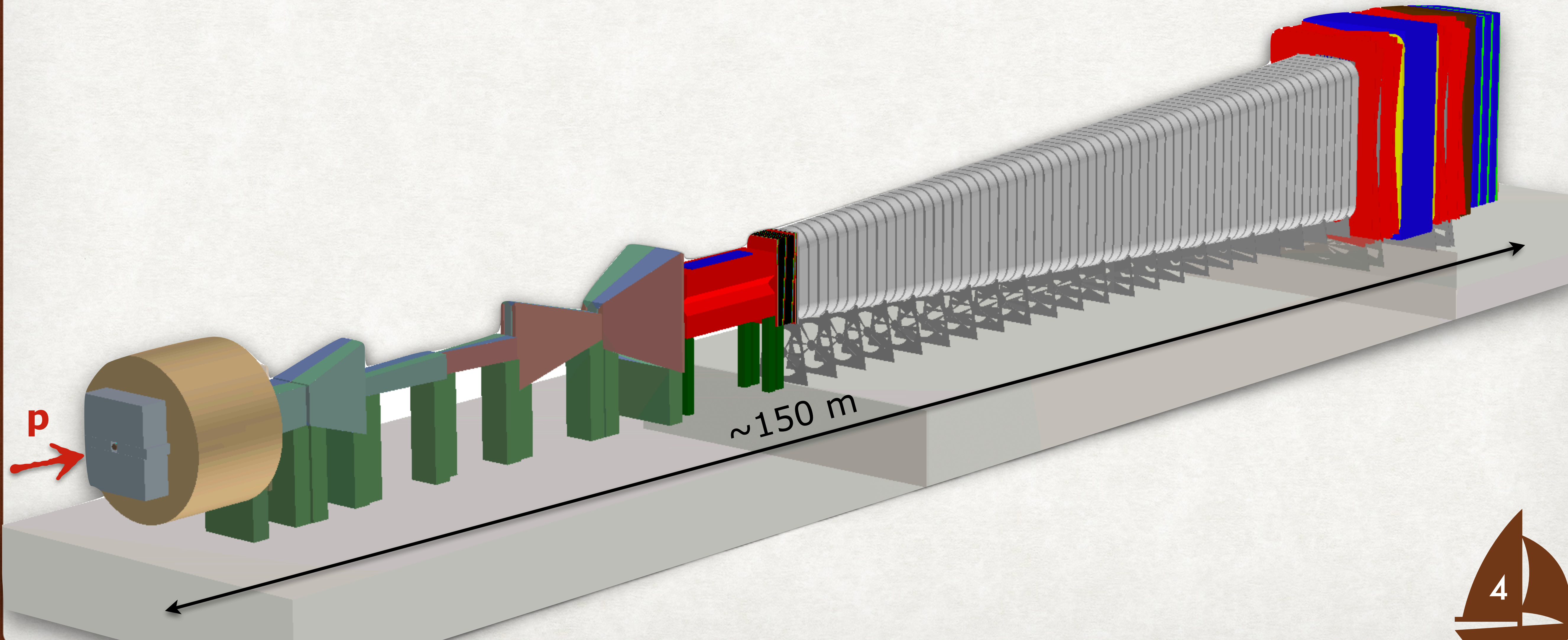


AIM: explore the Hidden Sector of weakly interacting and long lived particles

- Technical Proposal
  arXiv:1504.04956 (2015)
- Physics case signed by 80 theorists
  Rep. Prog. Phys. 79 (2016)
  arXiv:1504.04855

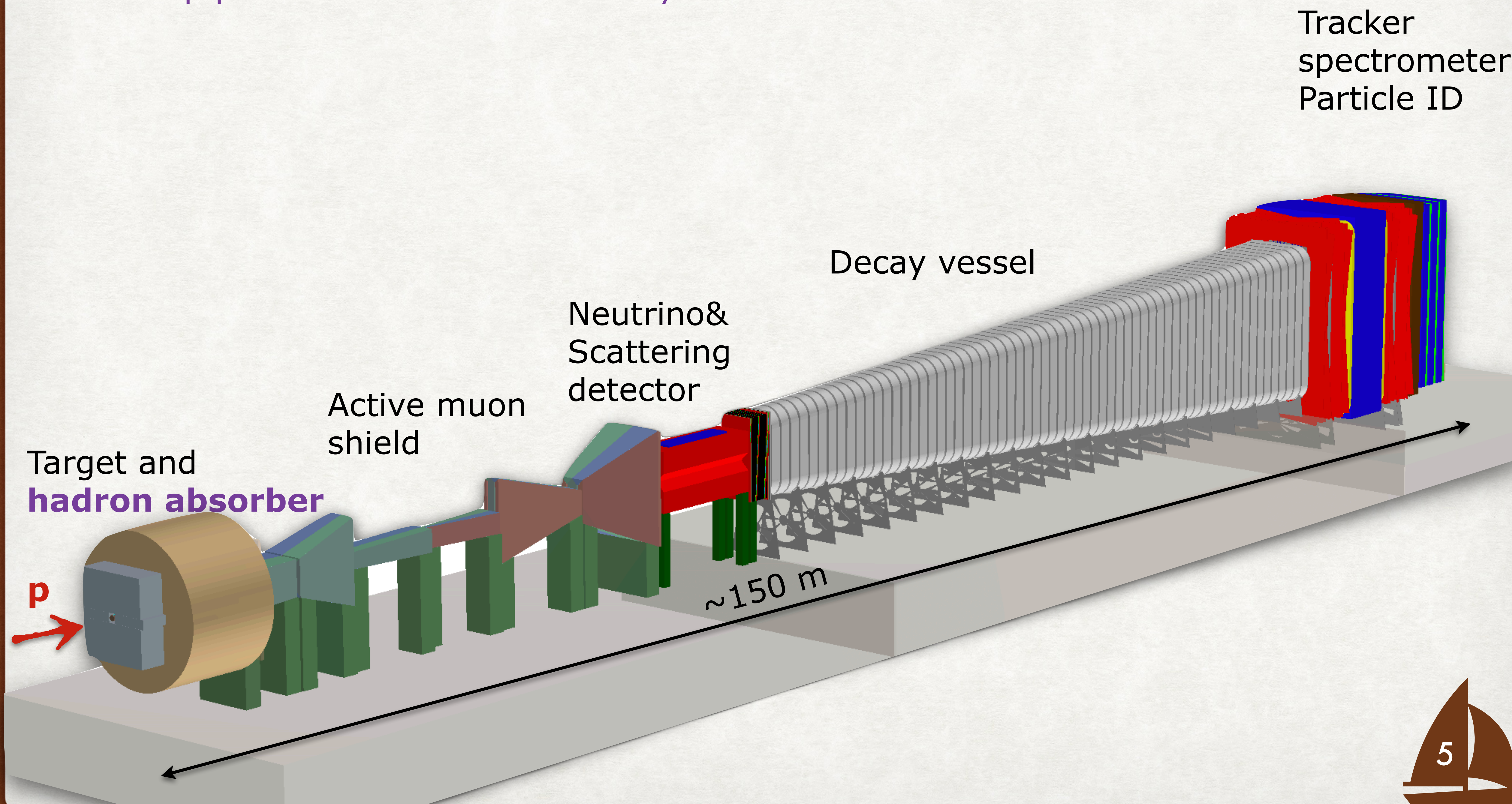
THE SHiP DETECTOR

- Designed for **large acceptance** and **zero background**
- 400 GeV protons on ~1 m long TZM, W target



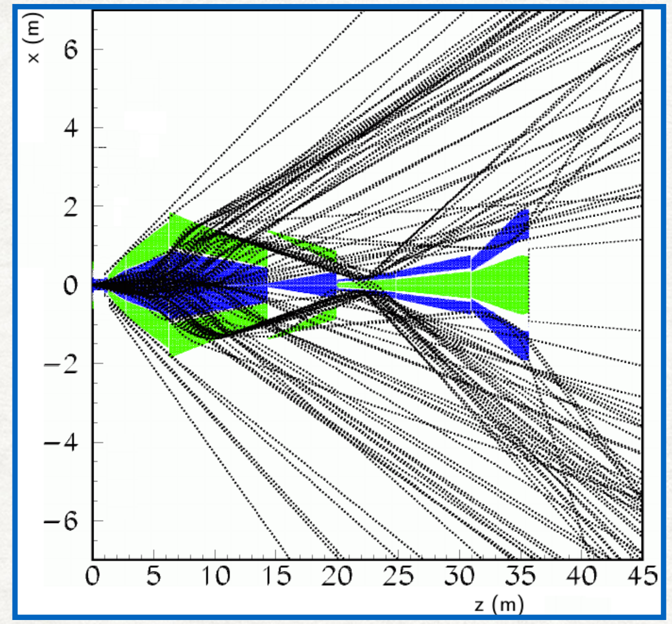
THE SHiP DETECTOR

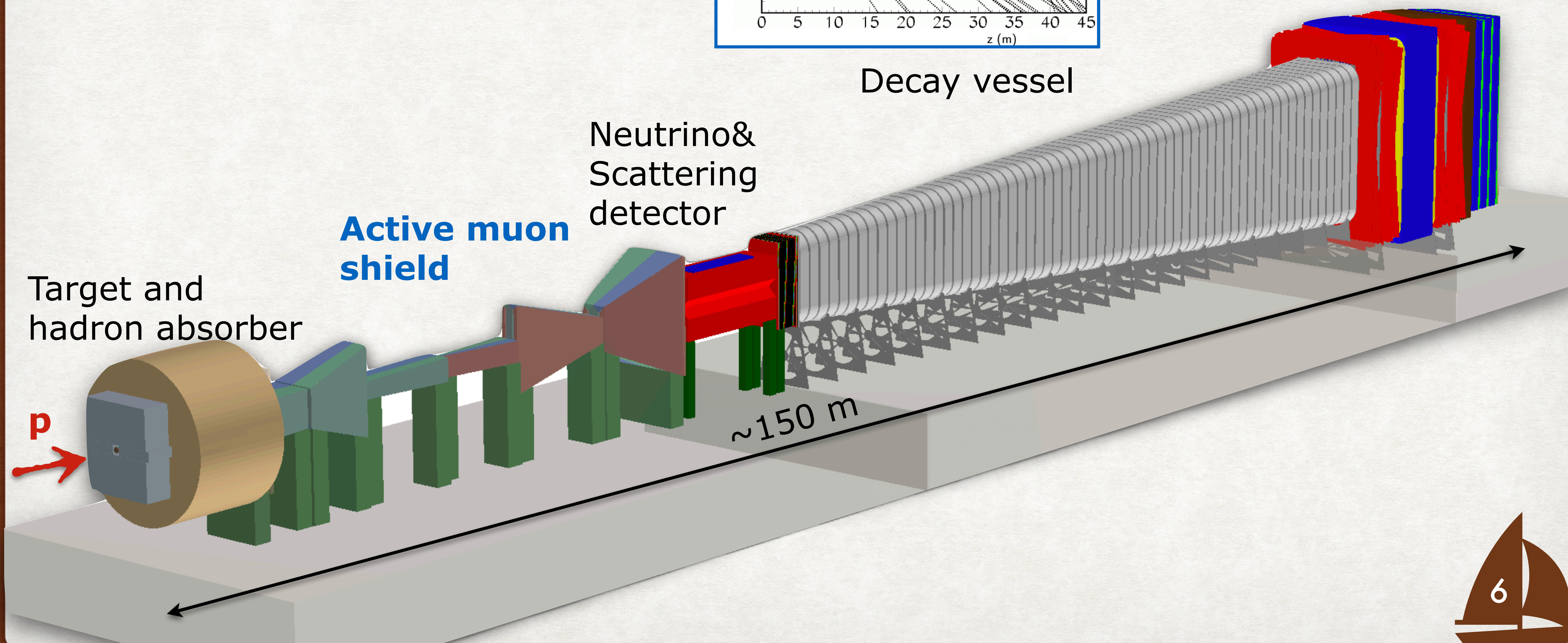
- Designed for **large acceptance** and **zero background**
- Hadron stopper
  - Absorb huge flux of SM particles
  - Stop pion and kaons before decay



THE SHiP DETECTOR

- Designed for **large acceptance** and **zero background**
- Hadron stopper
- Active muon shield
  - Magnetic deflection of muons

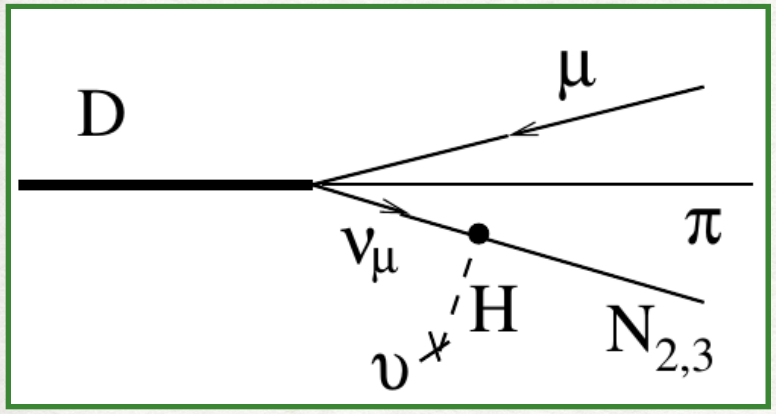


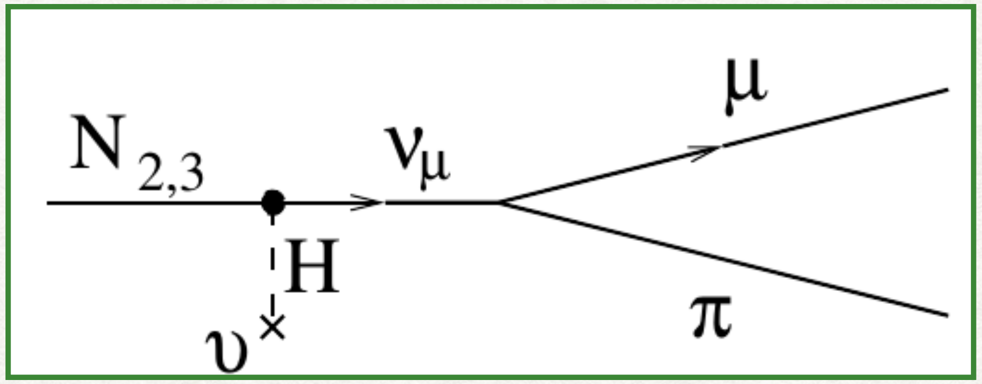


THE SHiP DETECTOR

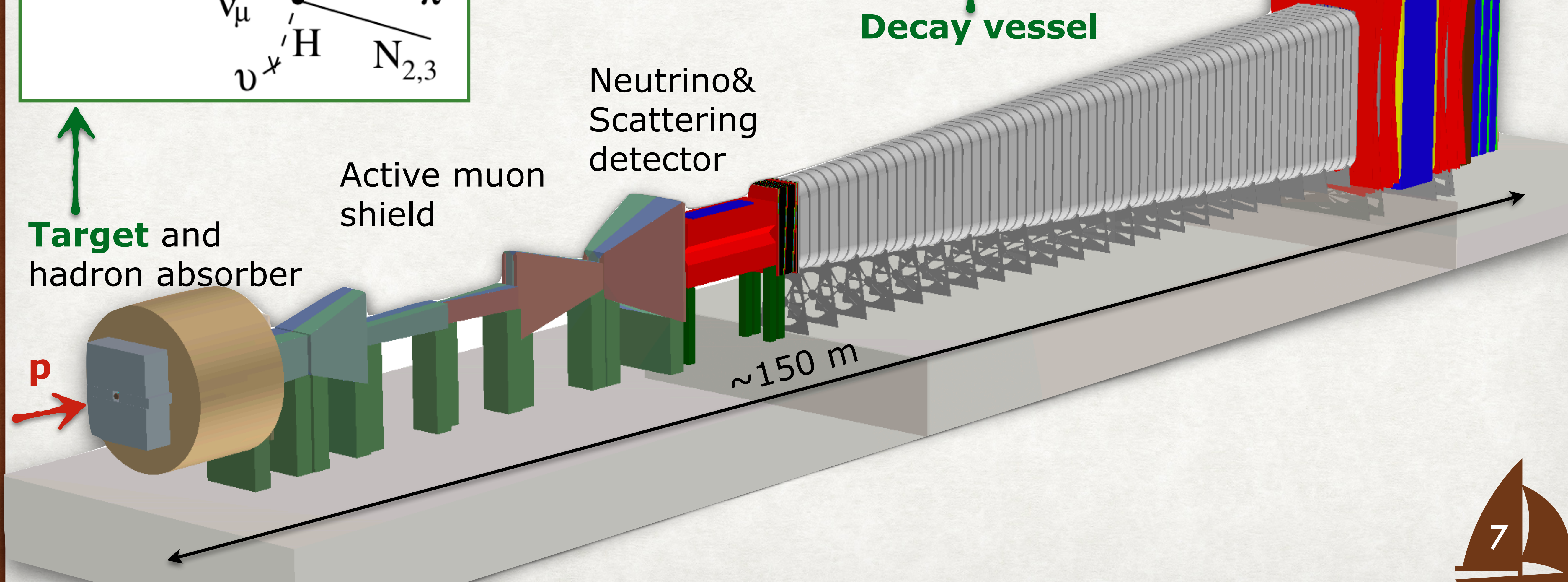
- Designed for **large acceptance** and **zero background**

Example of Hidden Sector search: Right-handed Neutrinos in the νMSM



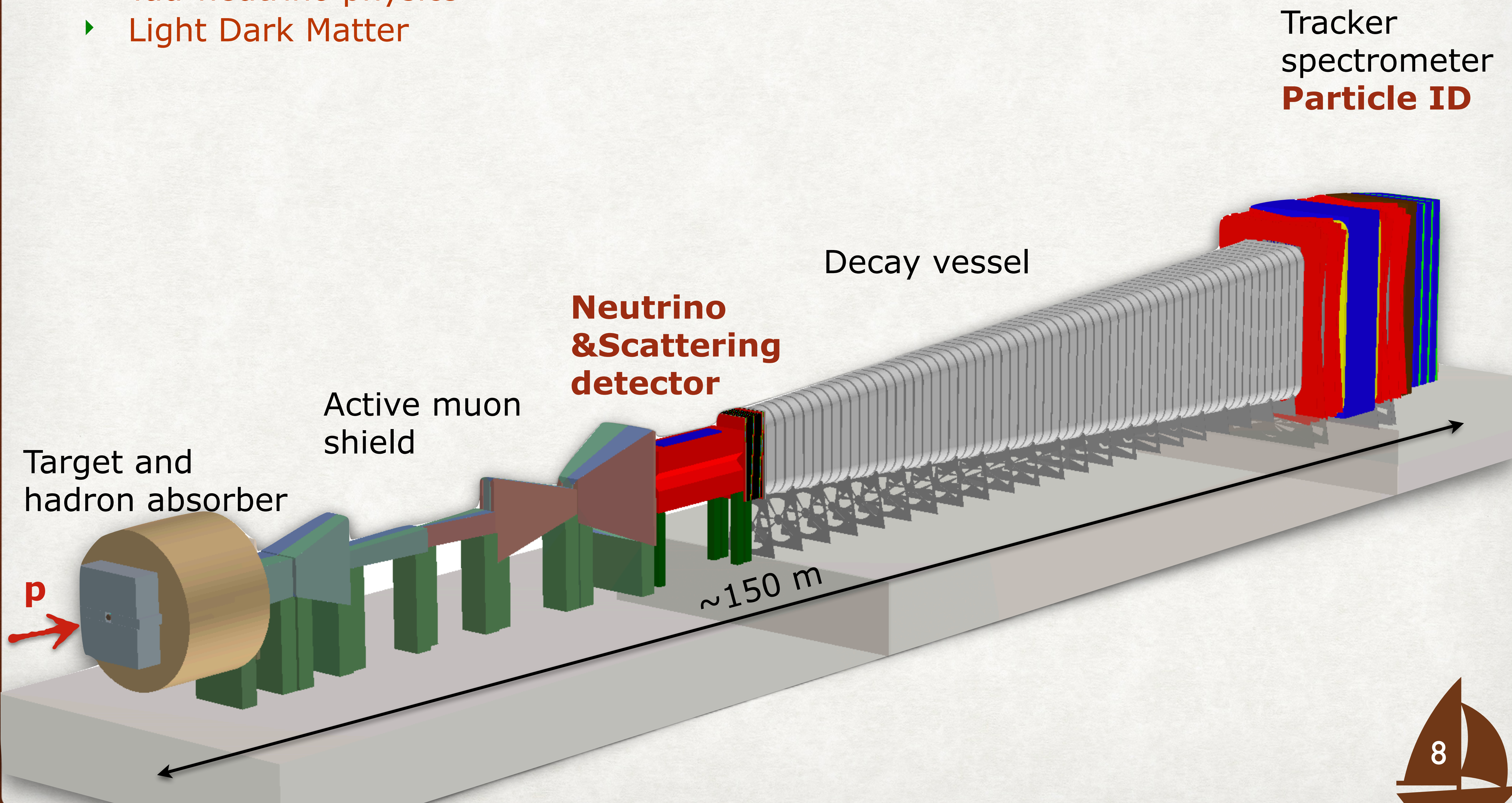


Tracker
spectrometer
Particle ID



THE SHiP DETECTOR

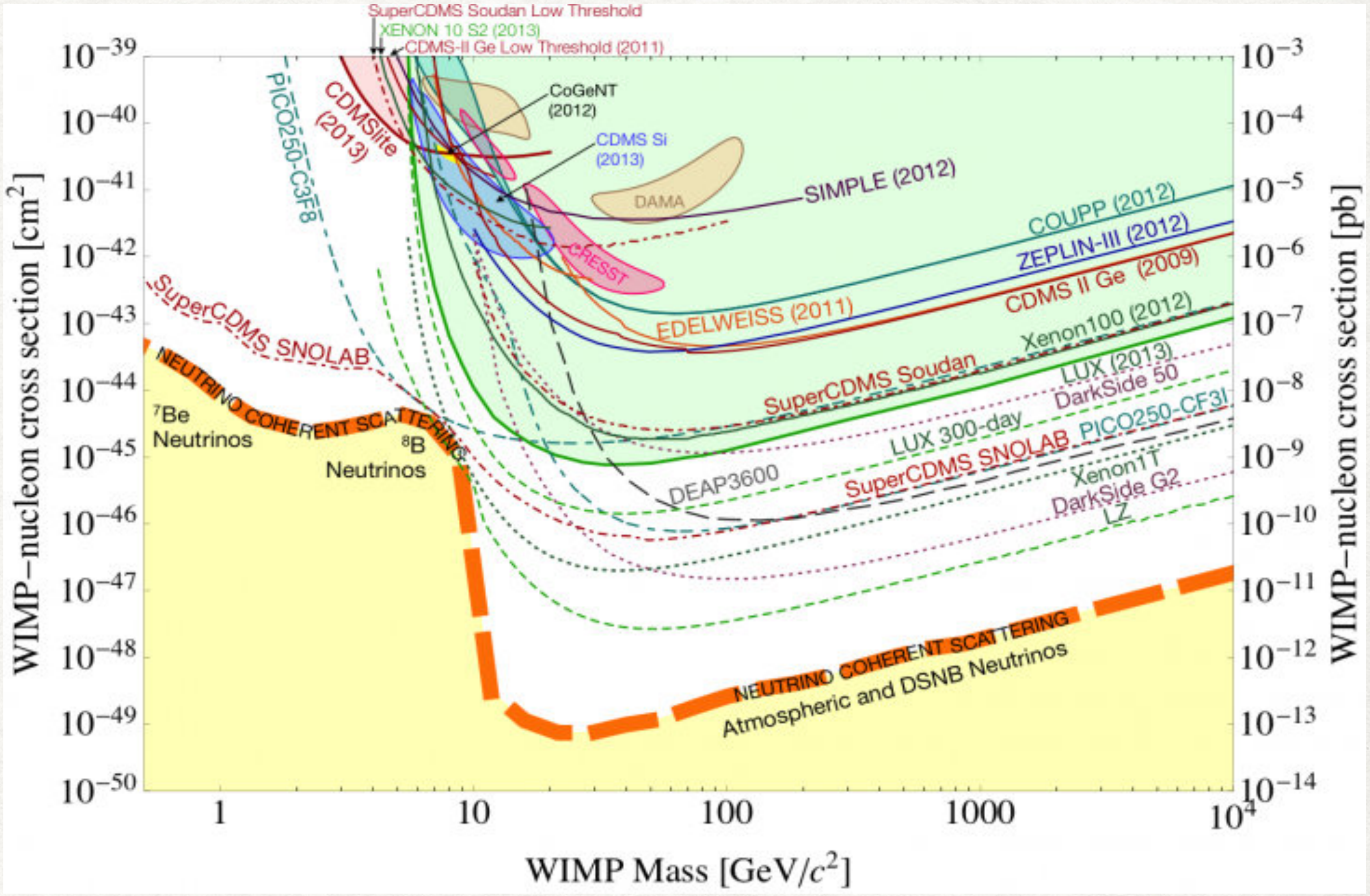
- Designed for **large acceptance** and **zero background**
- Wide physics program
  - Variety of possible decay modes
  - Tau-neutrino physics
  - Light Dark Matter



LIGHT DARK MATTER SEARCH

- The prediction for the mass scale of Dark Matter spans from 10^{-22} to 10^{20} GeV
- Extensive experimental search for WIMP with masses 10 GeV/c^2 -1 TeV/c^2

  - **Sensitivity very limited for masses below a few GeV due to recoil energy thresholds**



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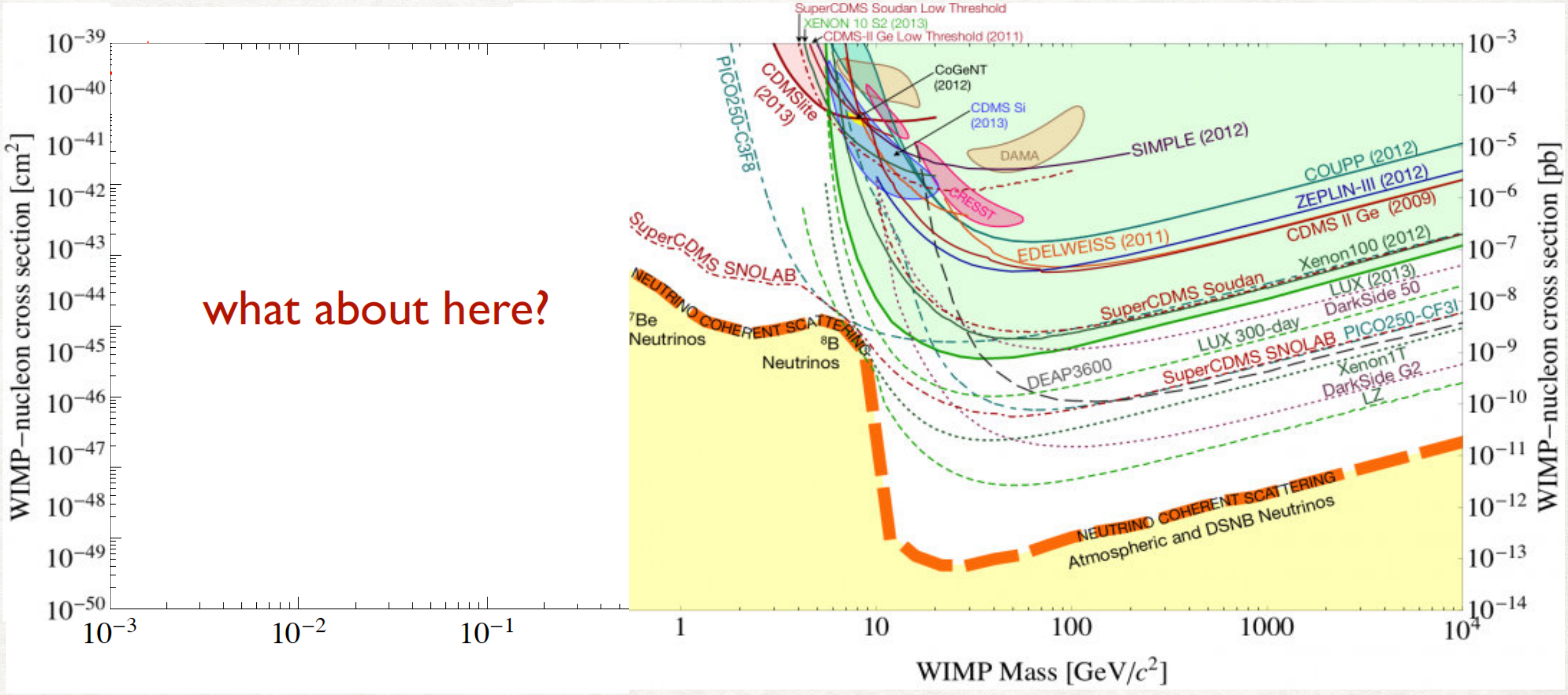
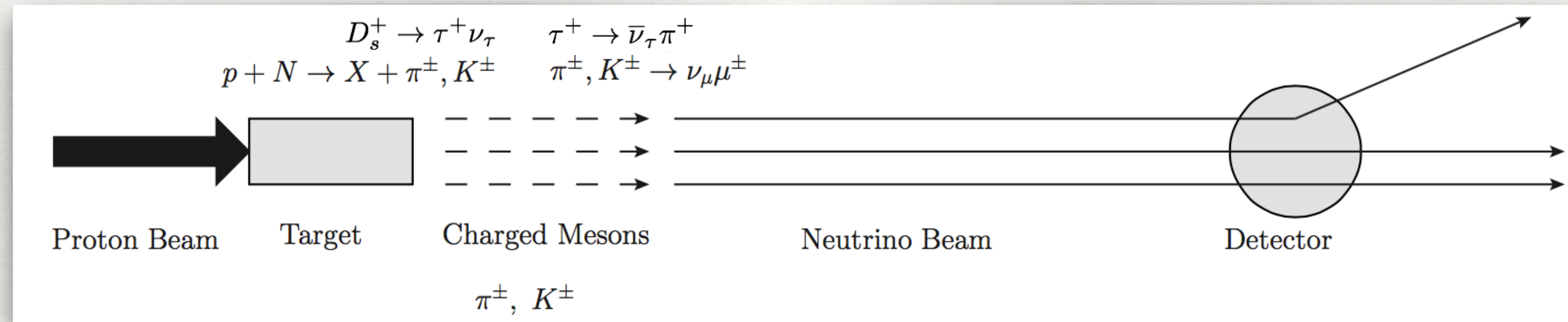
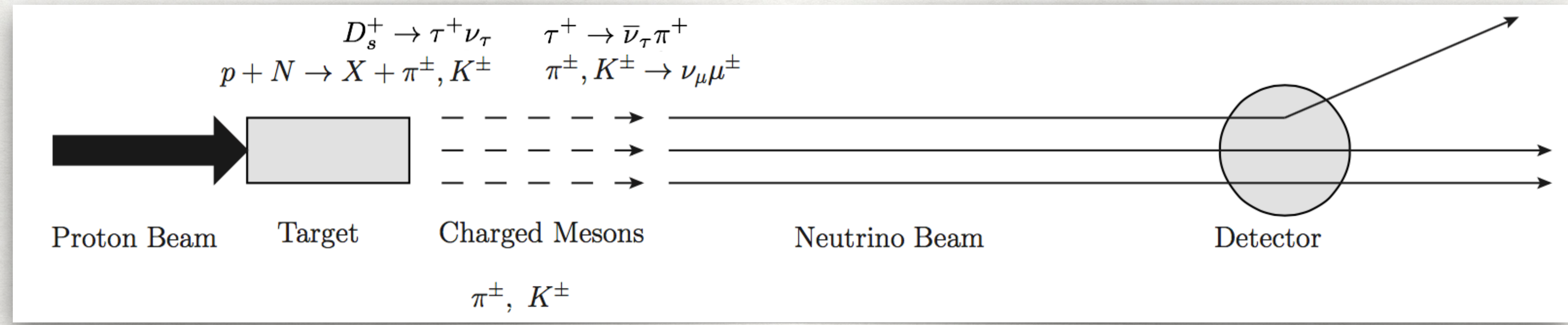


- **Essential to explore sub-GeV mass range for Dark Matter**
- **High luminosity fixed target experiments can play an important role**

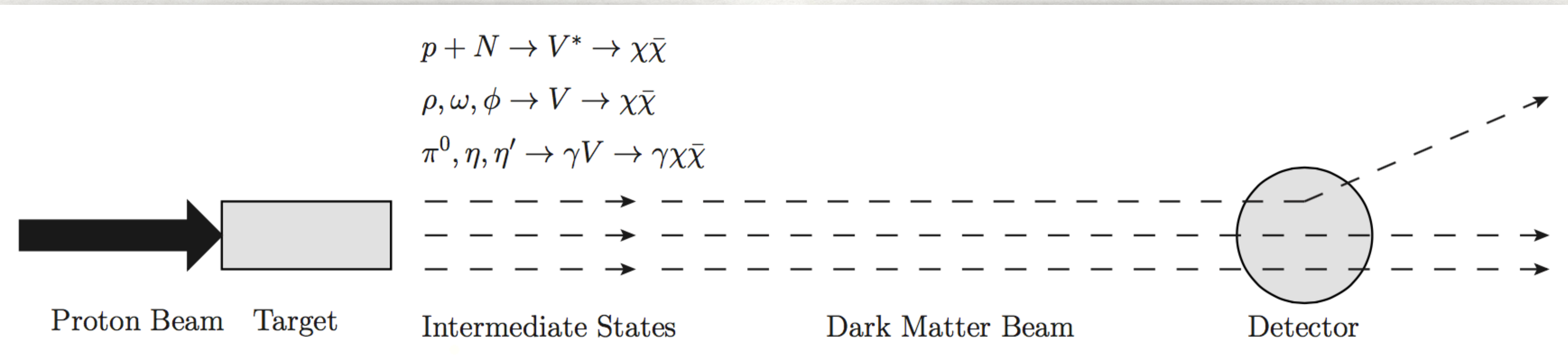
FIXED TARGET PROBES: NEUTRINO BEAM



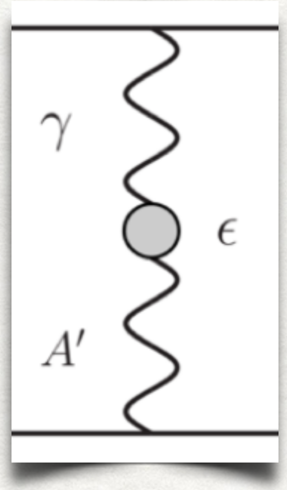
FIXED TARGET PROBES: NEUTRINO BEAM + DARK MATTER BEAM



Basic idea: use the neutrino detector as a dark matter detector, looking for recoil, but now from a **relativistic beam**



THE DARK PHOTON (DP) MODEL



- New gauge boson A' associated to an abelian gauge symmetry U(1)’, **kinematically mixed** with the photon (portal):

$$\mathcal{L}_{A'} = -\frac{1}{4}F'_{\mu\nu}F'^{\mu\nu} + \frac{m^2_{A'}}{2}A'^{\mu}A'_{\mu} - \frac{1}{2}\epsilon\, F'_{\mu\nu}F^{\mu\nu}$$

- A’ can decay in a couple of Dark Matter particles (χ)

$$\Gamma_{A'} = \sum_l \Gamma_{A'\to l^+l^-} + \sum_{hadrons} \Gamma_{A'\to hadrons} + \sum_\chi \Gamma_{A'\to\chi\chi}$$

- The relevant parameters for the phenomenology of the DP model are the ($M_{A'}$, ε)

- Benchmark model

$$\alpha_D = 0.1 \qquad \left(\frac{M_\chi}{M_{A'}}\right) = \frac{1}{3}$$

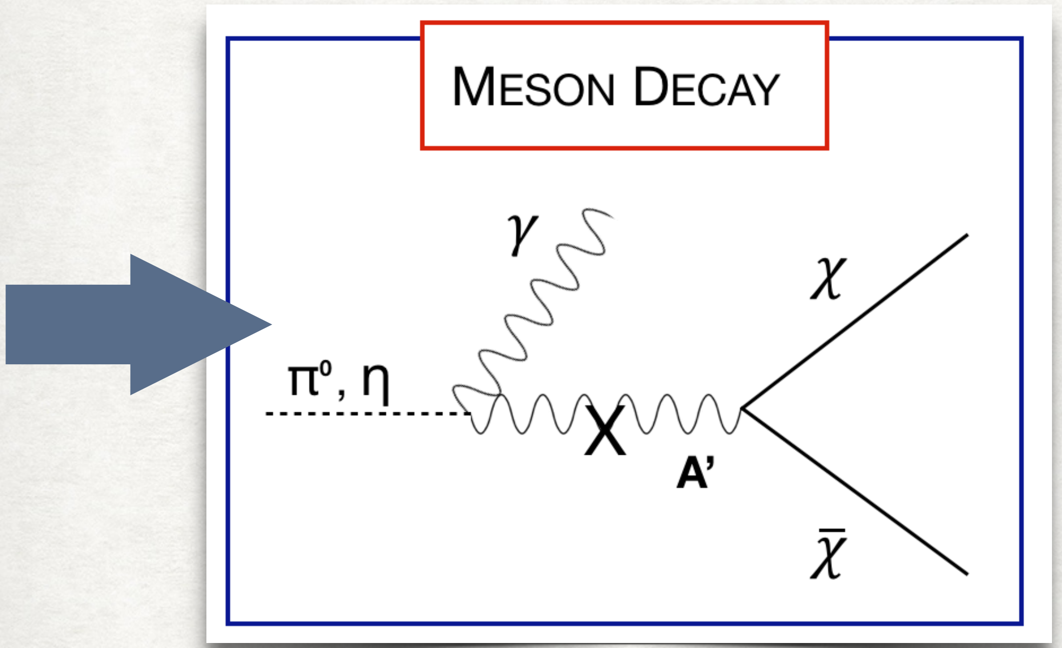
- In the exclusion plot, the coupling constant ε is usually replaced by the variable

$$Y = \alpha_D \epsilon^2 \left(\frac{M_\chi}{M_{A'}}\right)^4$$

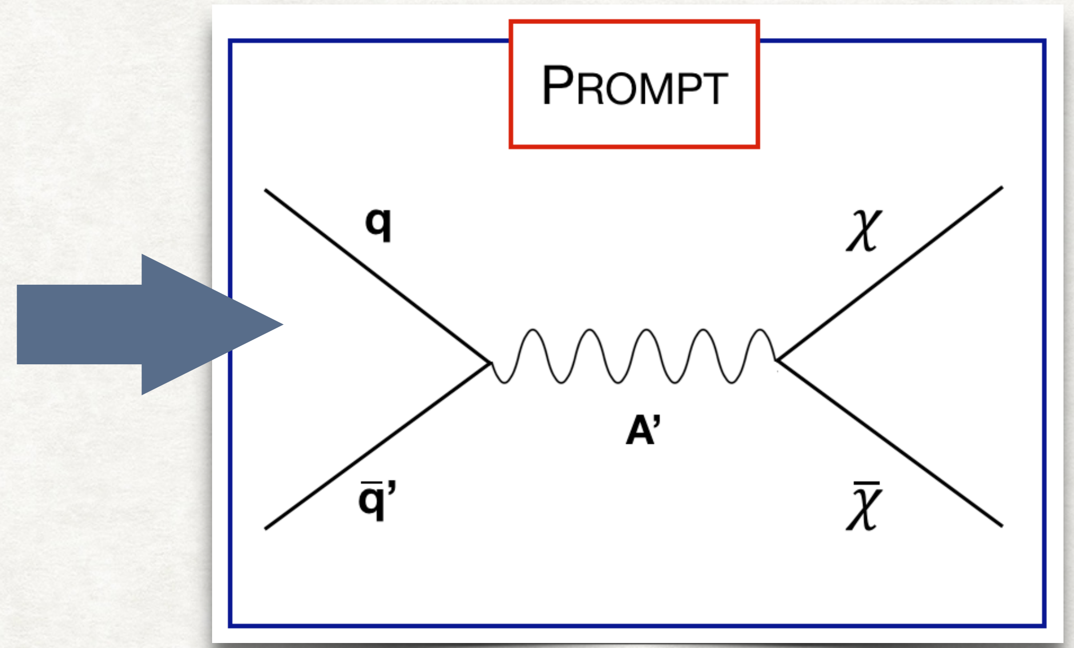
LIGHT DARK MATTER PRODUCTION @SHIP

- Generated in the beam-dump, e.g. via light dark photon mediators (***A′***)
- Main production modes in the mass regime: $m_{A'} > 2m_{\chi}$

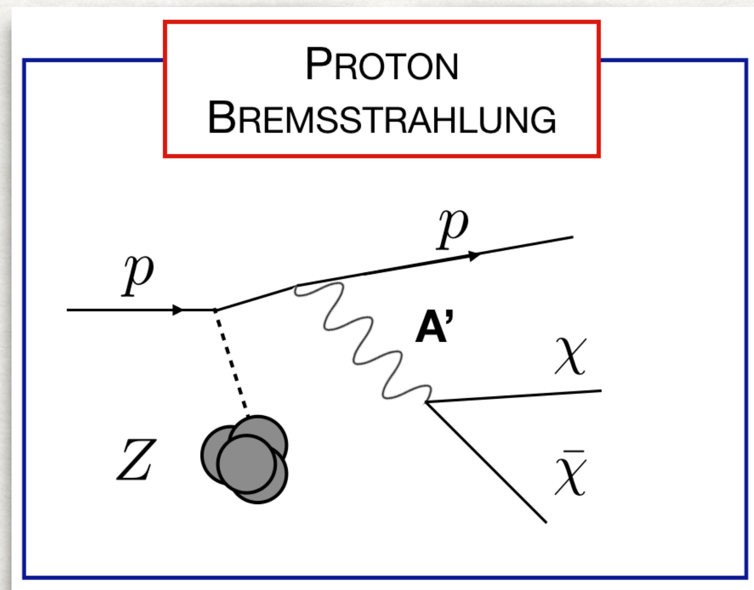
1) meson decay



2) prompt QCD



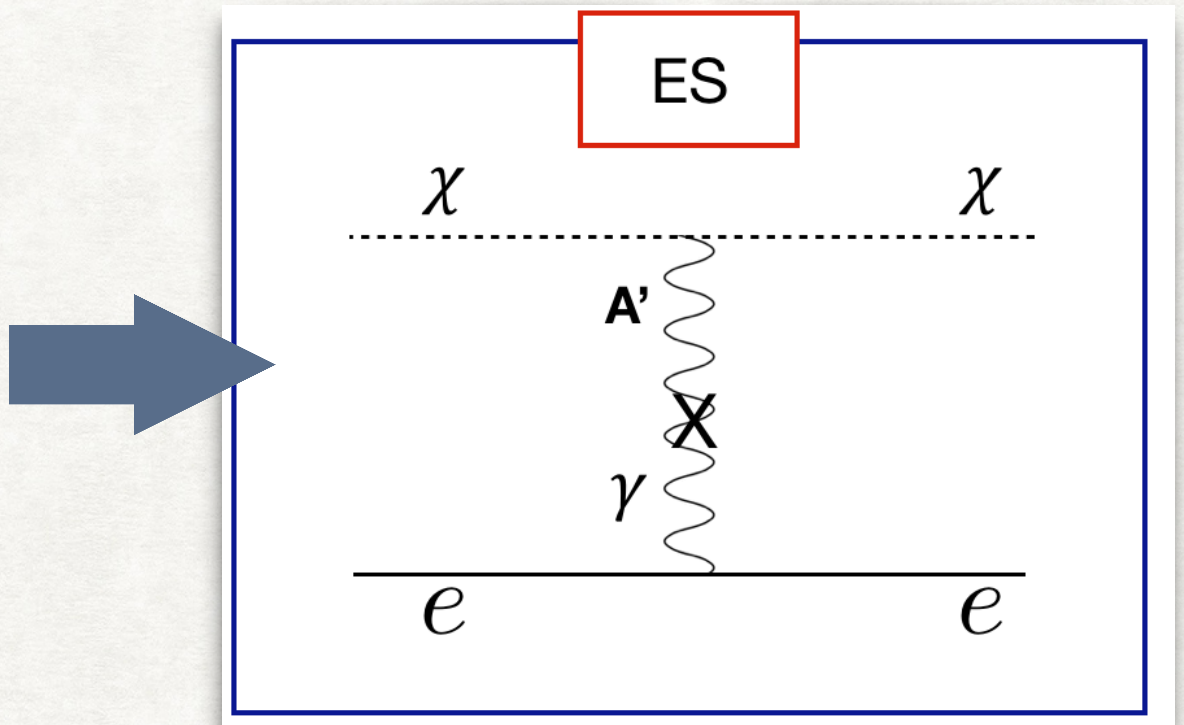
3) proton bremsstrahlung



Negligible in the mass range under investigation

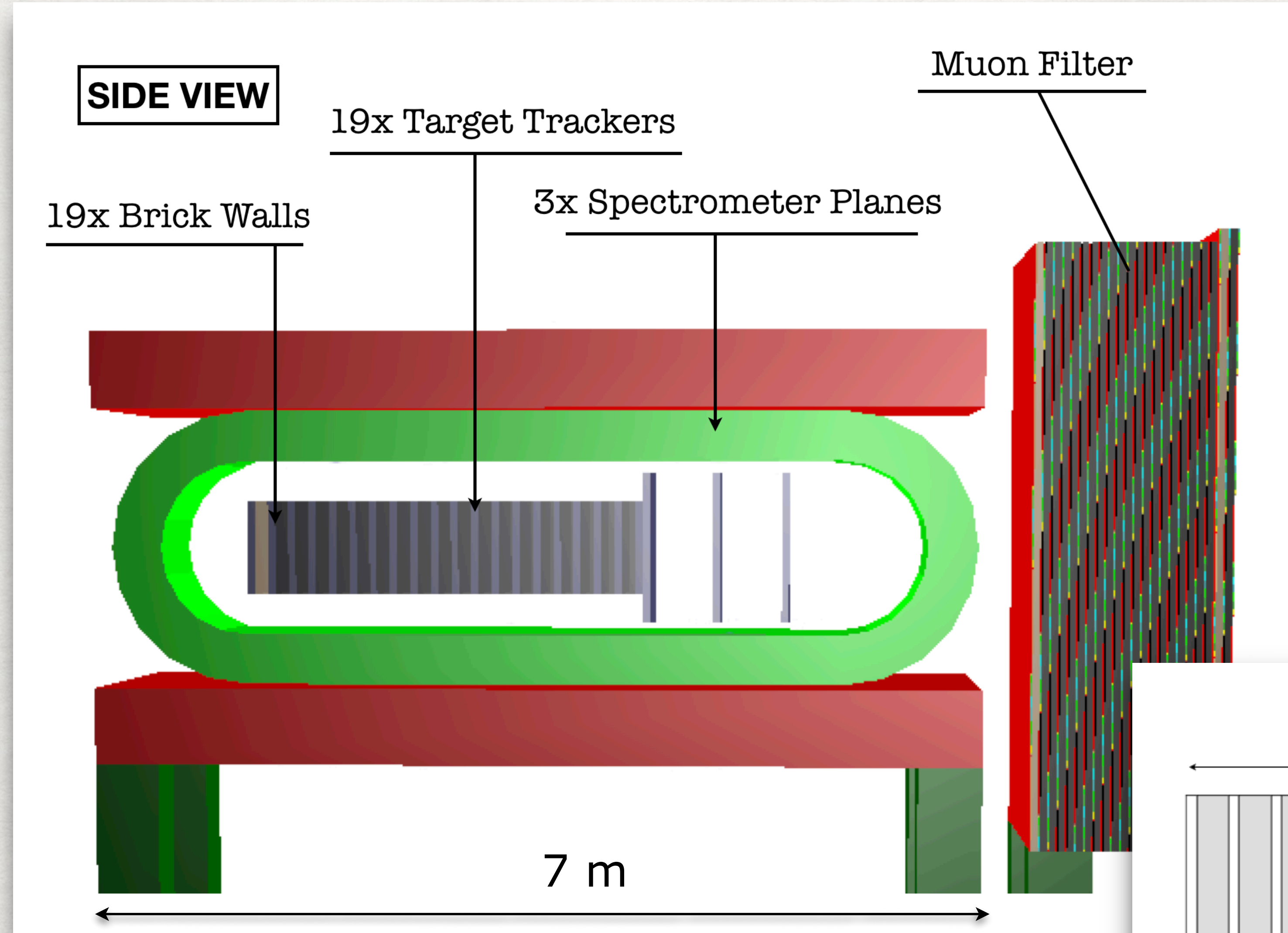
LIGHT DARK MATTER DETECTION @SHIP

- LDM elastic scattering on atomic electrons of the target



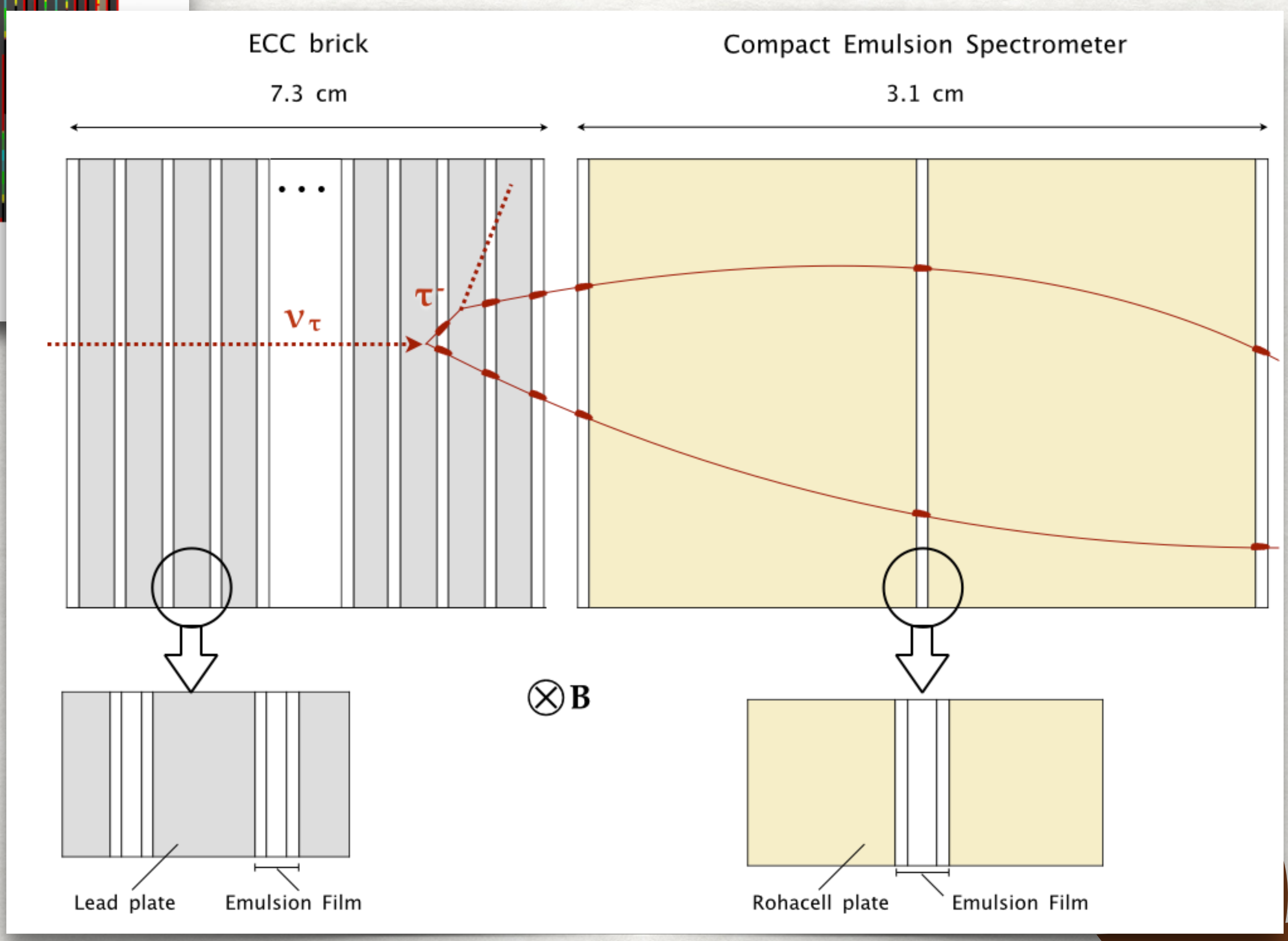
- High energy beam dump:
  → LDM-electron scattering is highly peaked in the forward direction

NEUTRINO & SCATTERING DETECTOR



REQUIREMENTS

- High spatial resolution to observe the τ decay (~1 mm)
  → ***EMULSION FILMS***
- Electronic detectors to give "time" resolution to emulsions
  → ***TARGET TRACKER PLANES***
- Magnetized target to measure the charge of τ products
  → ***MAGNET***

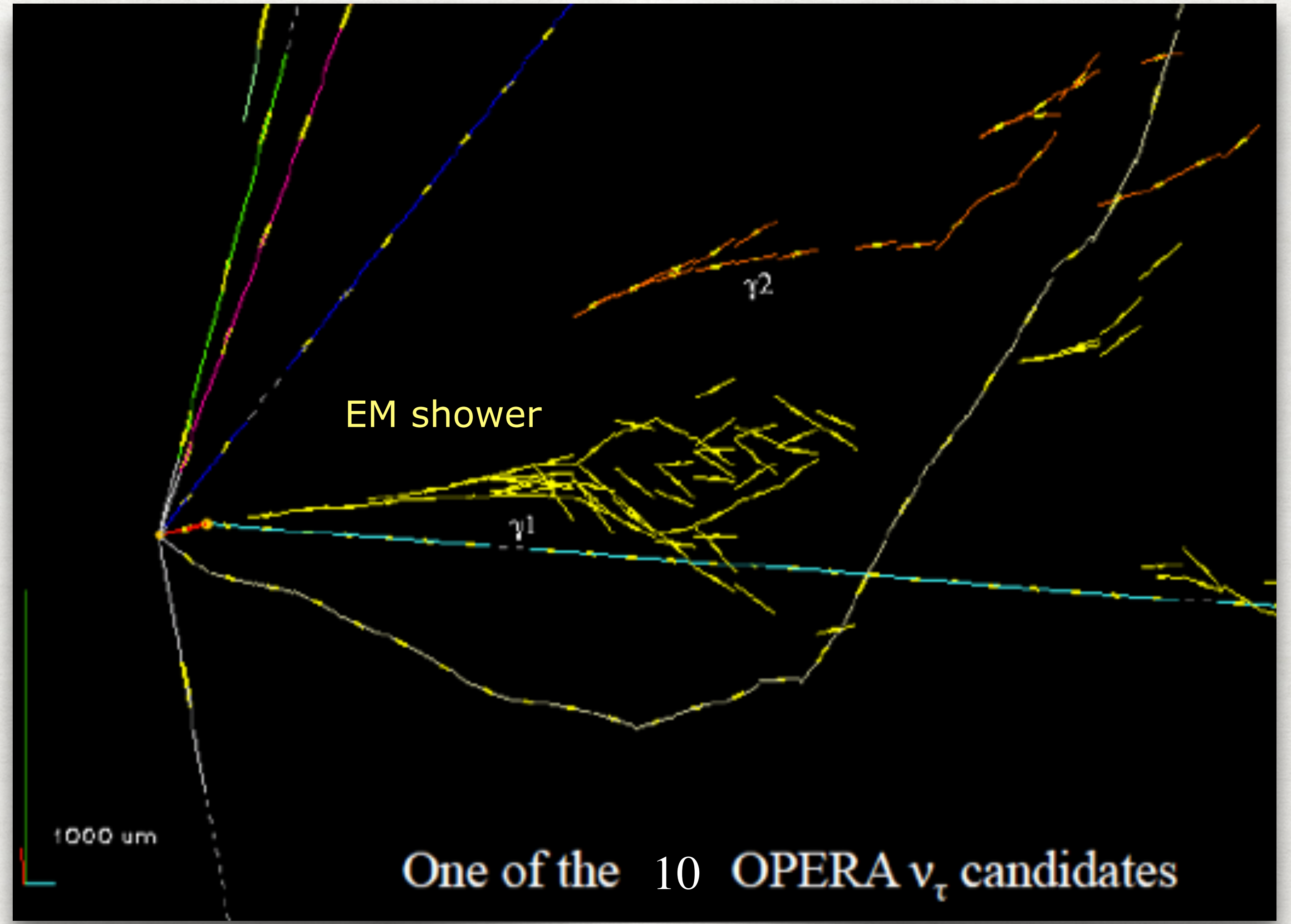


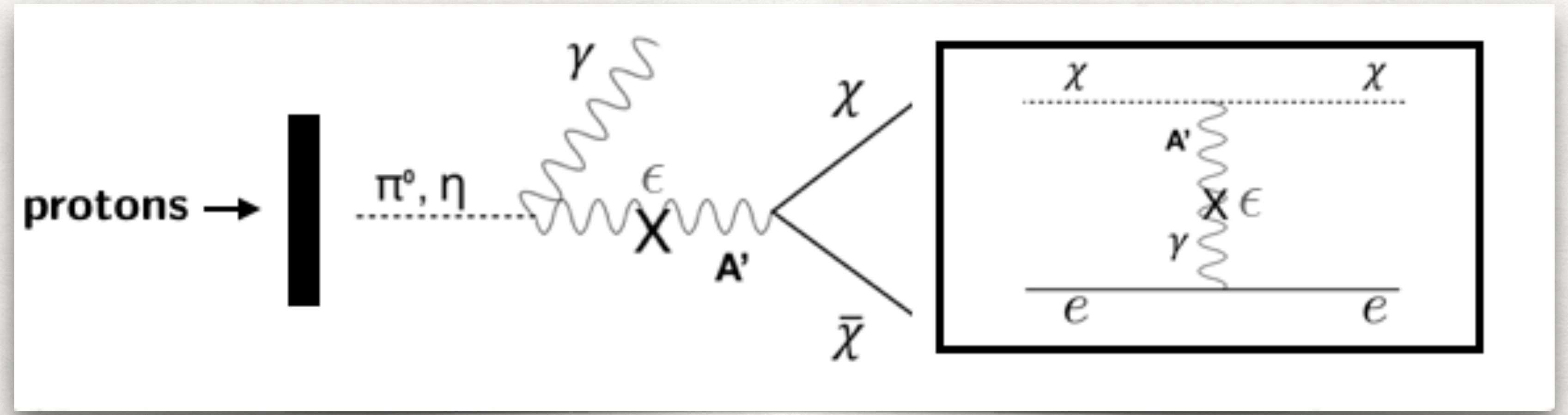
- The Emulsion Target exploits the **Emulsion Cloud Chamber (ECC)** technology
- Sensitive Trackers: nuclear emulsions
- Passive material: lead plates

LDM DETECTION IN THE EMULSION TARGET

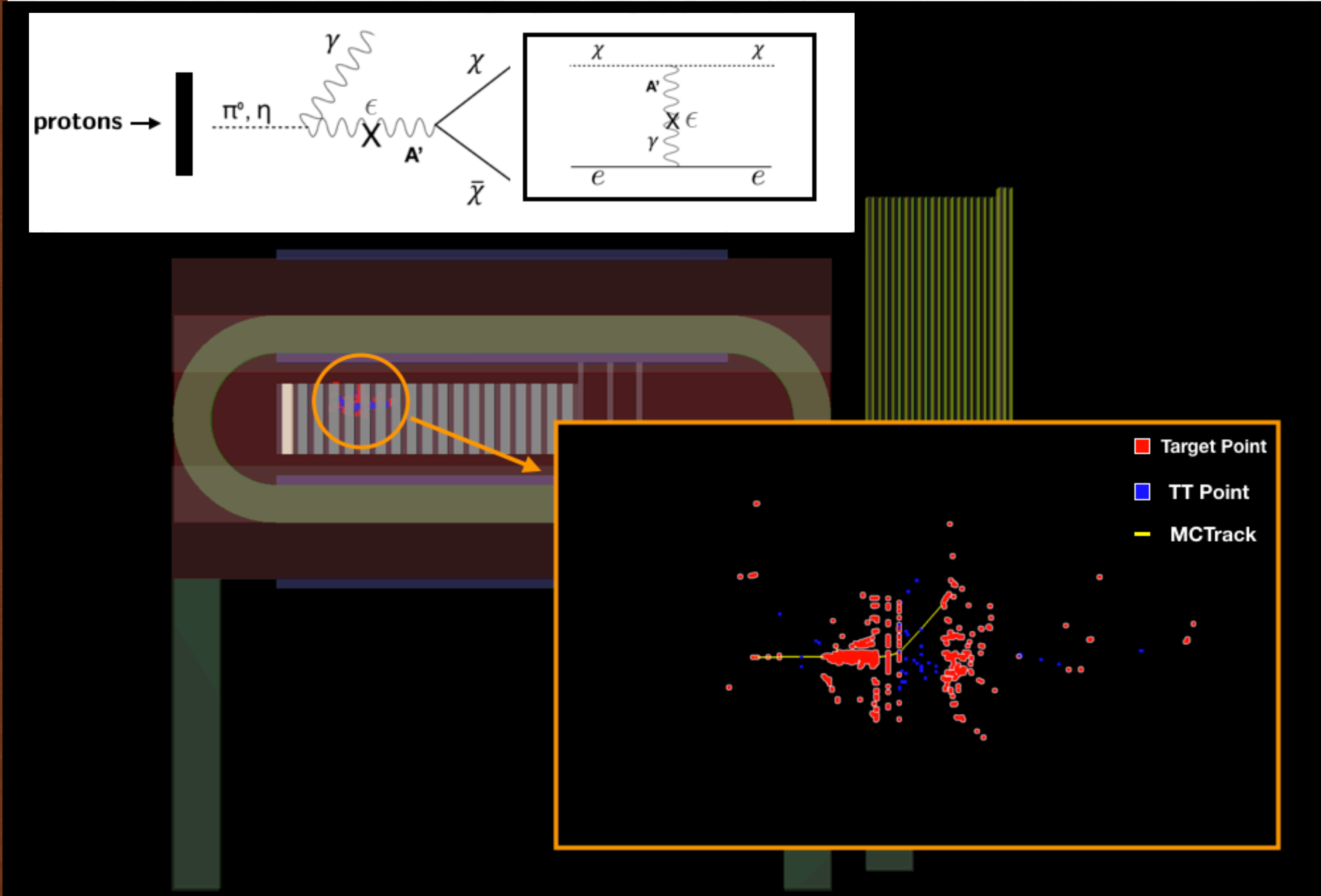
The Emulsion Target properties allow the search for **Light Dark Matter** particles (mass < 1 GeV/c^2) scattering off electrons

- **Electron identification**: electromagnetic shower reconstruction with calorimetric technique
- Angular resolution: **mrad**
- **Micrometric precision** in primary and secondary vertices separation

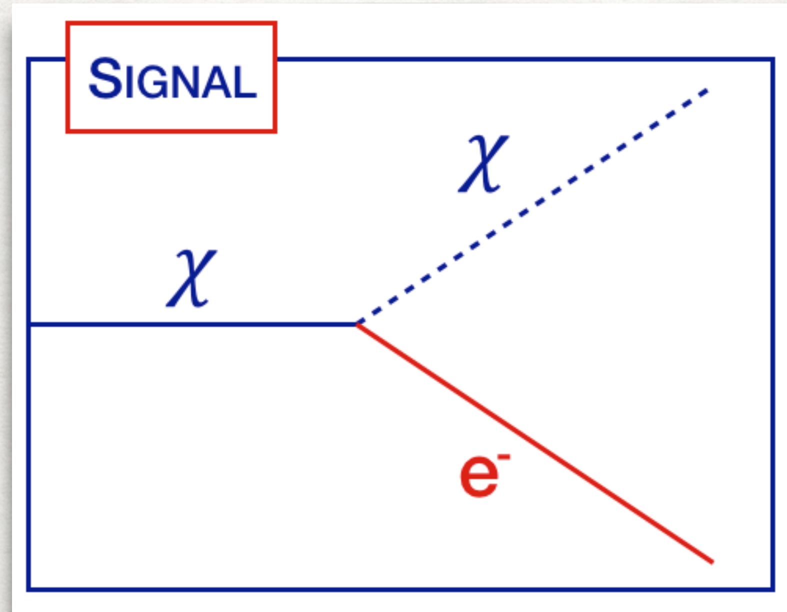




LDM SIGNAL EVENTS IN THE EMULSION TARGET

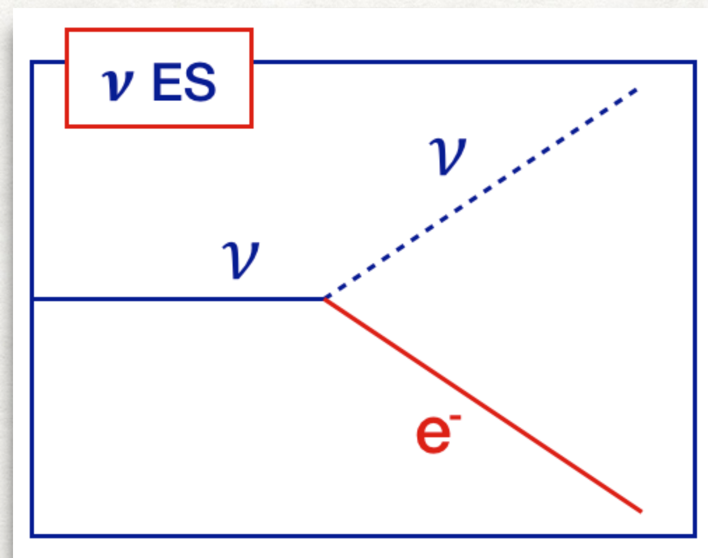


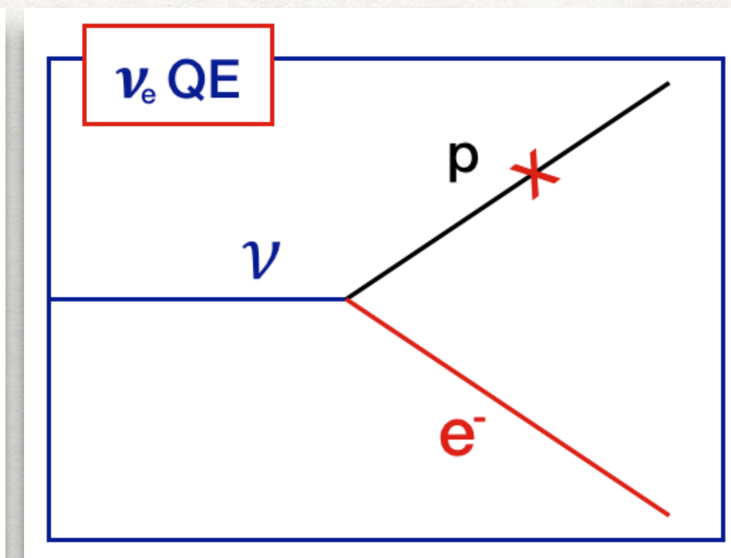
NEUTRINO BACKGROUND



We look for $\chi e^- \rightarrow \chi e^-$ elastic scattering within the Emulsion Target from the decay of a Dark Photon

Neutrinos can mimic LDM scattering in case of only one visible track at primary vertex



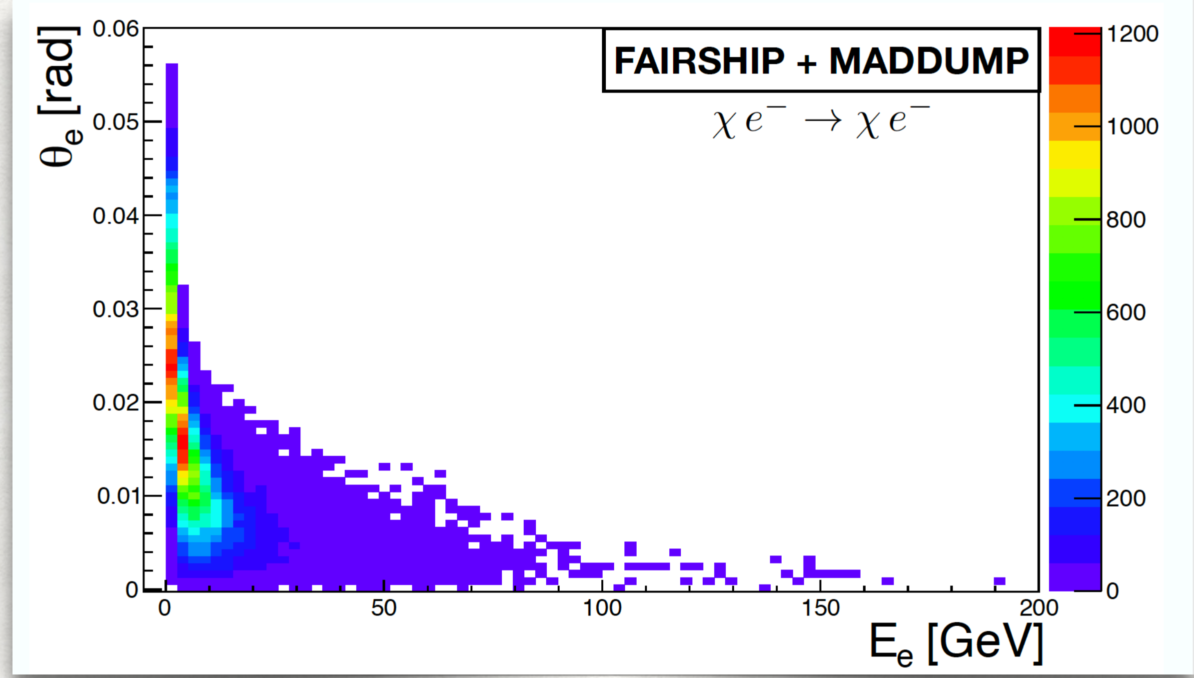


- $\nu_e\,(\bar{\nu}_e)$ - **Deep Inelastic Scattering (DIS)** on nuclei
- $\nu_e\,|(\bar{\nu}_e)$ - **Resonant Scattering (RES)** on nuclei
- $\nu_e\,(\bar{\nu}_e)$ - **Quasi-Elastic scattering (QE)** on nuclei
- $\nu_e\,(\bar{\nu}_e),\ \nu_\mu\,(\bar{\nu}_\mu)$ - **Elastic Scattering (ES)** on electrons

NEUTRINO BACKGROUND

Selection cuts on the recoil electron

- recoil energy $1 < E_e < 20$ GeV
- Scattering angle $10 < \theta_e < 20$ mrad

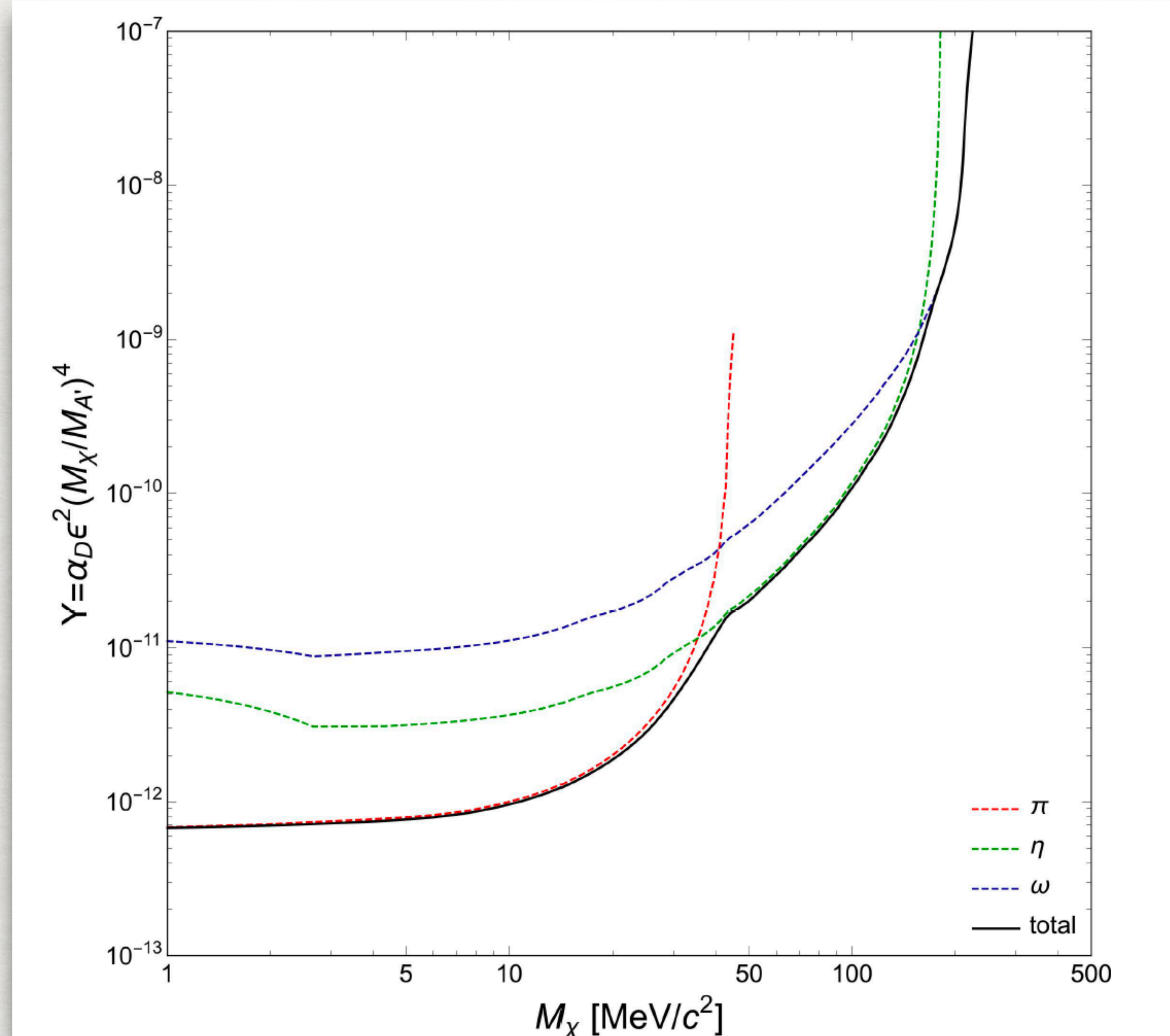


NEUTRINO BACKGROUND YIELD 2×10^{20} p.o.t.

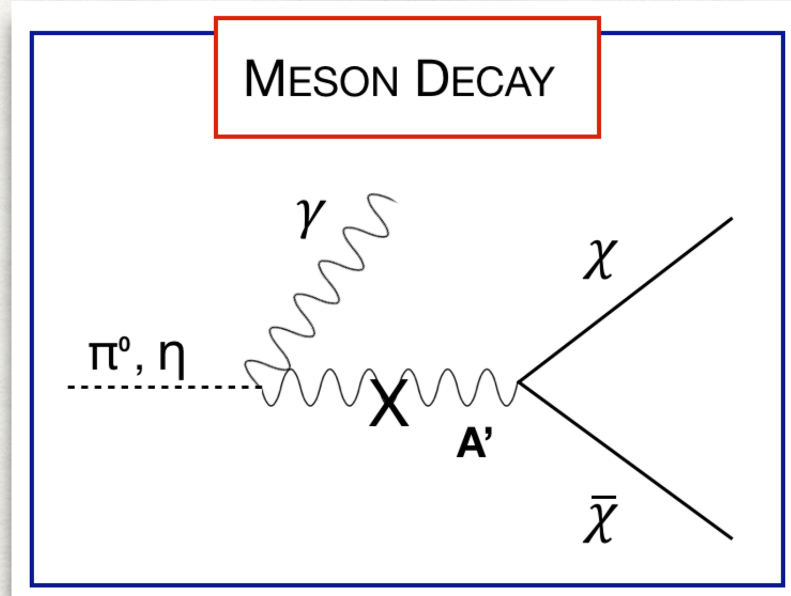
	ν_e	$\bar{\nu}_e$	ν_μ	$\bar{\nu}_\mu$	all
Elastic scattering on e^-	81	45	56	35	217
Quasi - elastic scattering	245	236			481
Resonant scattering	8	77			85
Deep inelastic scattering	-	14			14
Total	334	372	56	35	797

- **DOMINANT**
  - quasi-elastic scattering
  - *crucial*: proton visibility
- **IRREDUCIBLE**
  - elastic scattering
- **HIGH MULTIPLICITY**
  - deep inelastic scattering

MESON DECAYS



In the low mass range rare meson decays represent the dominant production mechanism

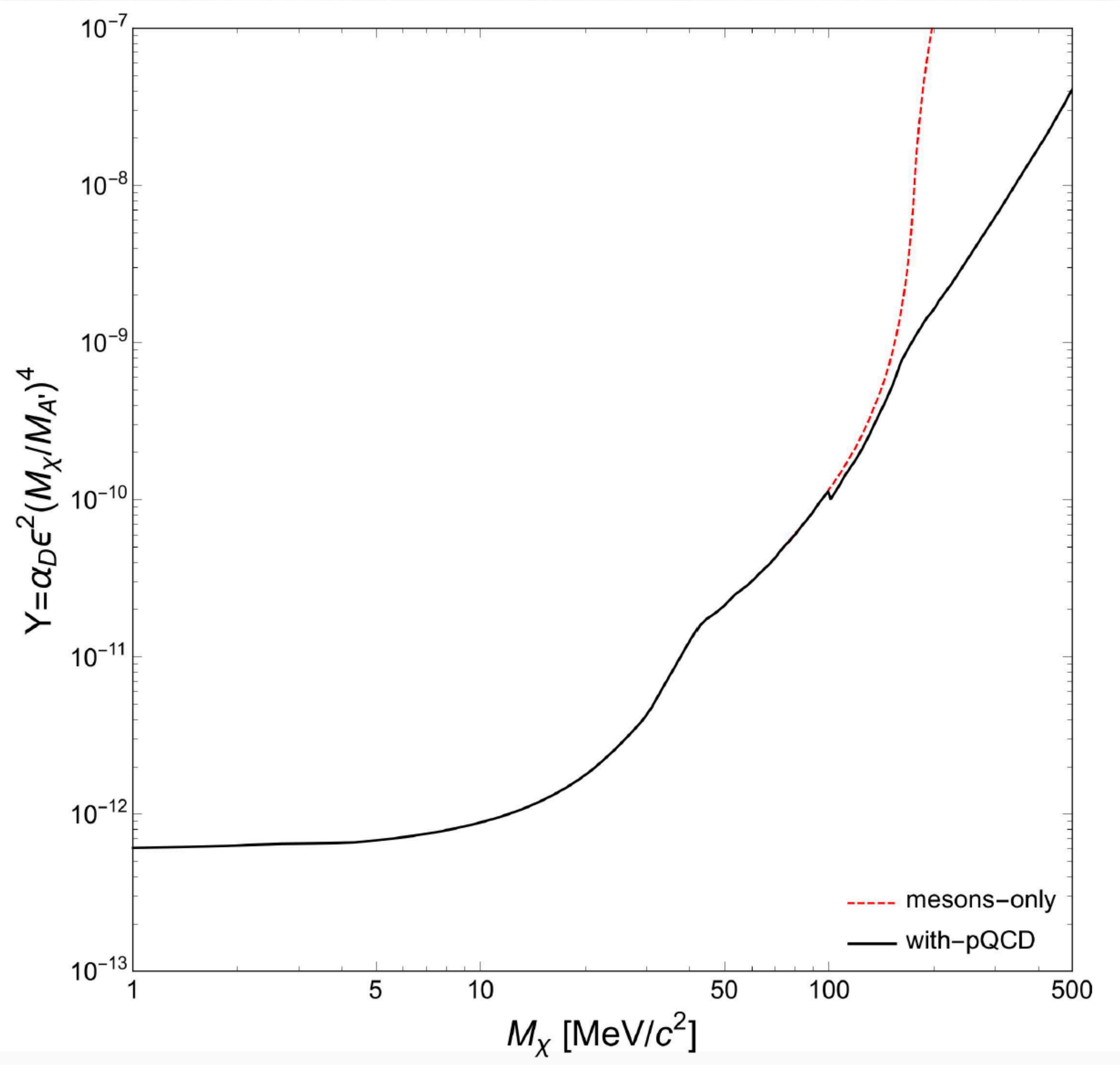


Steep raise due to phase space factor
[*P. deNiverville, M. Pospelov, A. Ritz, Phys.Rev. D84* (2011)]

$$\left(1-\frac{M_{A'}^2}{M_{\pi,\eta}^2}\right)^3$$

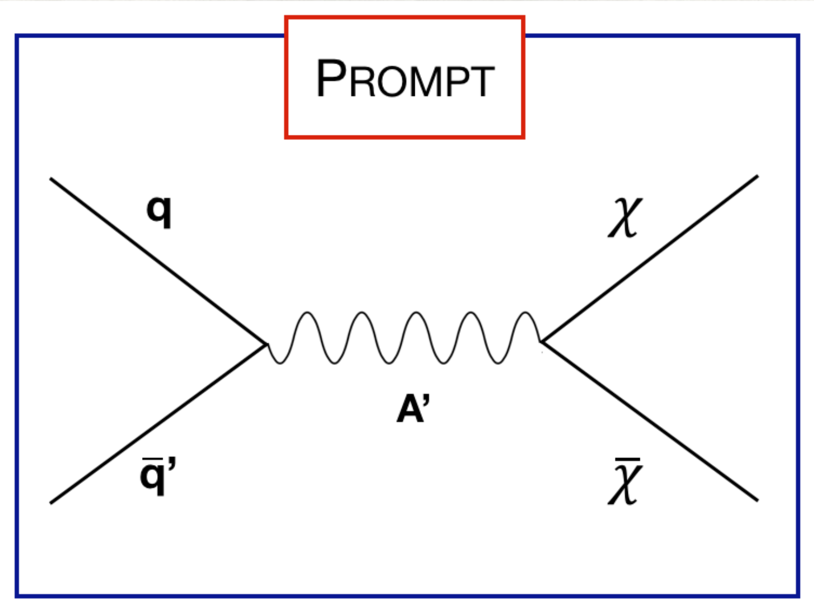
Plateau at low masses due to the cuts on the recoil electron

PROMPT QCD



Perturbative QCD competes with the contribution due to ω decays and improves the sensitivity above the ω threshold

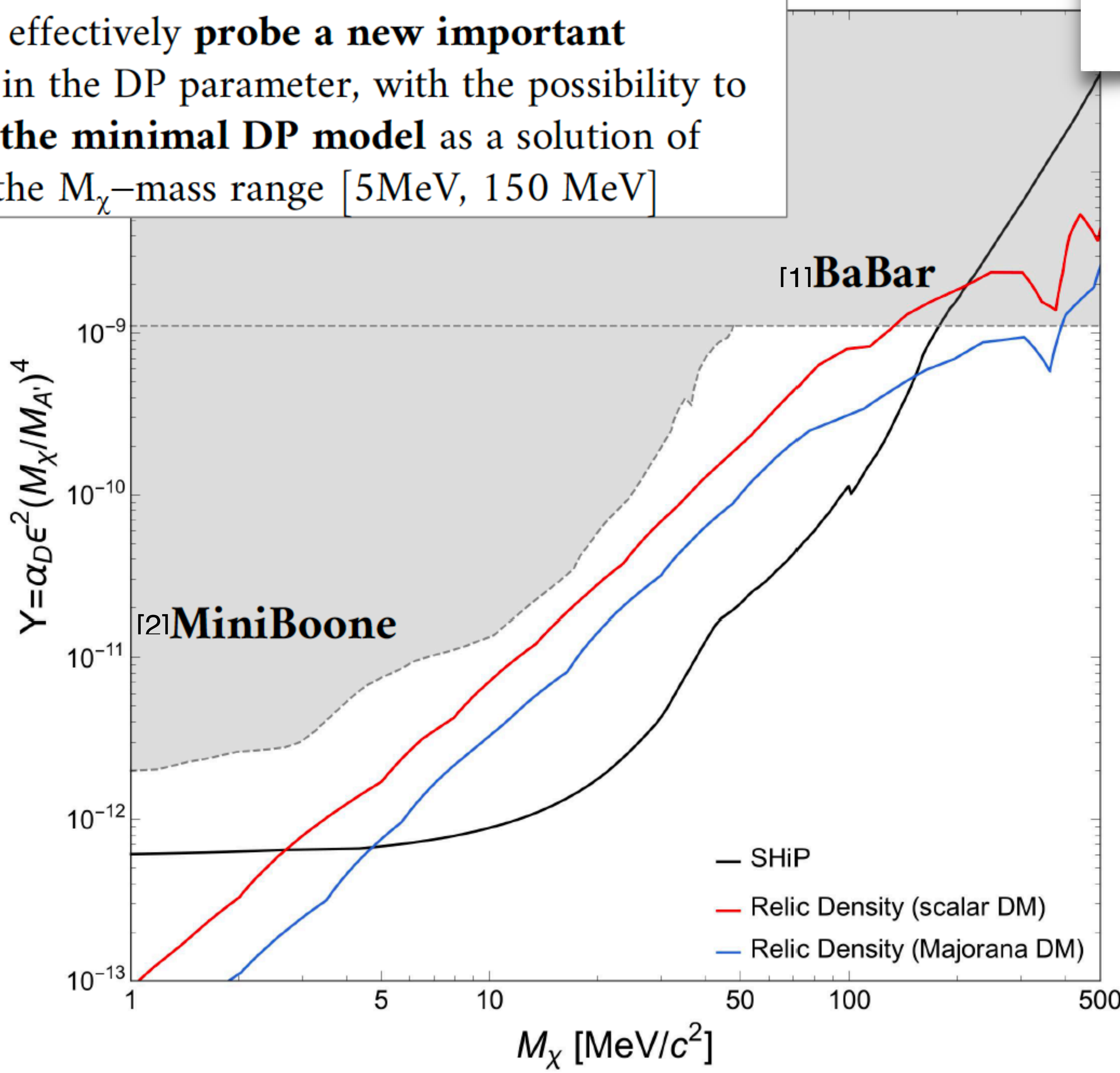
Relevant partonic tree-level processes

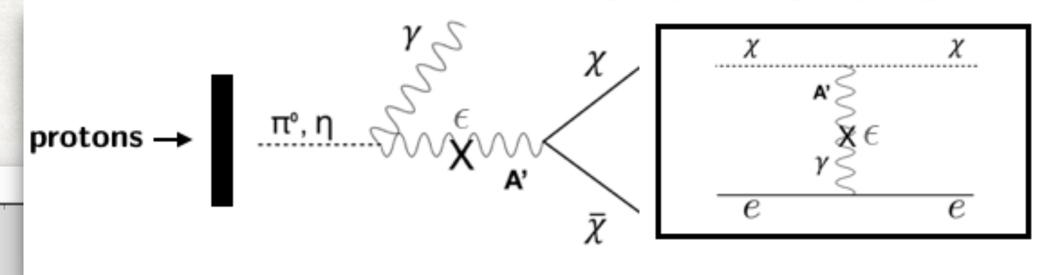


- Perturbation theory breaks down for $M_{A'}$ values ≲ Λ_{QCD}~300 MeV
- Our approach (reliable): we freeze out the renormalization and the factorization scales to 1.5 GeV (minimum in charm production) and we limit the mass range to $M_{A'}$ > 300 MeV

SHIP SENSITIVITY

SHiP can effectively **probe a new important window** in the DP parameter, with the possibility to **rule out the minimal DP model** as a solution of TDM in the M_χ–mass range [5MeV, 150 MeV]





Benchmark model

$$\alpha_D = 0.1 \qquad \left(\frac{M_\chi}{M_{A'}}\right) = \frac{1}{3}$$

$$Y = \alpha_D \epsilon^2 \left(\frac{M_\chi}{M_{A'}}\right)^4$$

[1] arXiv:1702.03327

[2] arXiv:1807.06137

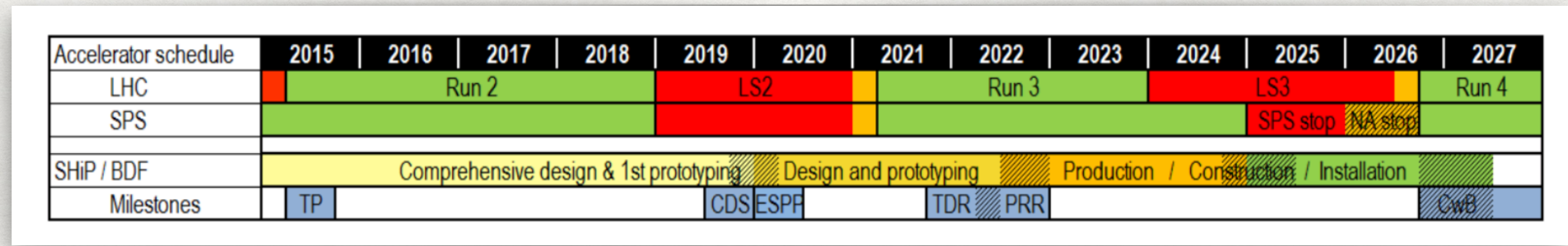
CONCLUSIONS

- The **Dark Photon** is a well motivated model that can be probed experimentally at high intensity and low energies
- The SHiP **Scattering and Neutrino Detector** can be effectively exploited for this searches, the electron scattering being the most promising signature

  - **SHiP** can probe a new important window of the parameter space, below the Majorana relic density curve in the range [5 MeV - 150 MeV]

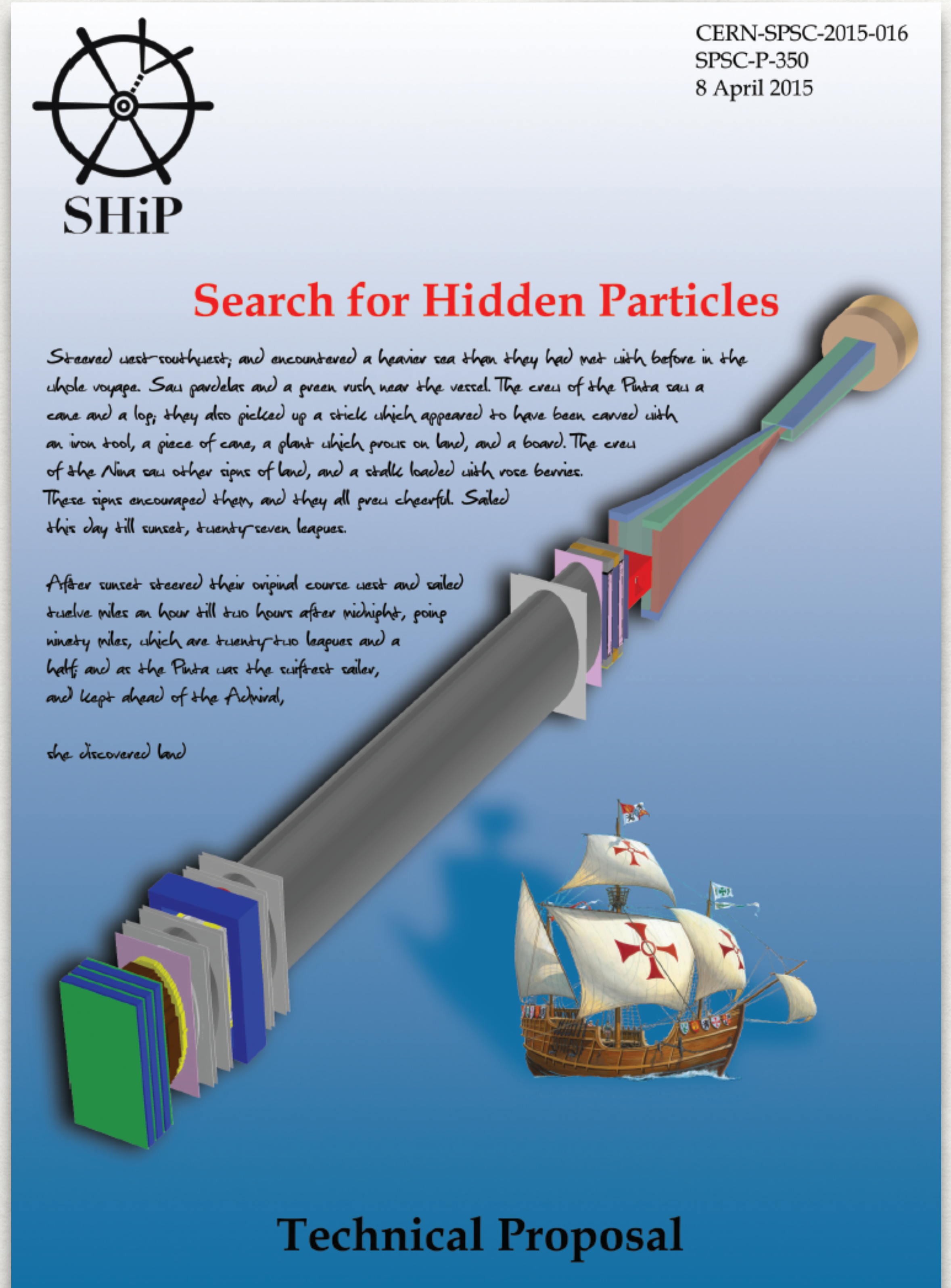
BACKUP SLIDES

PROJECT SCHEDULE



- **Form SHiP Collaboration** — **December 2014 ✔**
- **Technical Proposal** — **April 2015 ✔**
- **Positive SPSC recommendation for CDS** — **September 2016 ✔**
- Comprehensive Design Study — 2019
- Design and prototyping — 2020-2022
- Construction and Installation — 2023-2026
- Commissioning and data taking — 2027

THE SHiP PROJECT



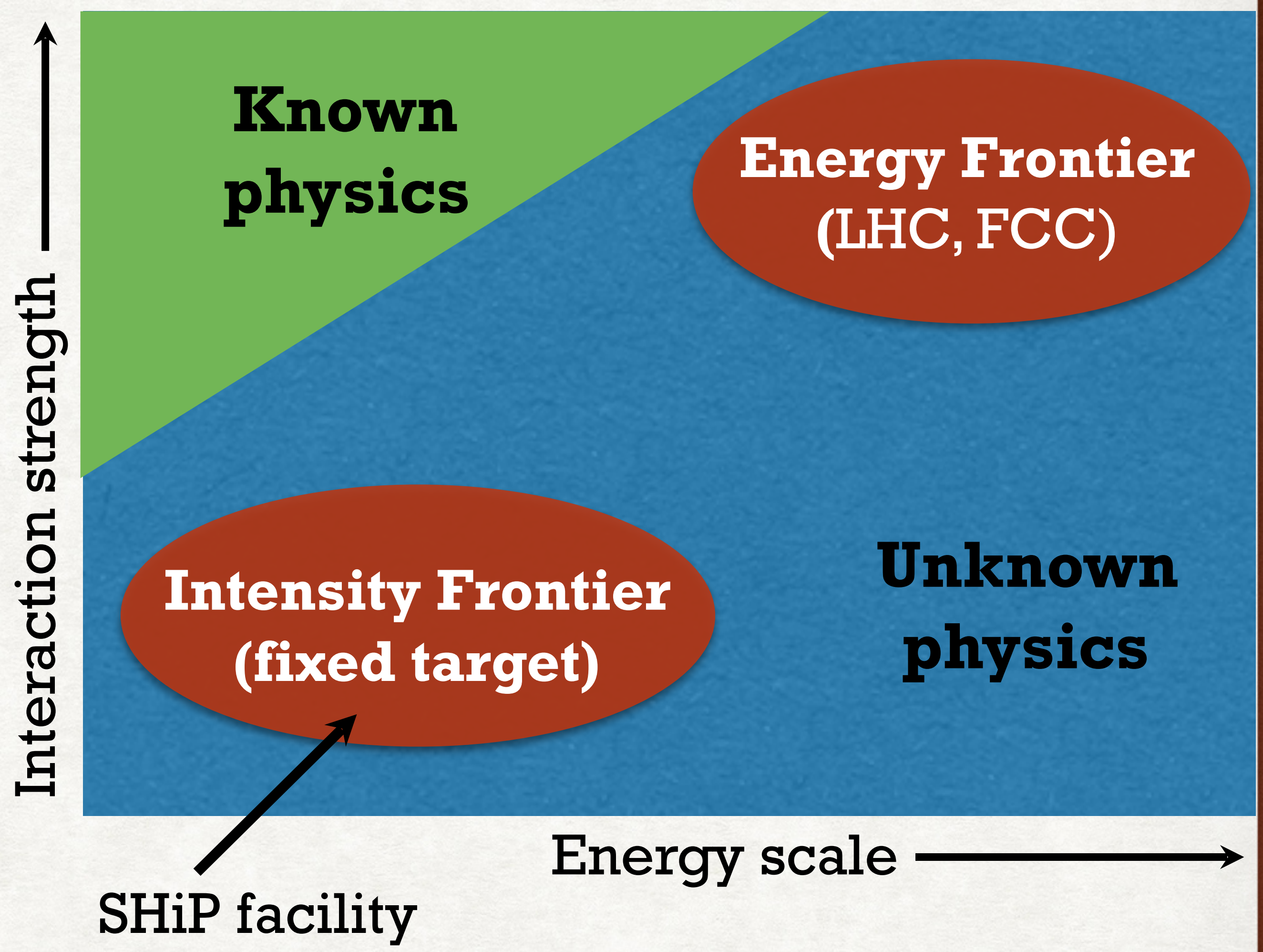
- **SHiP** (Search for Hidden Particles) in a proposed fixed target experiment at CERN SPS
- Collaboration of 250 members from 49 institutes, 17 countries
- Technical Proposal *arXiv:1504.04956 (2015)*
- Physics case signed by 80 theorists *Rep. Prog. Phys. 79 (2016)* *arXiv:1504.04855*
- Positive SPSC recommendation
- Comprehensive Design Study by 2019 → decision about approval in 2020
- Important actor in the CERN Physics Beyond Colliders study group

COSTS

Item		Cost (MCHF)
Muon Shield		**11.4**
Scattering and Neutrino Detector		**11.6**
Emulsion Target (no magnet)	6.8	
Target Tracker	2.5	
Muon Magnetic Spectrometer	2.3	
Decay Spectrometer		**46.8**
Decay Volume	11.7	
Surround Background Tagger	2.1	
Upstream Veto Tagger	0.1	
Straw Veto Tagger	0.8	
Spectrometer Straw Tracker	6.4	
Spectrometer Magnet	5.3	
Spectrometer Timing Detector	0.5	
Electromagnetic Calorimeter	10.2	
Hadron Calorimeter	4.8	
Muon Detector	2.5	
Muon iron filter	2.3	
Computing and online system		**0.2**
Total		**70.0**

MOTIVATION

- The **Standard Model** provides an explanation for many subatomic processes
- Although very successful, it fails to explain many observed phenomena
  - **Dark Matter**
  - **Neutrino Oscillation and masses**
  - **Matter/antimatter asymmetry in the Universe**
- A **Hidden Sector (HS)** of weakly-interacting BSM particles as an explanation



Energy Frontier:
Heavy particles → high energy collisions needed

Intensity Frontier:
Very weakly interacting particles → high intensity beam needed

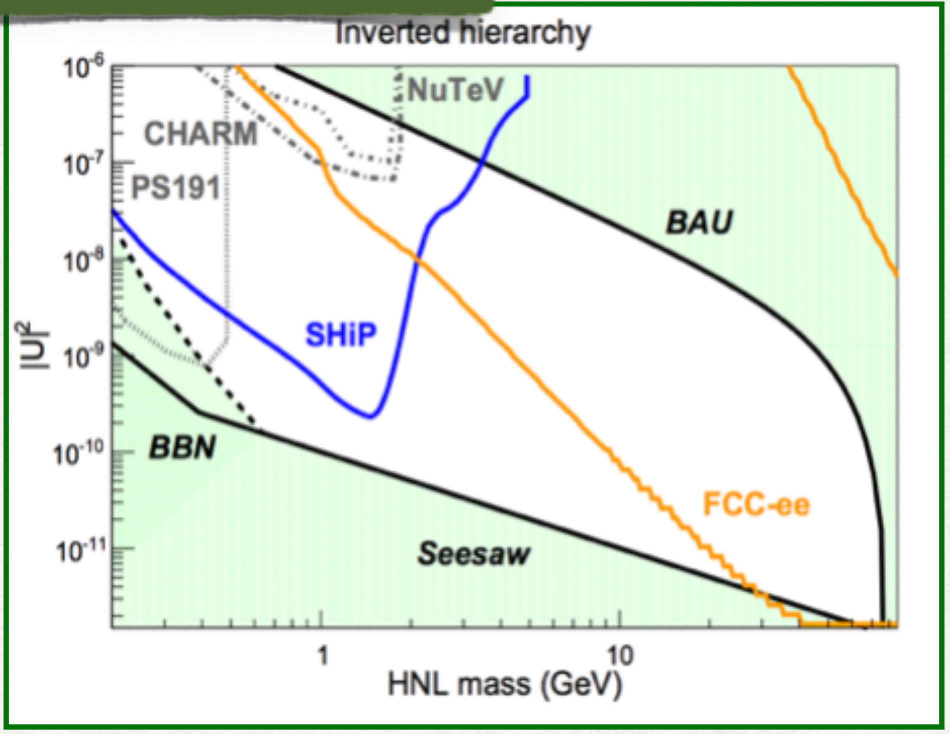
- **SHiP**: new fixed target facility at the intensity frontier to explore Hidden Sector
- Neutrino physics
- Light Dark Matter search

Several **portals** to the HS: scalar portal, neutrino portal, vector portal, SUSY…

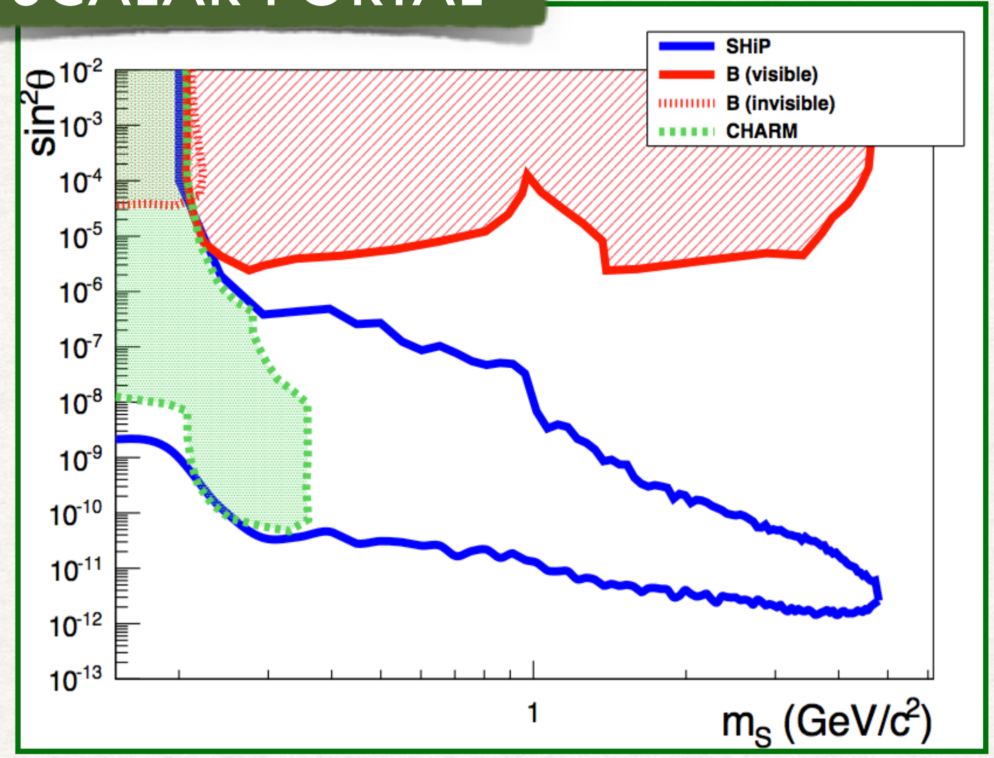
SENSITIVITIES

Based on 2×10^{20} pot
@400 GeV in 5 years

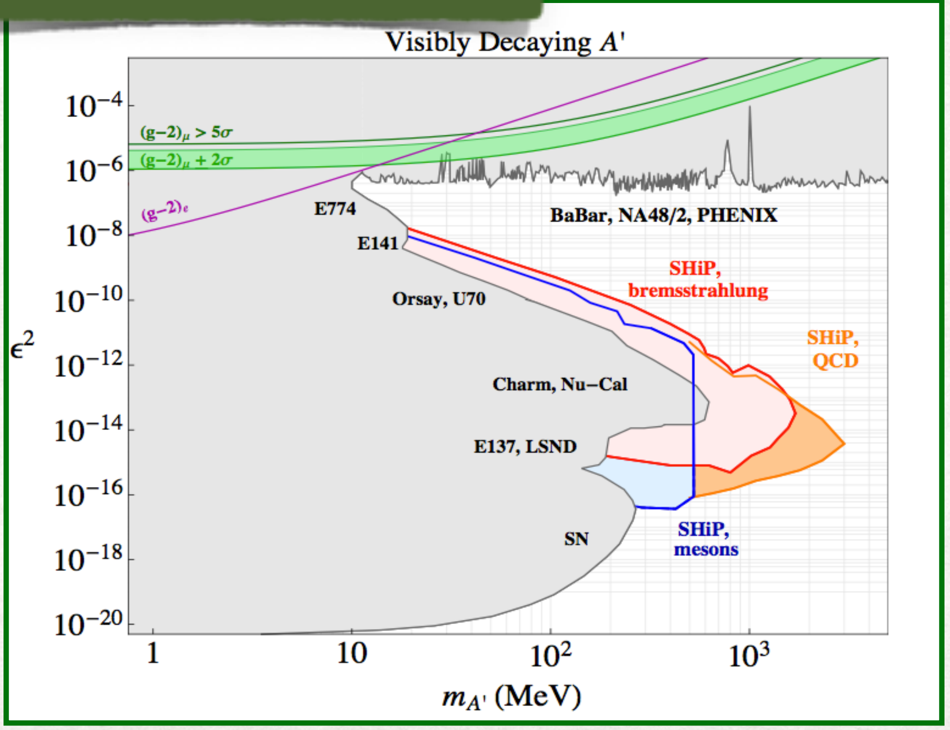
NEUTRINO PORTAL



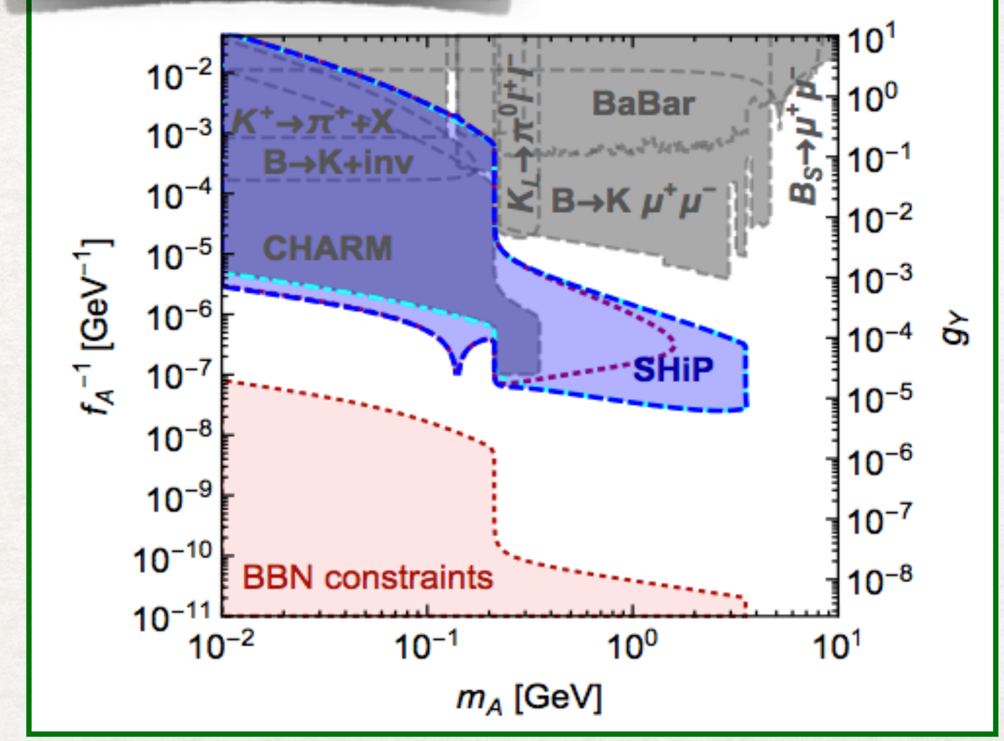
SCALAR PORTAL



VECTORIAL PORTAL

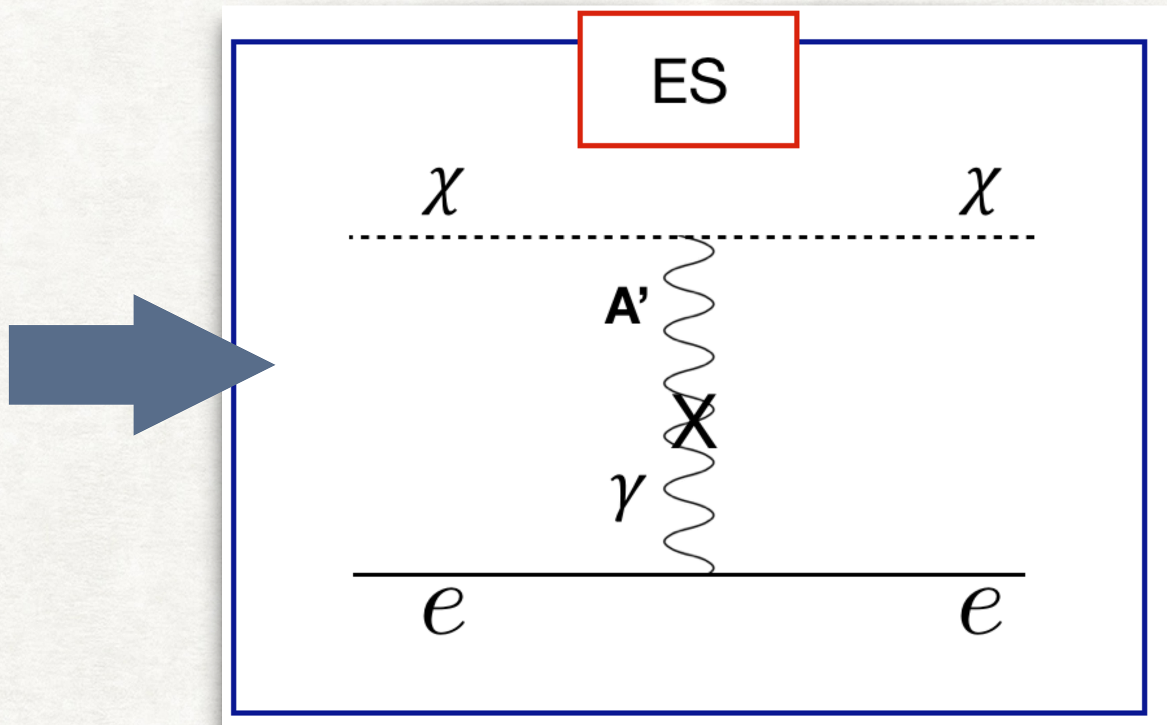


AXION PORTAL

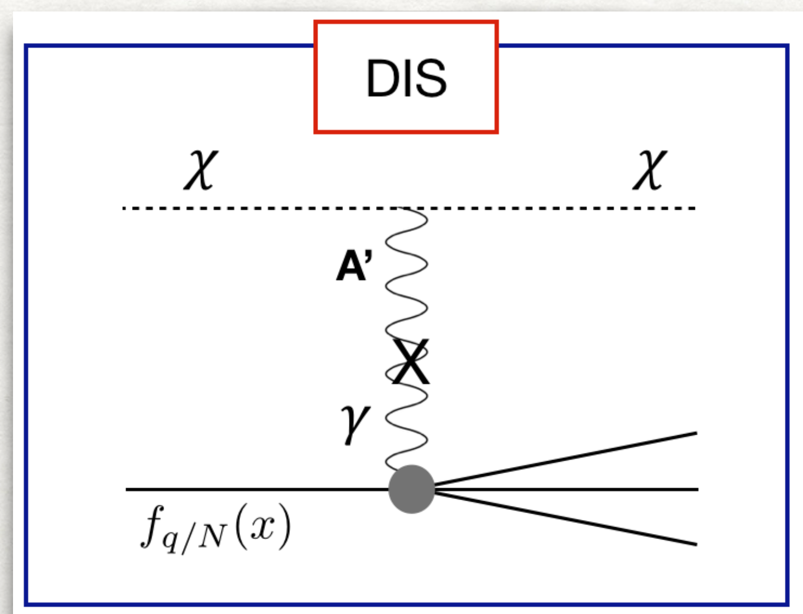


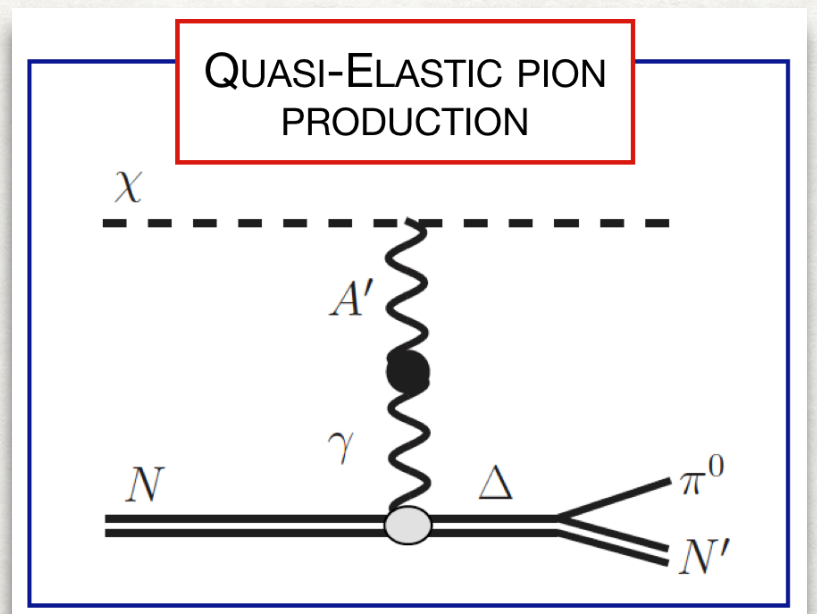
LIGHT DARK MATTER DETECTION @SHIP

- LDM elastic scattering on atomic electrons of the target

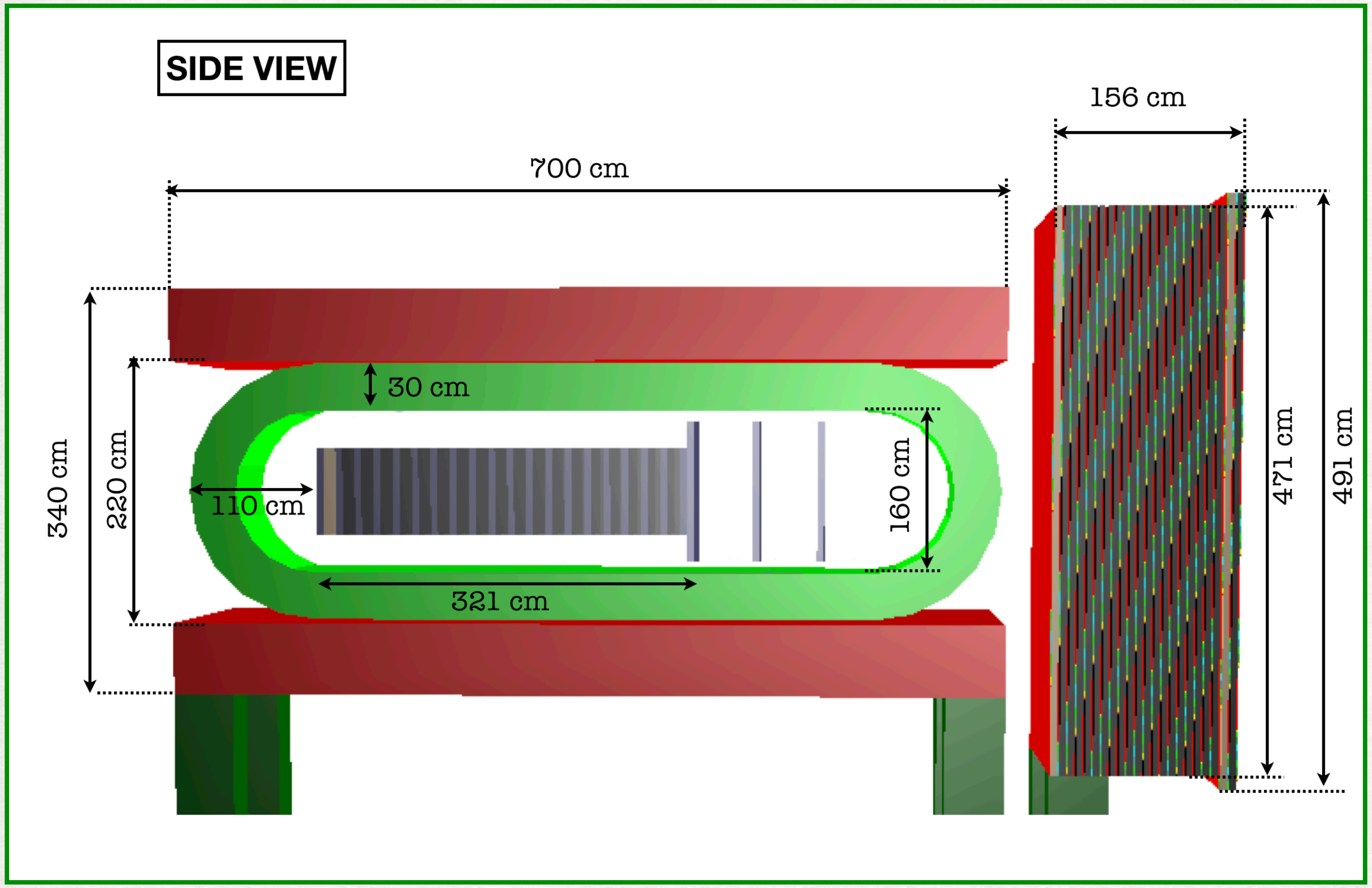


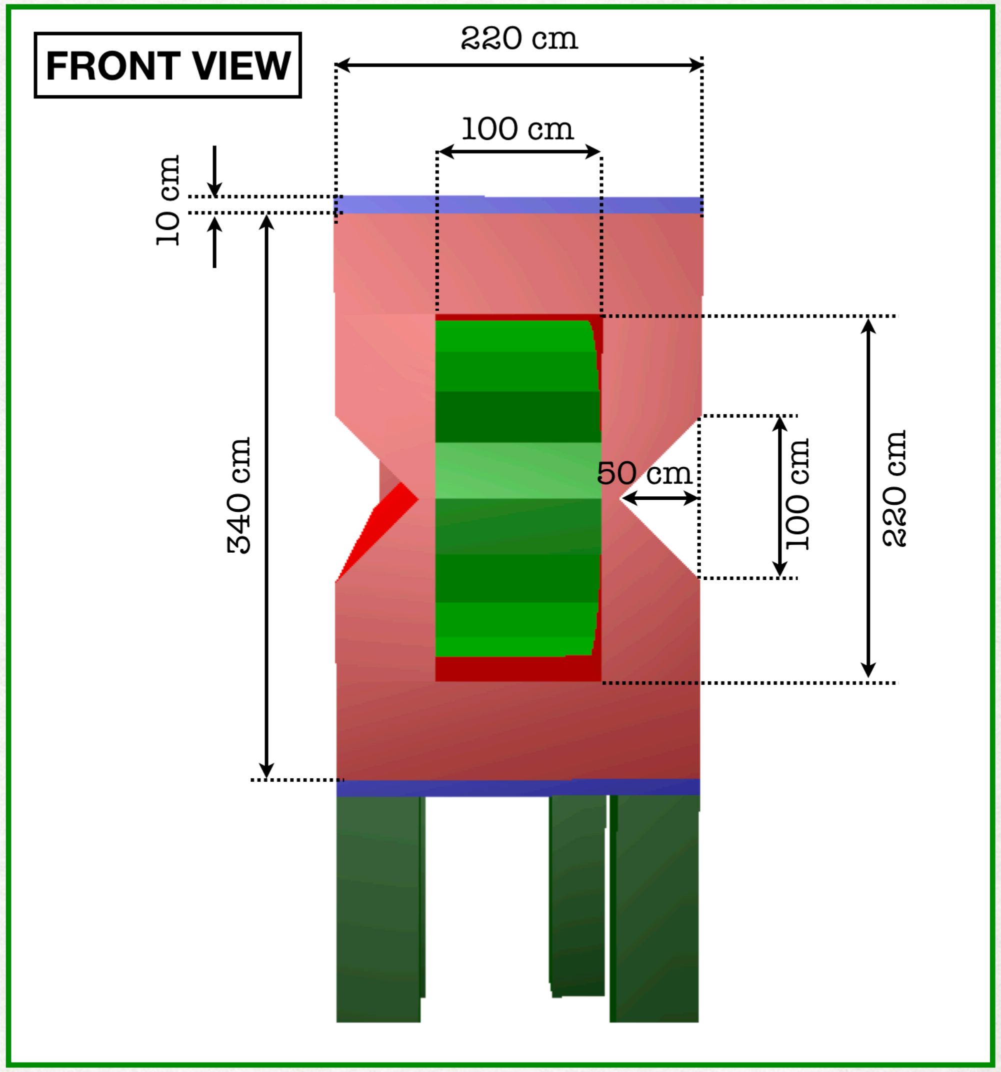
- High energy beam dump:
  → LDM-electron scattering is highly peaked in the forward direction



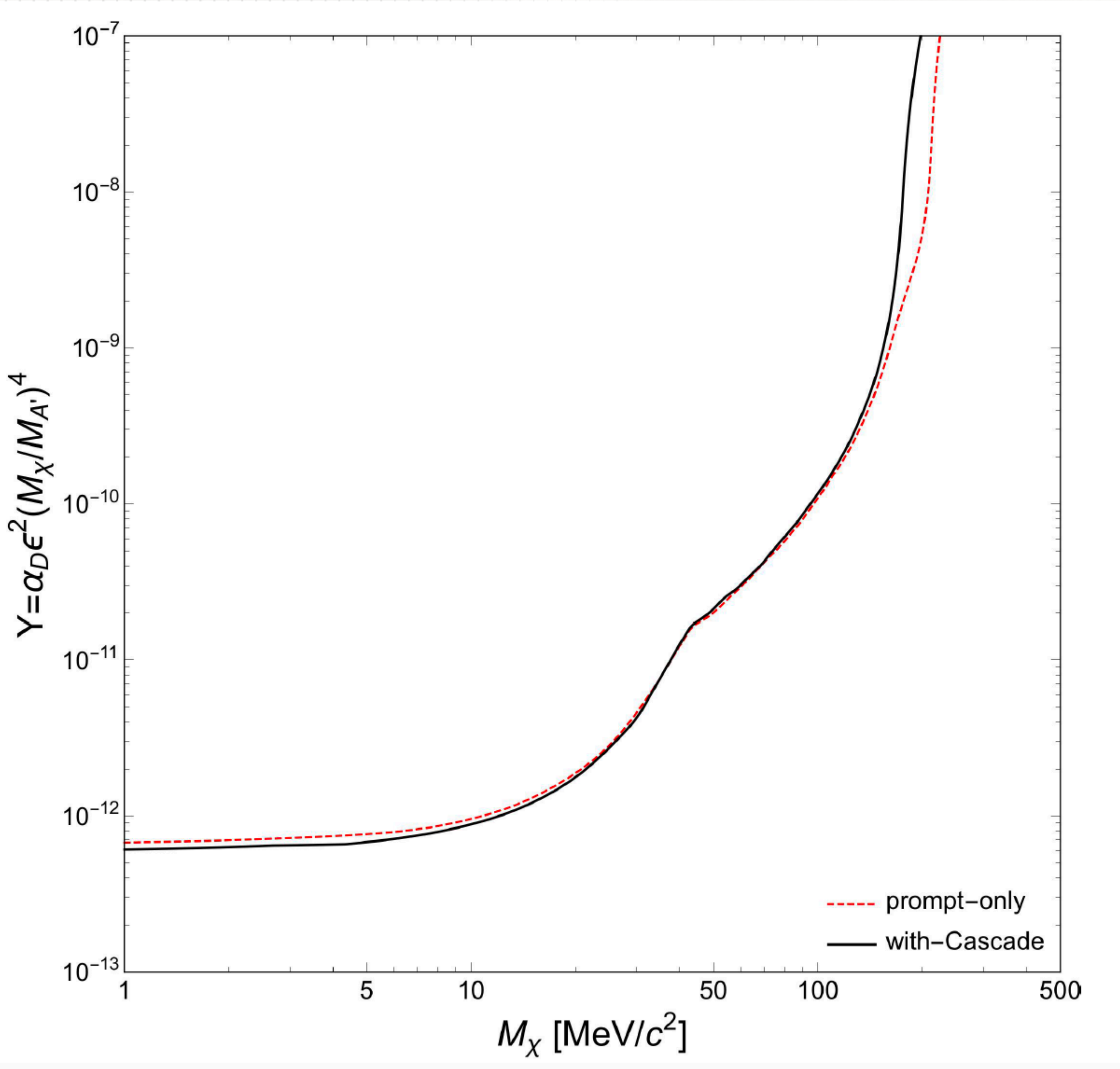


NEUTRINO DETECTOR





MESON DECAYS - CASCADE EFFECTS



Secondary production **modestly affects** dark matter yields from pion decays (10-40%) and it **is neglegible** for the eta case.

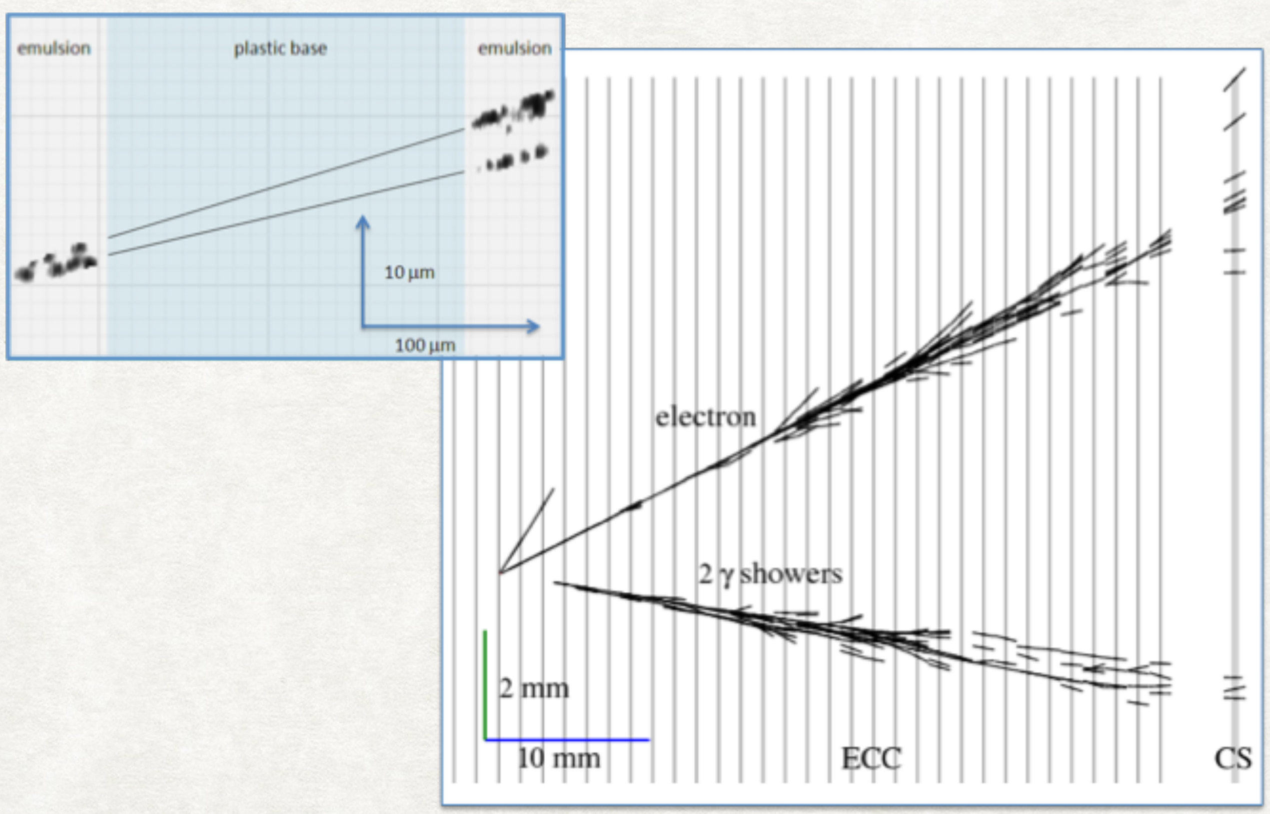
- In general, secondary production within the thick target greatly affects particle multiplicities *[H. Dijkstra, T. Ruf, SHiP-NOTE-2015-009]*
- The spectrum of the secondary particles is softer than the one produced in the prompt collisions.

LEPTON FLAVOR IDENTIFICATION

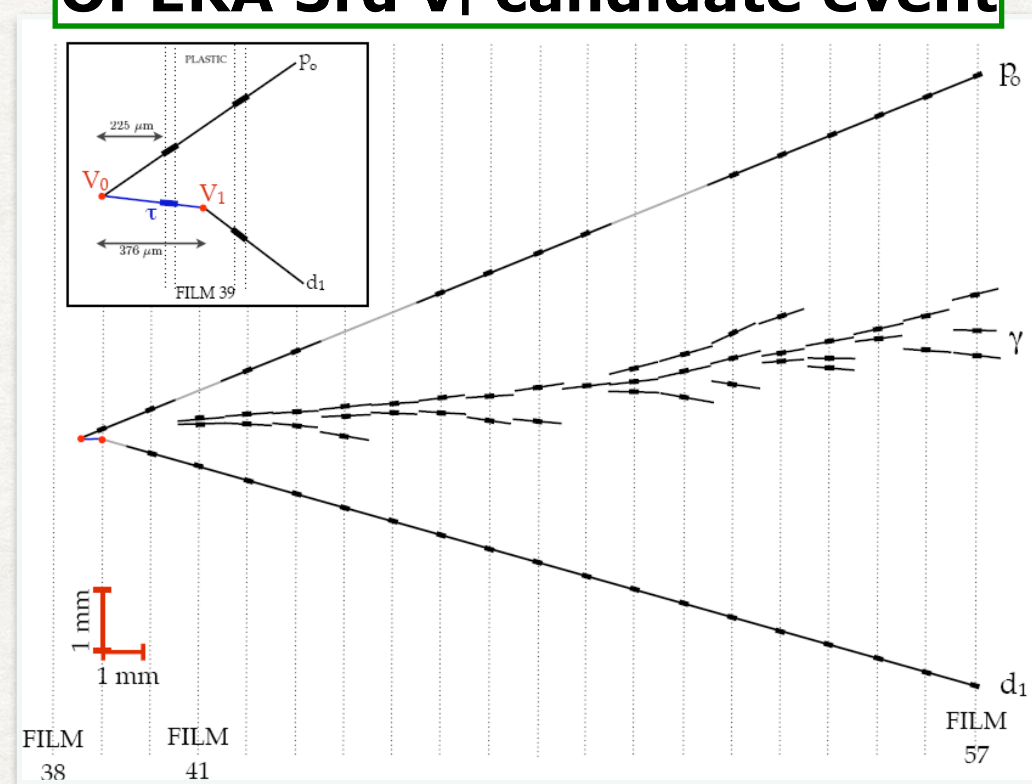
Emulsion Cloud Chamber technique

Lead plates (high density material for the interaction) interleaved with **emulsion films** (tracking devices with **μm resolution**)

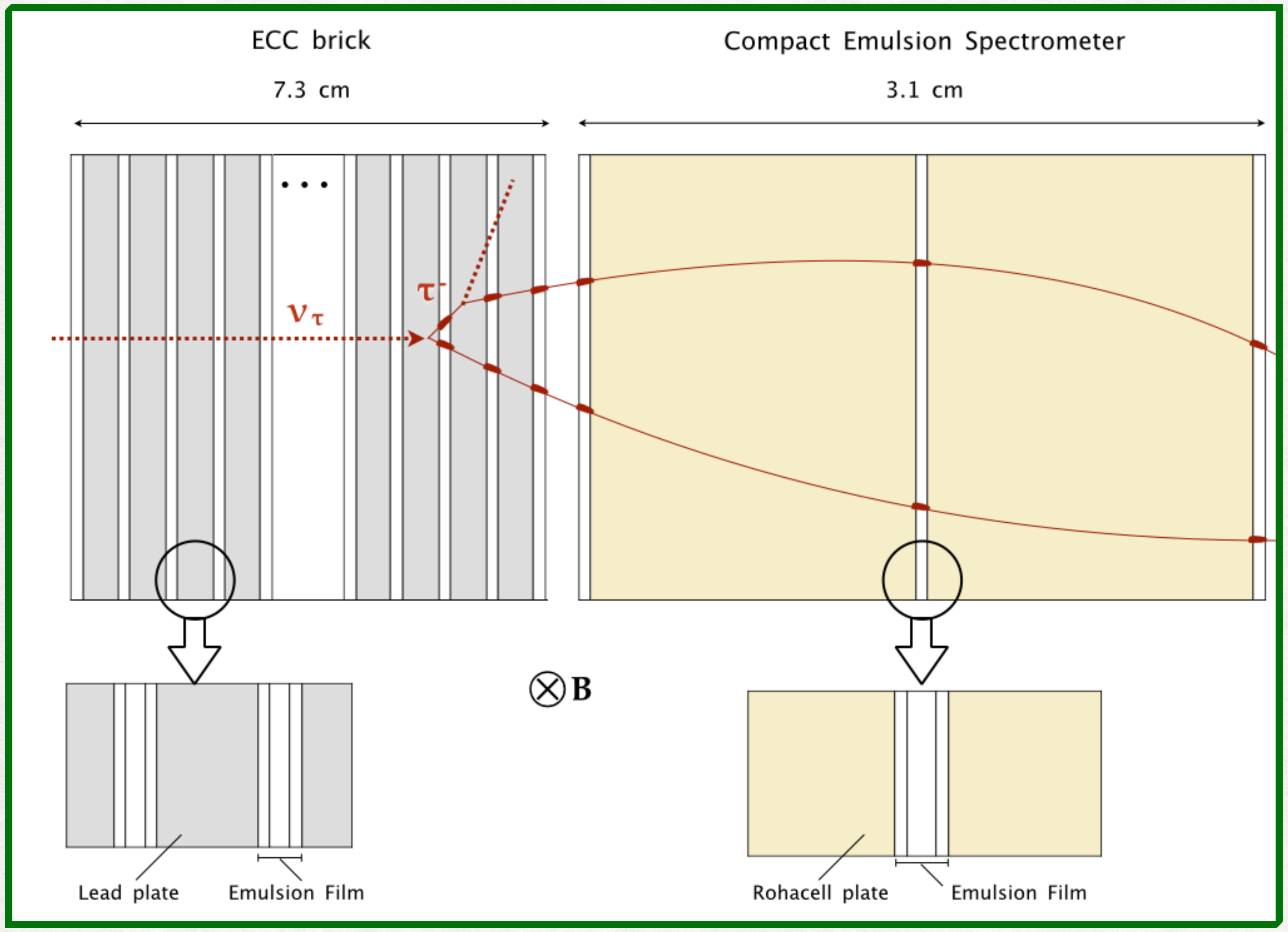
- ***ν_μ identification*:** muon reconstruction in the magnetic spectrometer
- ***ν_e identification:*** electron shower identification in the brick
- ***ν_τ identification:*** disentanglement of τ production and decay vertices



OPERA 3rd ν_τ candidate event



NEUTRINO TARGET



Emulsion Cloud Chamber (ECC) BRICK

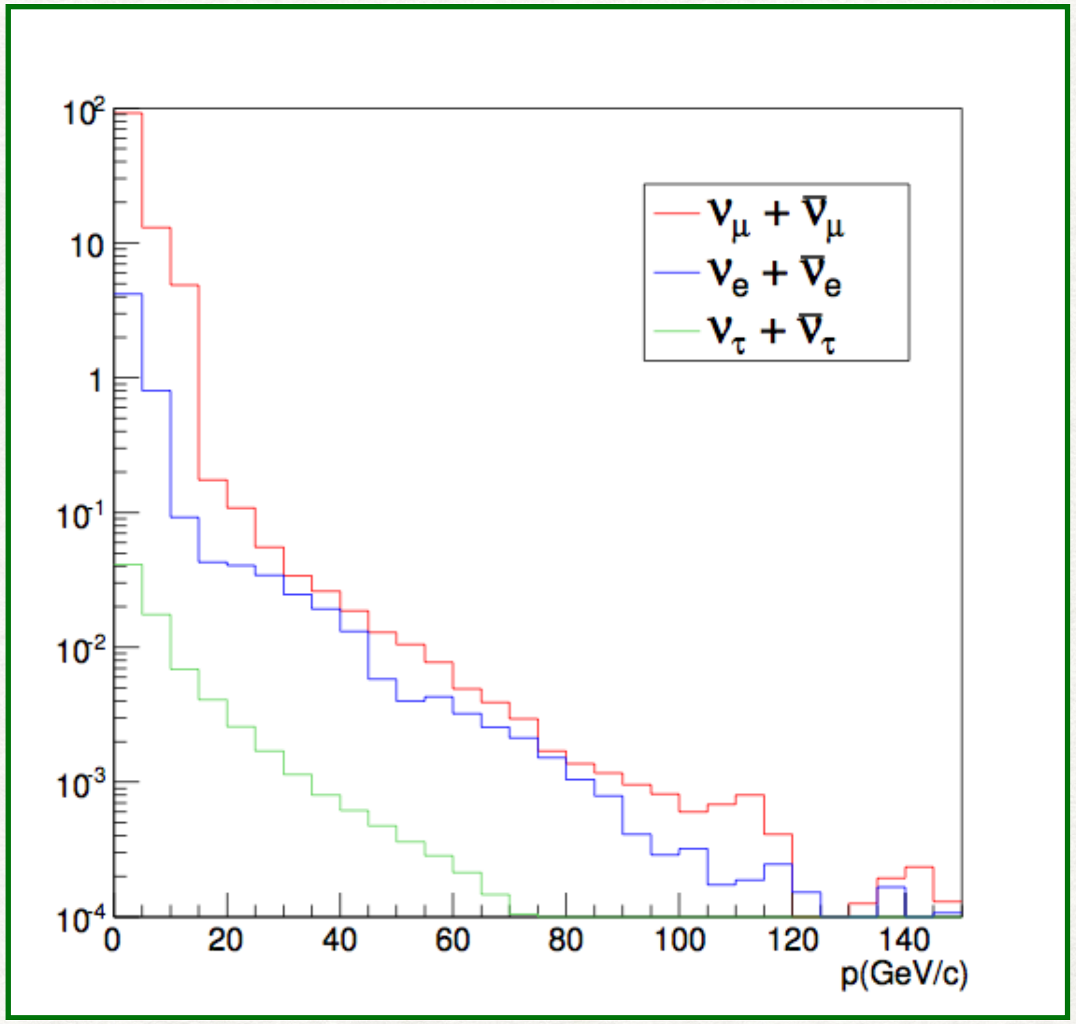
- Passive material (Lead) - 56 layers -
- High resolution tracker (Nuclear emulsions) - 57 films -
- 10 X_0

PERFORMANCES

- Primary and secondary vertex definition with μm resolution
- Momentum measurement by Multiple Coulomb Scattering - largely exploited in the OPERA experiment -
- Electron identification: shower ID through calorimetric technique

NEUTRINO PHYSICS @SHiP

- High neutrino flux expected
- Unique possibility of performing studies of ν_μ, ν_e, ν_τ



- Energy spectrum of different neutrino flavors @beam dump

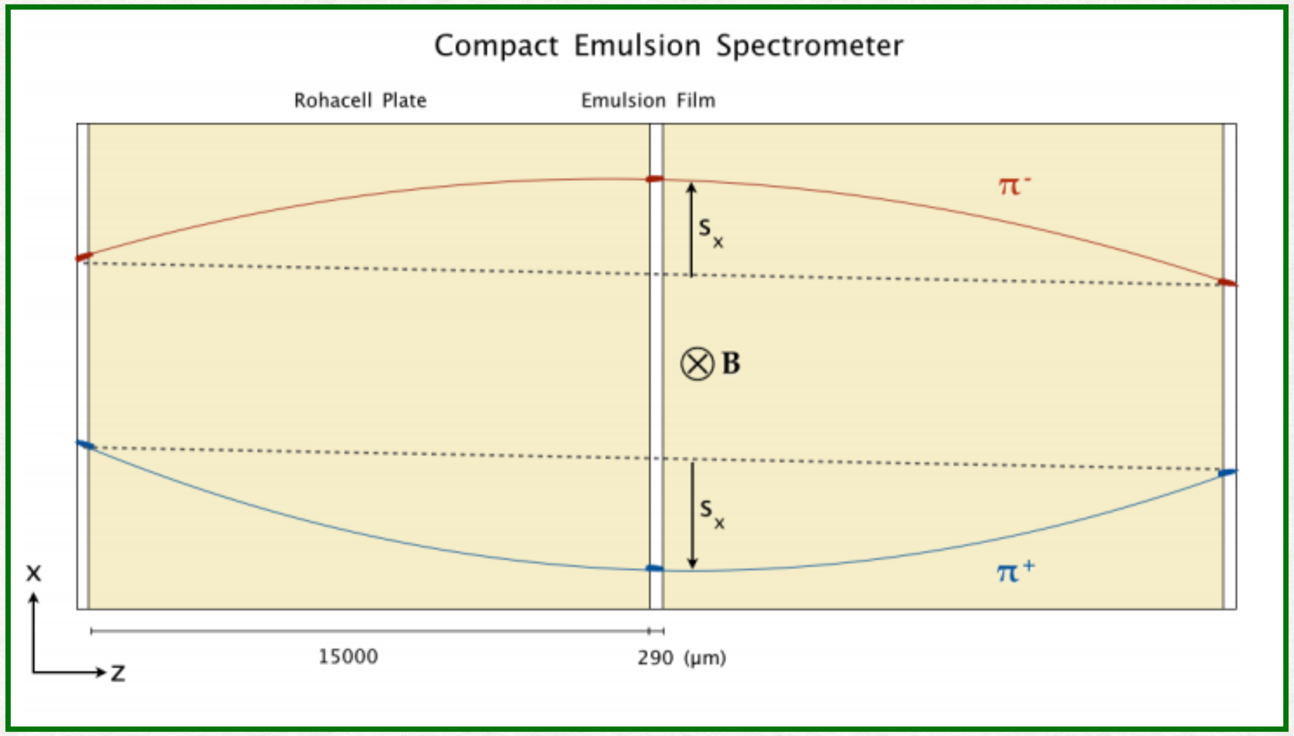
ν_τ/ANTI-ν_τ SEPARATION

REQUIREMENTS

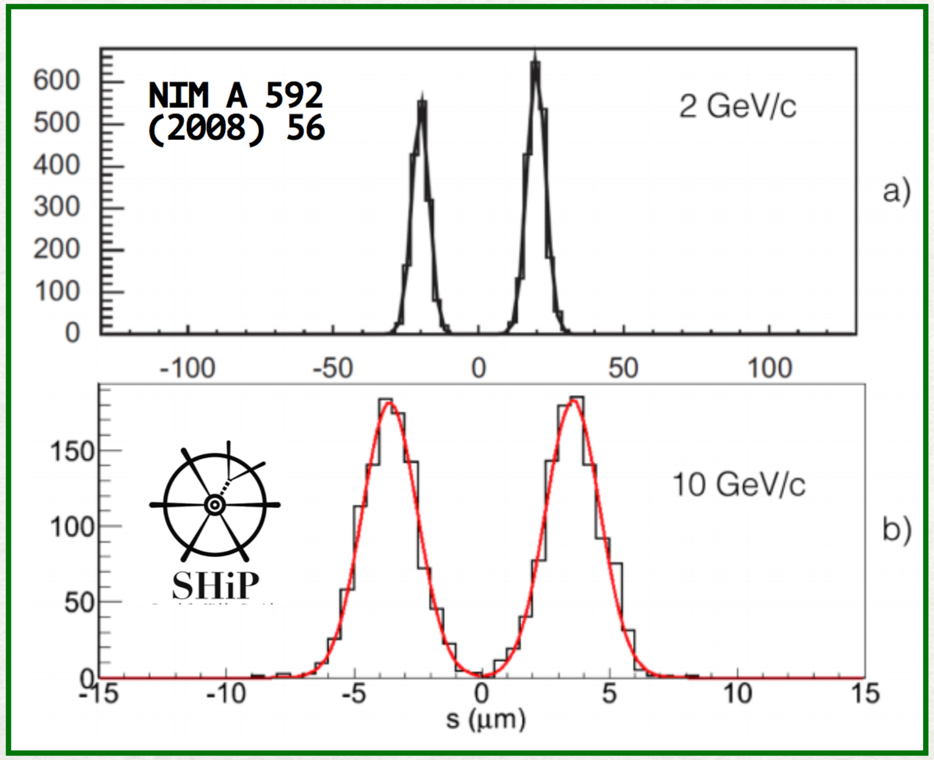
- Electric charge measurement of τ lepton decay products
- Key role for $\nu_\tau/\bar{\nu}_\tau$ separation in the $\tau \rightarrow h$ decay channel
- Momentum measurement

LAYOUT

- 3 OPERA-like emulsion films
- 2 Air gaps
- 1.2 Tesla magnetic field



Charge measured from the curvature of the track with the **sagitta** method



PERFORMANCES

- Sign of the **electric charge** can be determined with better than 3 standard deviation level up to 12 GeV
- The **momentum** of the track can be estimated from the sagitta
- $\Delta p/p < 20\%$ up to 12 GeV/c

ν_τ PHYSICS

- ν_τ and anti-ν_τ produced in the leptonic decay of a D^-_s meson into τ^- and anti-ν_τ, and the subsequent decay of the τ^- into a ν_τ
- Number of ν_τ and anti-ν_τ produced in the beam dump

$$N_{\nu_\tau+\bar{\nu}_\tau} = 4N_p\frac{\sigma_{c\bar{c}}}{\sigma_{pN}} f_{D_s} Br(D_s \to \tau) = 3.26 \times 10^{-5} N_p = 6.5 \times 10^{15}$$

- Main background source: charm production in ν_μ^{CC} (anti-ν_μ^{CC}) and ν_e^{CC} (anti-ν_e^{CC}) interactions, when the primary lepton is not identified

- Geometrical, location and decay search efficiencies considered
- Expectations in 5 years run (2×10^{20}pot)

SIGNAL EXPECTATION

BACKGROUND

R = S/B RATIO

decay channel	ν_τ N^{exp}	ν_τ N^{bg}	ν_τ R	$\bar{\nu}_\tau$ N^{exp}	$\bar{\nu}_\tau$ N^{bg}	$\bar{\nu}_\tau$ R
$\tau \to \mu$	570	30	19	290	140	2
$\tau \to h$	990	80	12	500	380	1.3
$\tau \to 3h$	210	30	7	110	140	0.8
total	1770	140	13	900	660	1.4

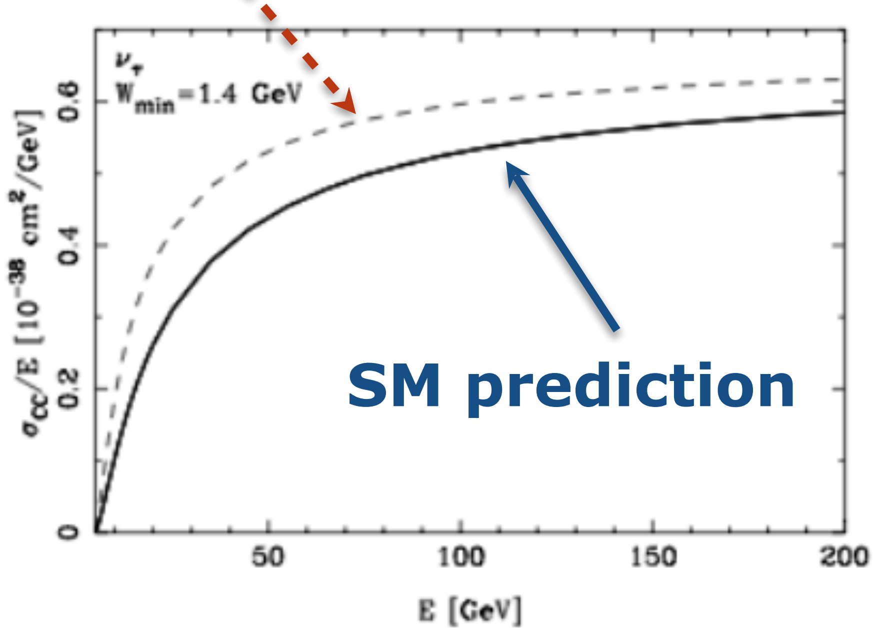
STRUCTURE FUNCTIONS

First evaluation of F_4 and F_5, not accessible with other neutrinos

$$\frac{d^2\sigma^{\nu(\bar{\nu})}}{dxdy} = \frac{G_F^2 M E_\nu}{\pi(1+Q^2/M_W^2)^2}\Bigg(\Big(y^2 x + \frac{m_\tau^2 y}{2E_\nu M}\Big)F_1 + \Big[\Big(1 - \frac{m_\tau^2}{4E_\nu^2}\Big) - \Big(1 + \frac{Mx}{2E_\nu}\Big)\Big] F_2 \pm \Big[xy\Big(1-\frac{y}{2}\Big) - \frac{m_\tau^2 y}{4E_\nu M}\Big] F_3 + \frac{m_\tau^2(m_\tau^2+Q^2)}{4E_\nu^2 M^2 x} F_4 - \frac{m_\tau^2}{E_\nu M} F_5\Bigg),$$

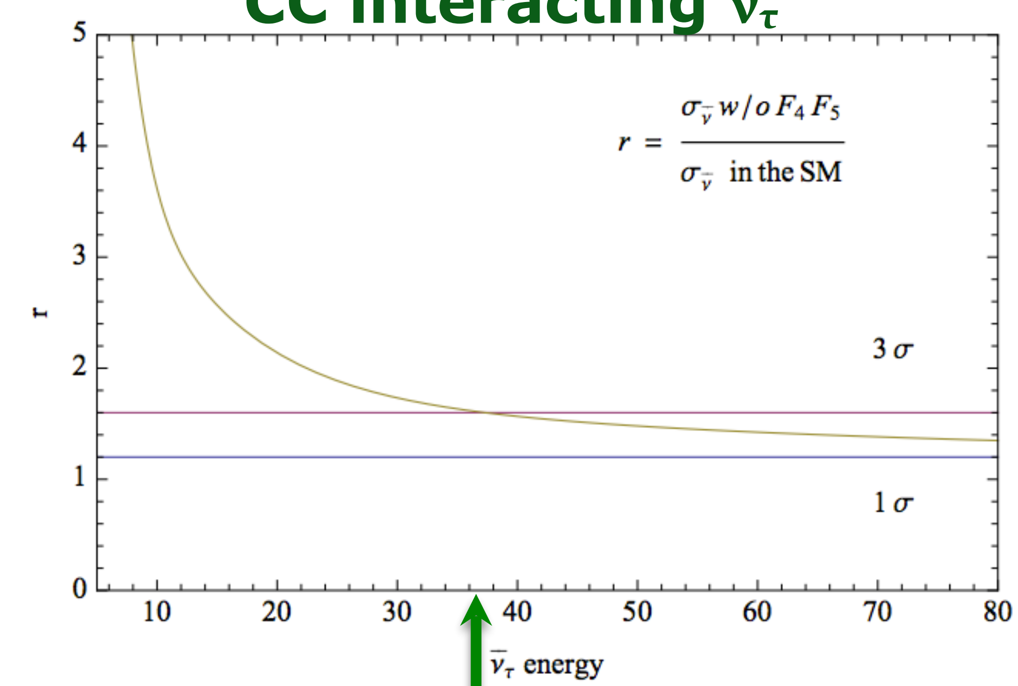
r = ratio between the cross sections in the two hypotheses

$F_4 = F_5 = 0$



ν_τ CC DIS cross-section

CC interacting ν_τ

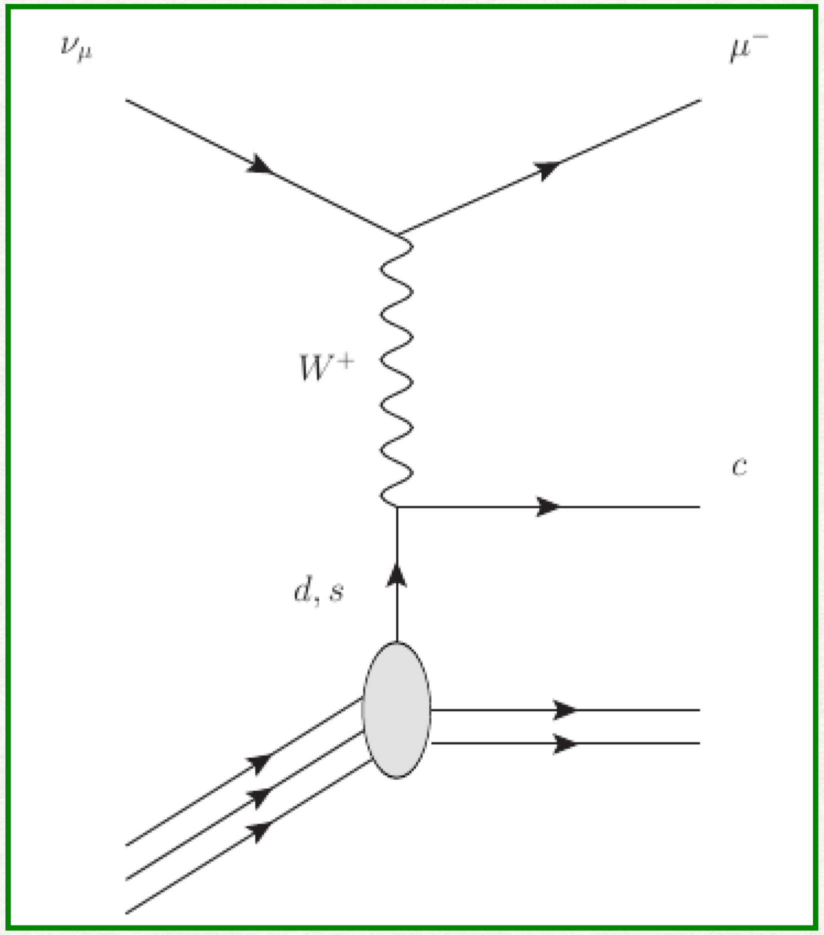


$E(\nu_\tau) < 38$ GeV

(~300 events expected)

CHARM PHYSICS @SHiP

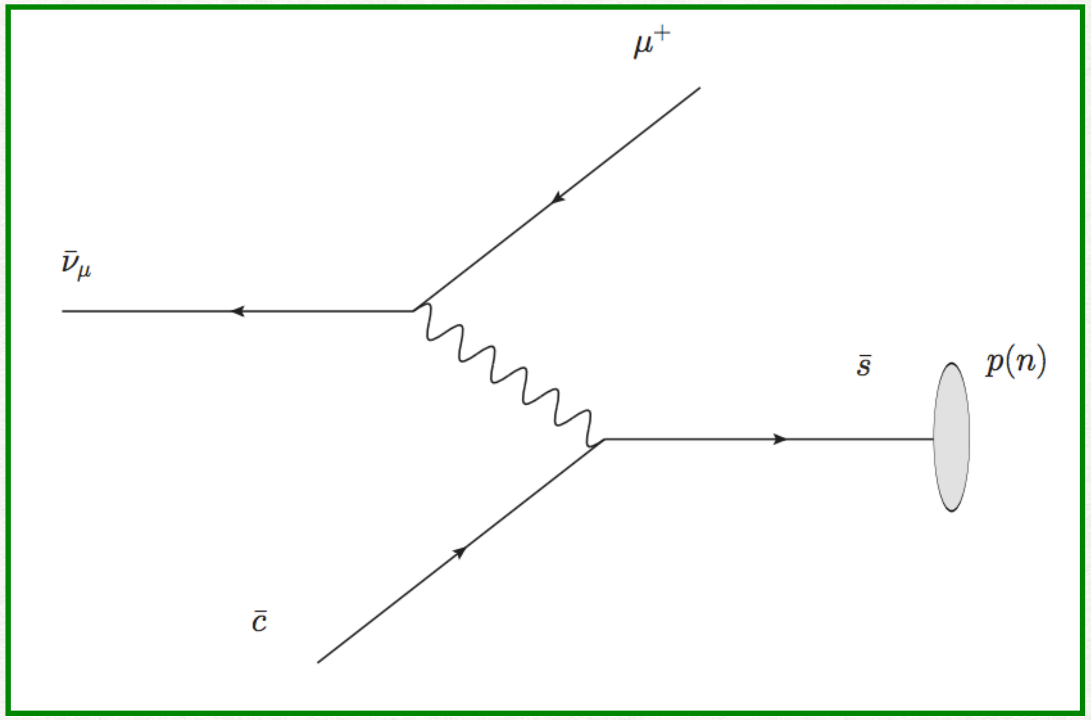
- Large **charm production** in ν_μCC and ν_eCC interactions
- Process sensitive to **strange quark** content of the nucleon



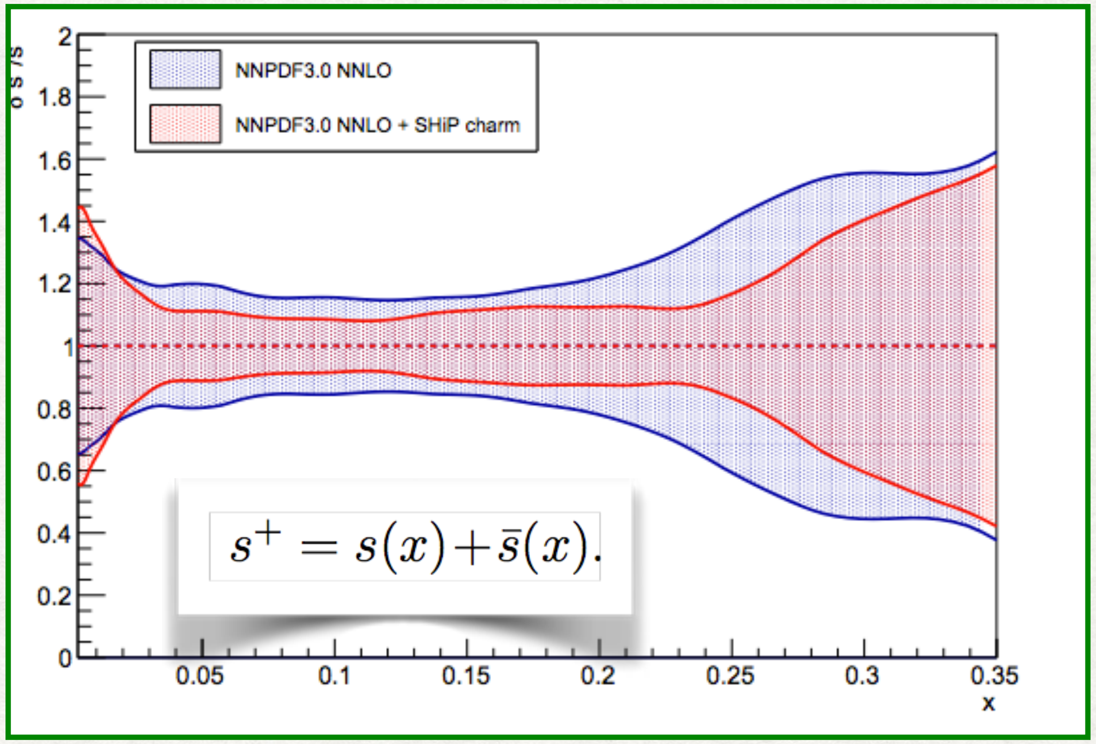
- Charm production with electronic detectors tagged by di-muon events (high energy cut to reduce background)
- **Nuclear emulsion** technique: charmed hadron identification through the observation of its decay
- Loose kinematical cuts → good sensitivity to the **slow-rescaling** threshold behavior and to the charm quark mass

STRANGE QUARK NUCLEON CONTENT

- Charmed hadron production in anti-neutrino interactions selects anti-strange quark in the nucleon



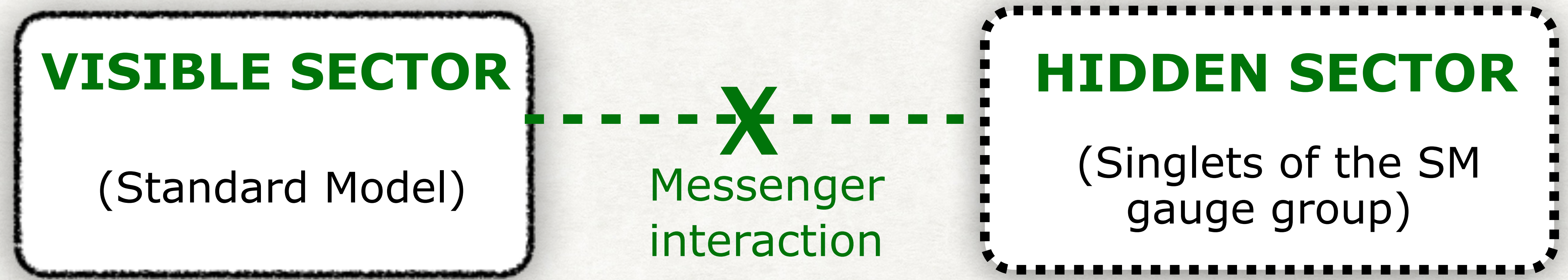
- Improvement achieved on s^+/s^- versus x
- Significant gain with SHIP data (factor 2) obtained in the x range between 0.03 and 0.35



Observed anti-ν in CHORUS ~32
in NuTeV ~1400
Expected in SHIP ~ 27 000

HIDDEN SECTOR AND NEUTRINOS

- Hidden Sector accessible to **intensity frontier** experiments via sufficiently light particles, coupled to the Standard Model sector via renormalizable "**portals**"



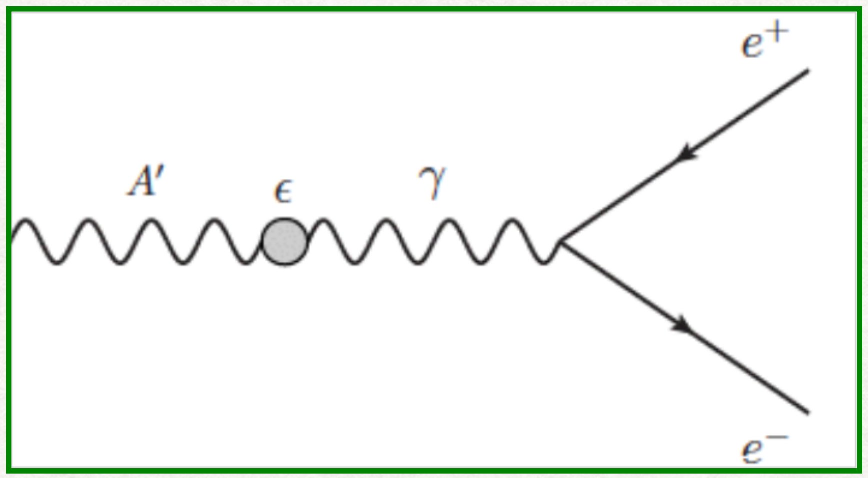
- **SHiP**: new fixed target facility at the intensity frontier to explore Hidden Sector
- Neutrino physics
- Light Dark Matter search

> - Several **portals** to the HS: scalar portal, neutrino portal, vector portal, SUSY…
> - All of these can be probed at the **intensity frontier** with **SHiP**!

STANDARD MODEL PORTALS

VECTOR PORTAL

- Kinetic mixing with the **dark photon**
- Possible dark matter candidate



Production of the dark photon at CERN SPS

- proton bremsstrahlung
- decay of pseudo-scalar mesons
- limits on mean life from BBN $\tau_\gamma < 0.1$s

Dark photons decay

- e^+e^-, $\mu^+\mu^-$, $q\bar{q}$
- light dark matter $\chi\bar{\chi}$

HIGGS PORTAL

- **Scalar singlet**
- Mixing with the SM Higgs

$$\begin{pmatrix} H \\ h \end{pmatrix} = \begin{pmatrix} \cos\rho & -\sin\rho \\ \sin\rho & \cos\rho \end{pmatrix} \begin{pmatrix} \phi_0' \\ S' \end{pmatrix}$$

Main production mechanism

- Rare decay of B mediated by light scalar φ

Decay channels

- e^+e^-, $\mu^+\mu^-$

STANDARD MODEL PORTALS

AXION PORTAL

- **Pseudo-scalar** particles (pNGB, Axions, ALPs)
- Produced by symmetry breaking at high mass scale *F*
- Interaction proportional to *1/F*
- Mixing with SM particles proportional to m_X/F

Production mechanism

- Mixing with π^0

Decay channels

- e^+e^-, $\mu^+\mu^-$, $q\bar{q}$, $\gamma\gamma$

NEUTRINO PORTAL

- Mixing with **right-handed** neutrino *(details in the following slides)*

SUSY PORTAL

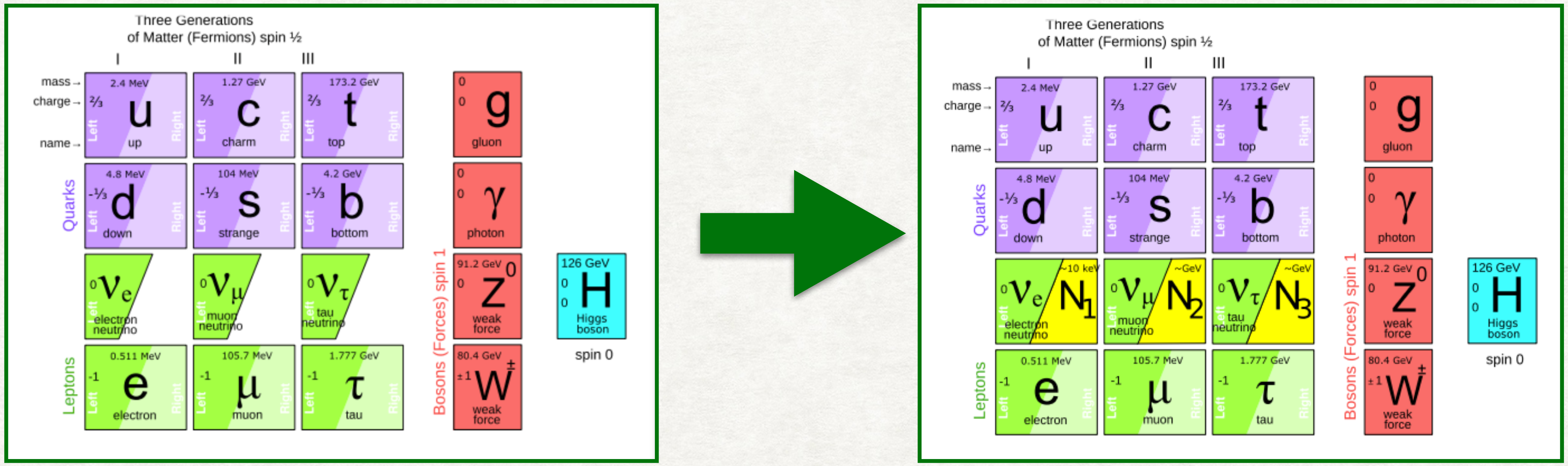
… and possibly higher dimensional operators portals and **Super-Symmetric** portals

(light neutralino, light sgoldstino, …)

NEUTRINO PORTAL

- **νMSM**: **ν-**Minimal Standard Model

3 additional Heavy Neutral Leptons: right-handed Majorana neutrinos



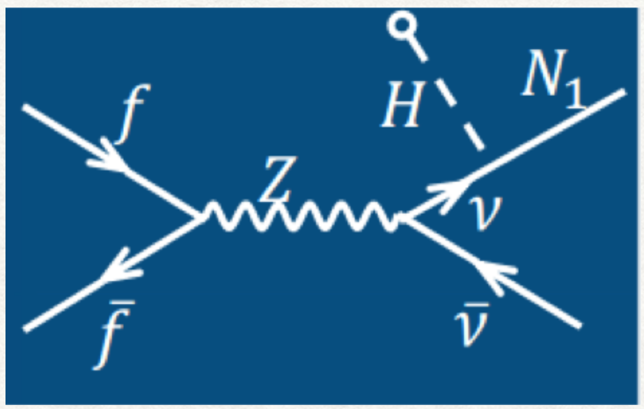
- **N₁** : Dark Matter candidate
- **N₂,₃** : give mass to neutrinos via see-saw mechanism, produce baryon asymmetry

T.Asaka, M.Shaposhnikov PL B620 (2005) 17
M.Shaposhnikov Nucl. Phys. B763 (2007) 49

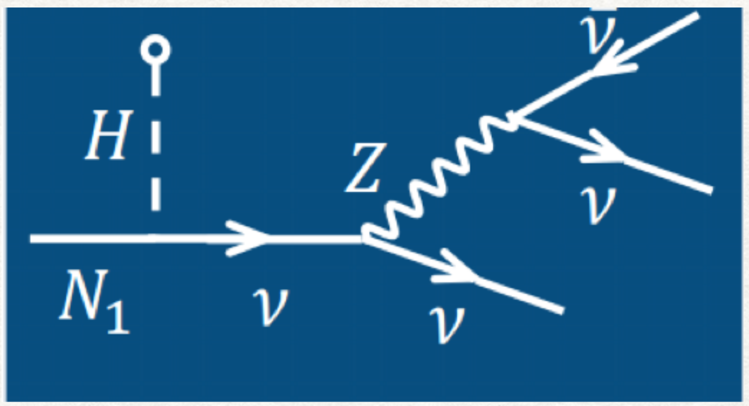
N_1: DARK MATTER CANDIDATE

- Weak coupling with other leptons
- Mass(N_1) ~ 10 KeV
- Enough stable to be a dark matter candidate

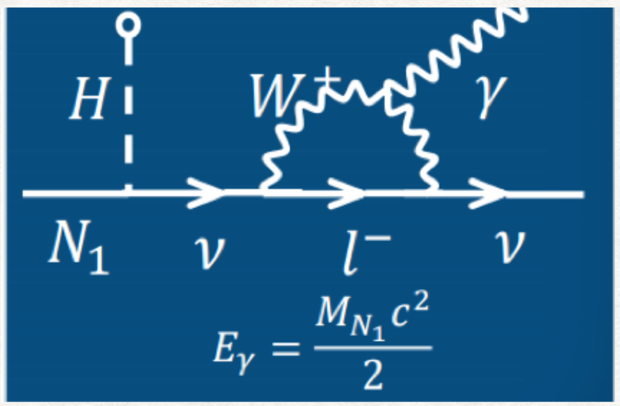
mixing ν-N

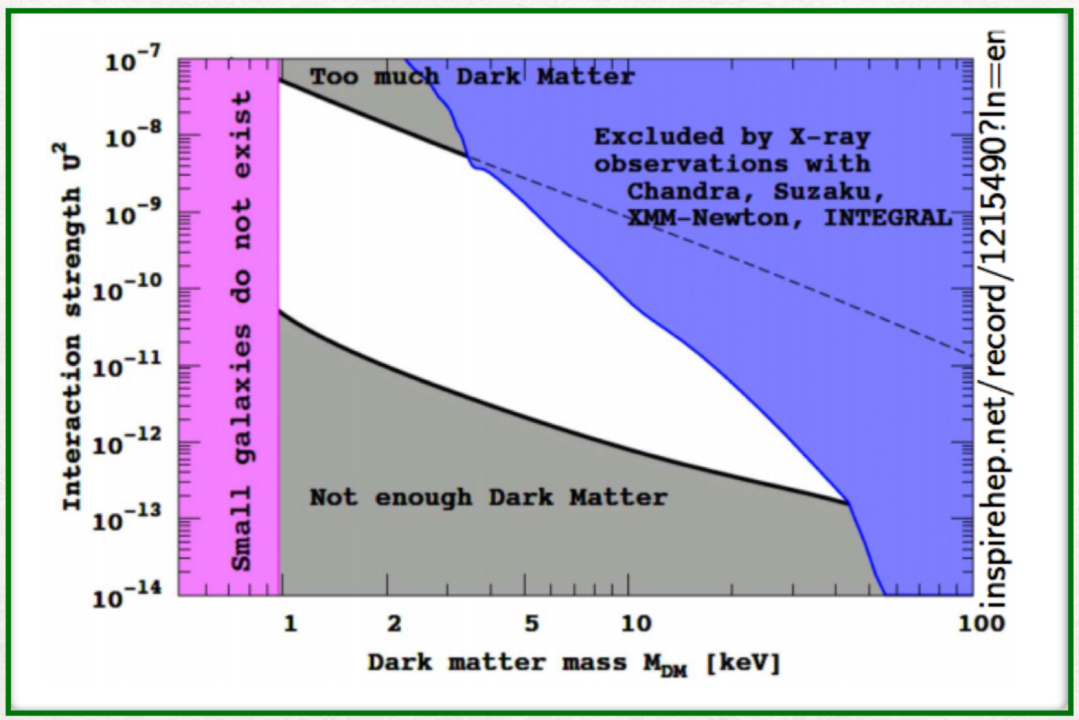


dominant process



subdominant radiative decay





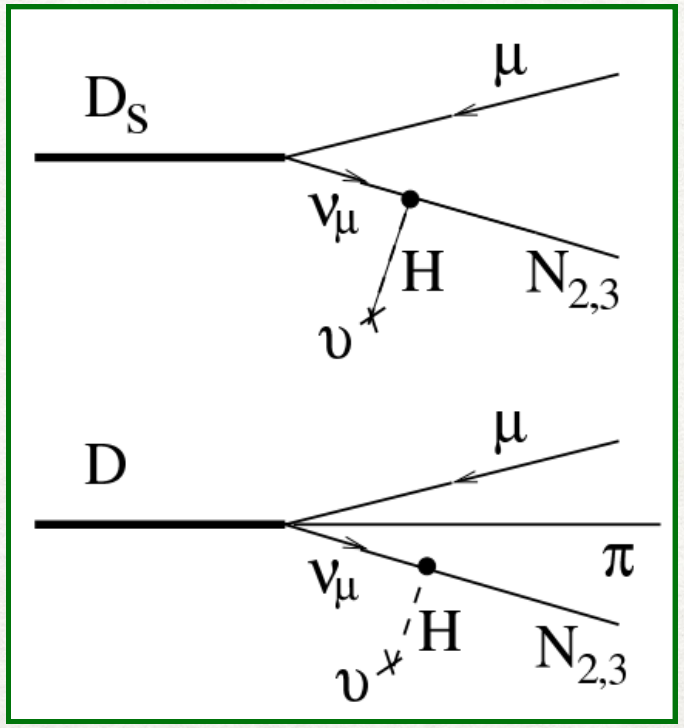
- **GALACTIC HINTS**
- *Astr. Phys. J. 789 (2014) 13, Phys. Rev. Lett. 113 (2014) 251301*
- Not identified line in the X-ray spectrum of Andromeda and Perseus galaxies ($E\gamma$=3.5 keV)

$N_{2,3}$: PRODUCTION AND DECAY

- Mass(N_2) ~ Mass(N_3) ~ few GeV
- Weak mixing with active neutrino
  - ➙ very long lifetimes wrt SM particles >10 μs
  - ➙ flight length ~km

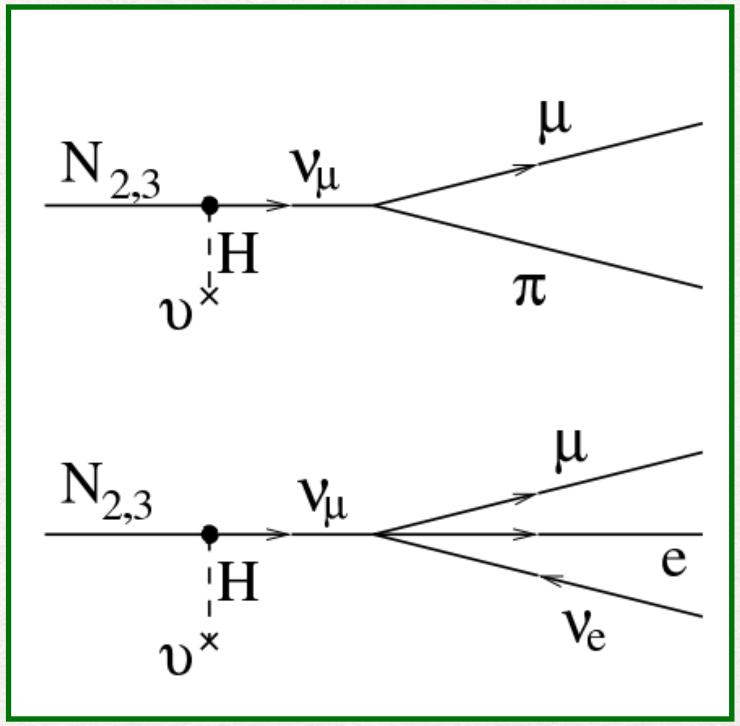
PRODUCTION

- Mixing with active neutrino
- Semi-leptonic decay



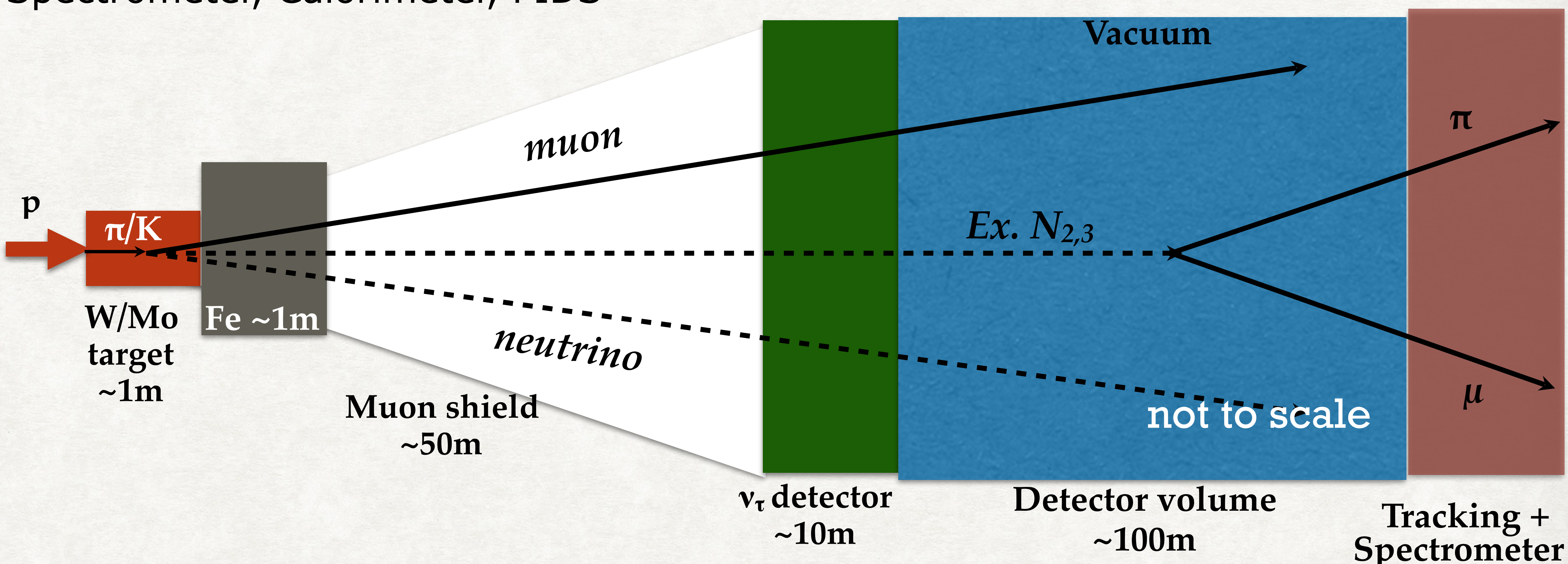
DECAY

- Br(N →μ/e π) ~ 0.1 - 50 %
- Br(N →μ/e ρ) ~ 0.5 - 20%
- Br(N →νμe) ~ 1 - 10%



REQUIREMENTS

- High intensity beam dump experiment ⇒ K, D, B mesons
- Long-lived, weakly interacting particles require:
  - large decay volume
  - shielded from SM particles
- Spectrometer, Calorimeter, PIDS

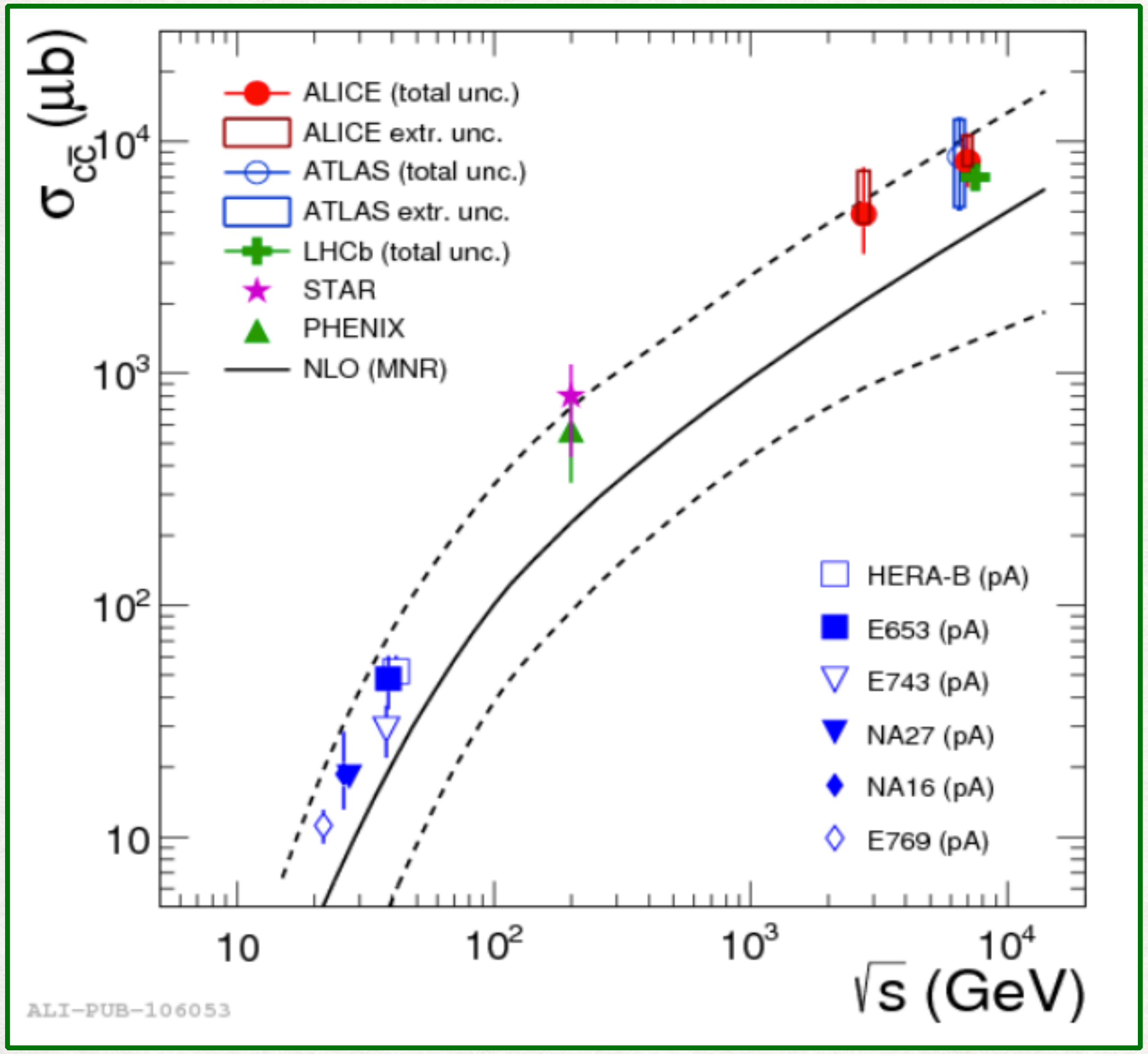


SIGNAL SIGNATURE

- charged tracks forming an isolated vertex inside the fiducial volume acceptance
- Candidate momentum pointing back to the target
- "silent" VETO detectors

SHiP-CHARM PROJECT: Motivation

- Charm production in **proton interactions** and in **hadron cascades** in the SHiP target important for Hidden Sector searches normalization and ν_τ cross-section measurement



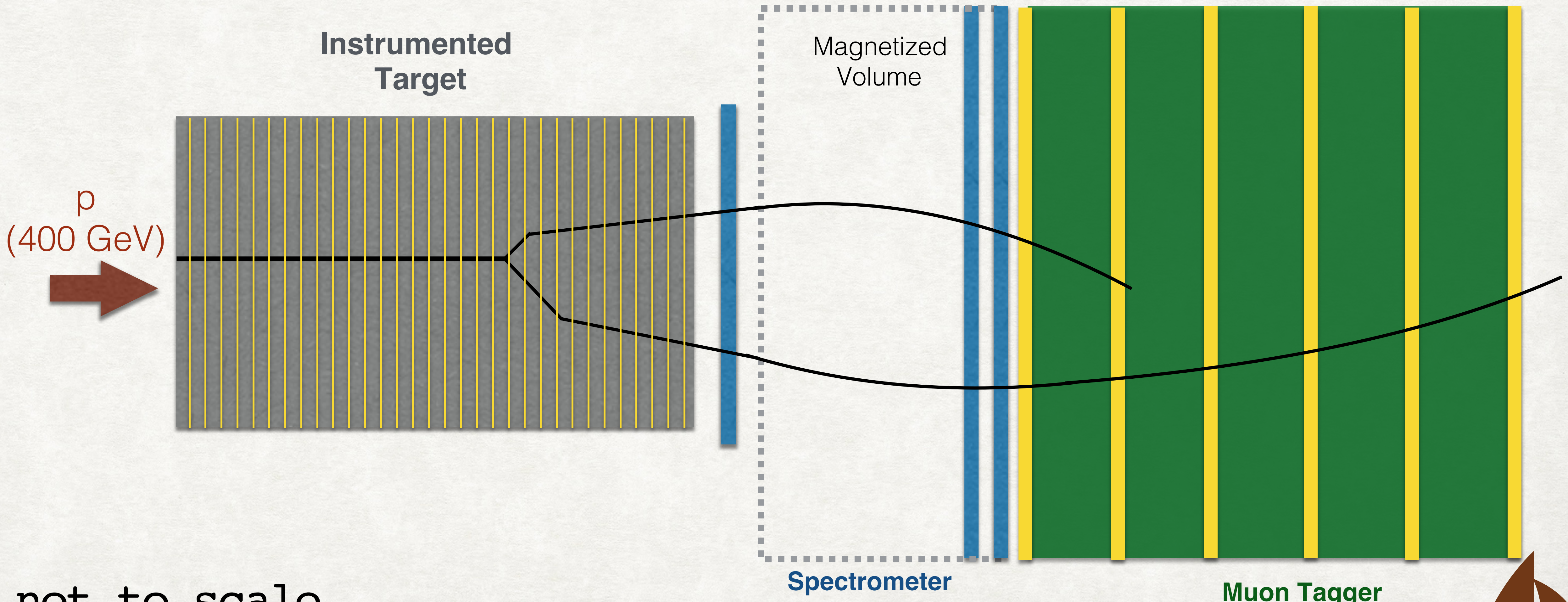
- Inclusive double-charm cross-section measured in NA27 using thin target

	exp NA27
$\sigma[\mu b]$	18.1 ± 1.7

- Missing information: charm production in **hadron cascades**
- Charm yield from cascade expected 2.3 times larger than prompt contribution

SHiP-CHARM PROJECT: Conceptual design

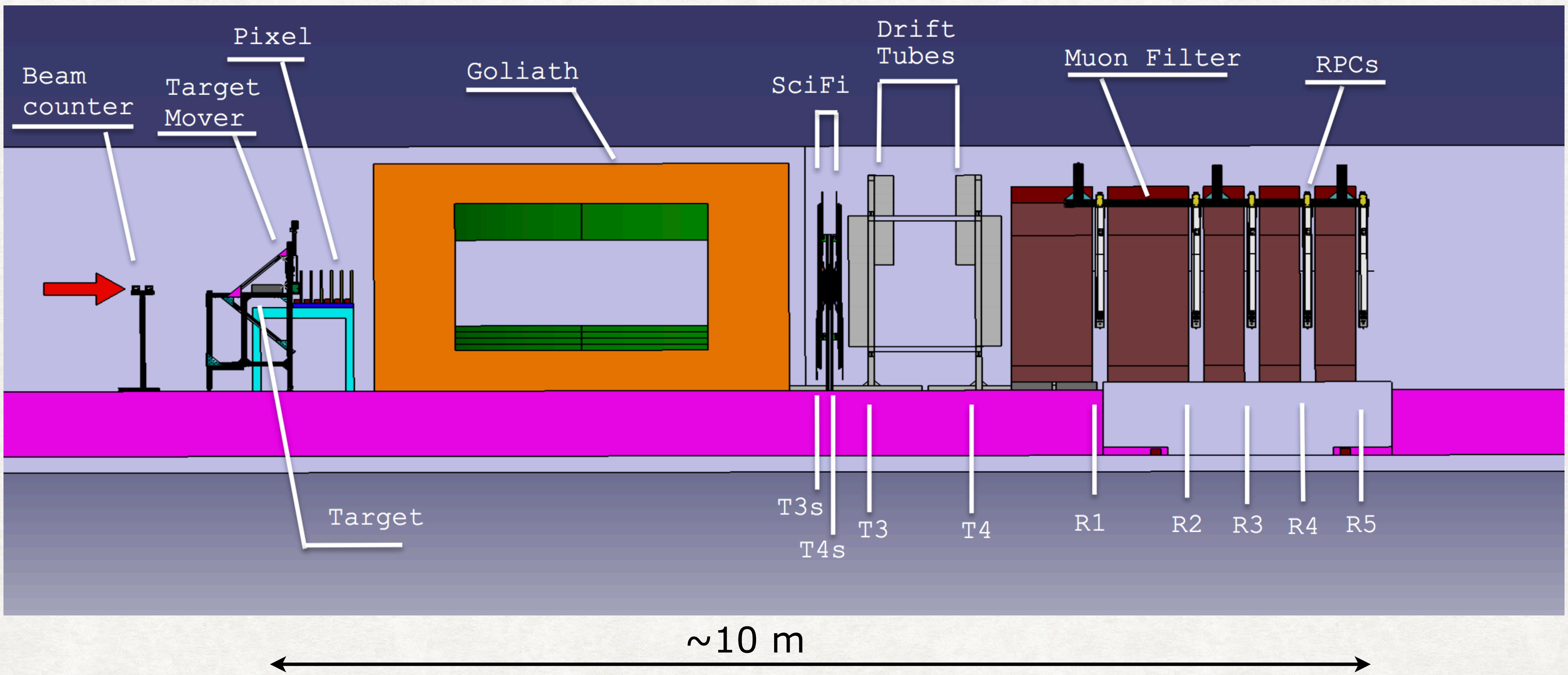
- **Double-differential** cross-section measurement ***($d^2\sigma/dEd\theta$)***
- Proton collisions in Mo/W target instrumented with **nuclear emulsions**
- **Nuclear emulsions** as tracking detector
  - identification of hadronic and leptonic charm decay modes
  - volume of sensitive layers << target volume
- Charm daughters charge and momentum by a dedicated **Spectrometer** based on silicon pixel detectors, Scintillator fibers and drift tubes
- Muon identification with a **Muon Tagger** based on RPC



not to scale

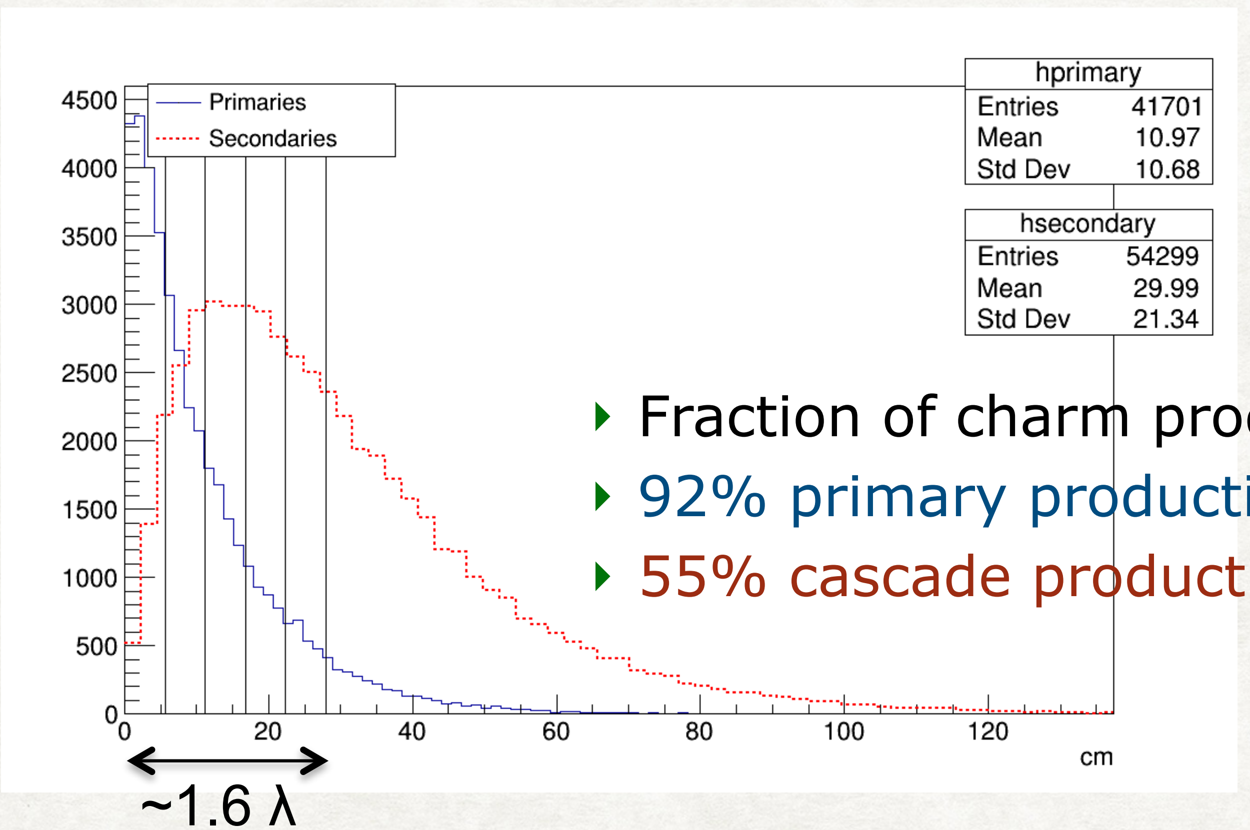
MEASUREMENT IN 2018

- **Lead target**, 12×10 cm² Pb blocks (few cm) interleaved with emulsion to identify charm topology
- **Spectrometer** to measure momentum and charge of the charm daughters
- **Muon tagger** to identify muons

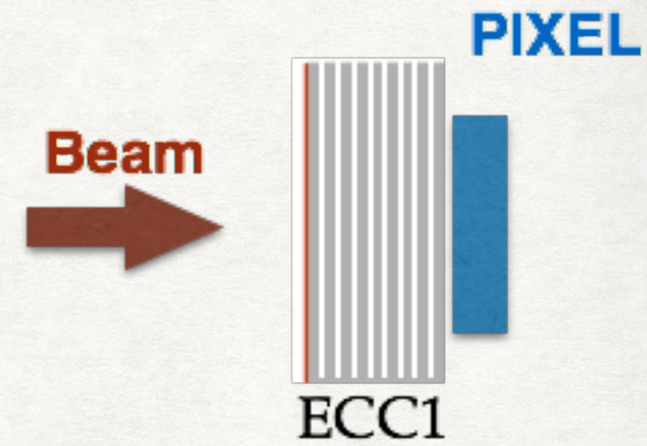


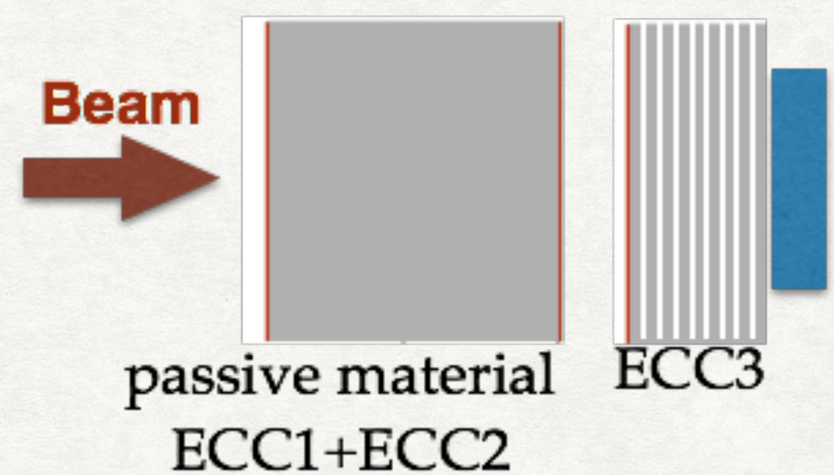
EXPOSURE CONFIGURATION

- Target material: lead
- Instrumentation of ~1.6 λ to study charm production in primary interactions and hadron cascades



- Fraction of charm produced in ~1.6 λ
- 92% primary production
- 55% cascade production

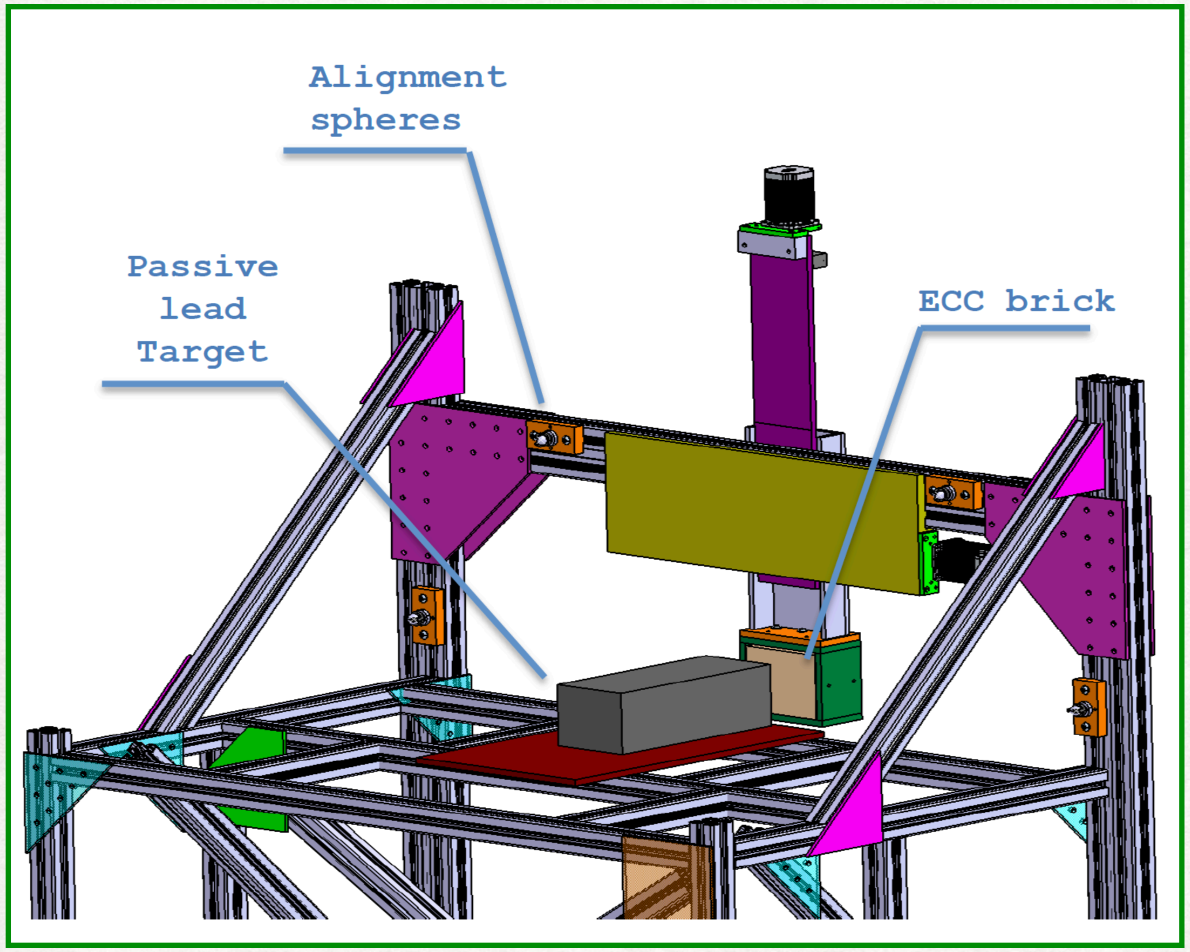




- Instrumentation of ~1.6 λ allows the study of a large fraction of charmed hadrons
- Five Emulsion Cloud Chambers (ECC)
- ECC is the most downstream target part to let charm daughters reach the spectrometer
- Target modules retained upstream of the ECC

ECC TARGET

- Target mover to have protons uniformly distributed on the emulsion films
- Design: shift along y axis during the spill
    - Shift along x axis in the inter-spill



2018 EXPOSURE PLAN

- Maximum track density in emulsion films: 10^3/mm^2
- Emulsion surface available in July 2018: 10 m^2
- ~20 ECC bricks exposed to proton beam with maximum intensity 10^4 pot/spill
- Fully reconstructed charm-pairs: ~150

Full data taking after LS2: ~1000 fully reconstructed charm pairs