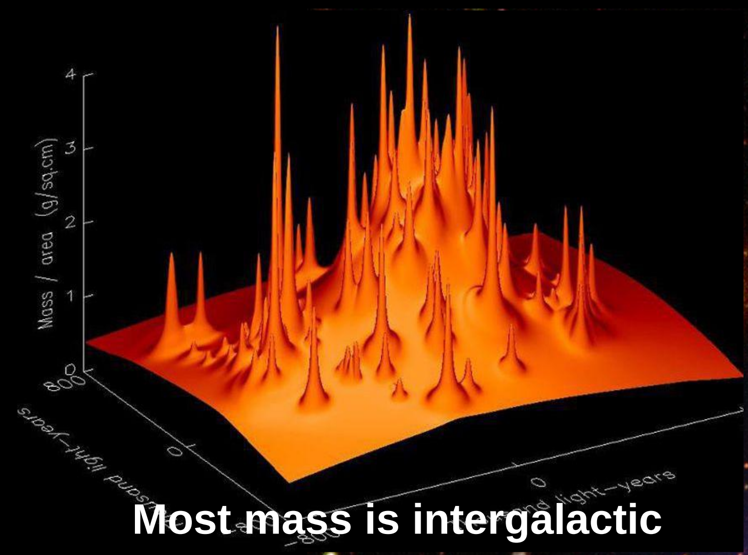
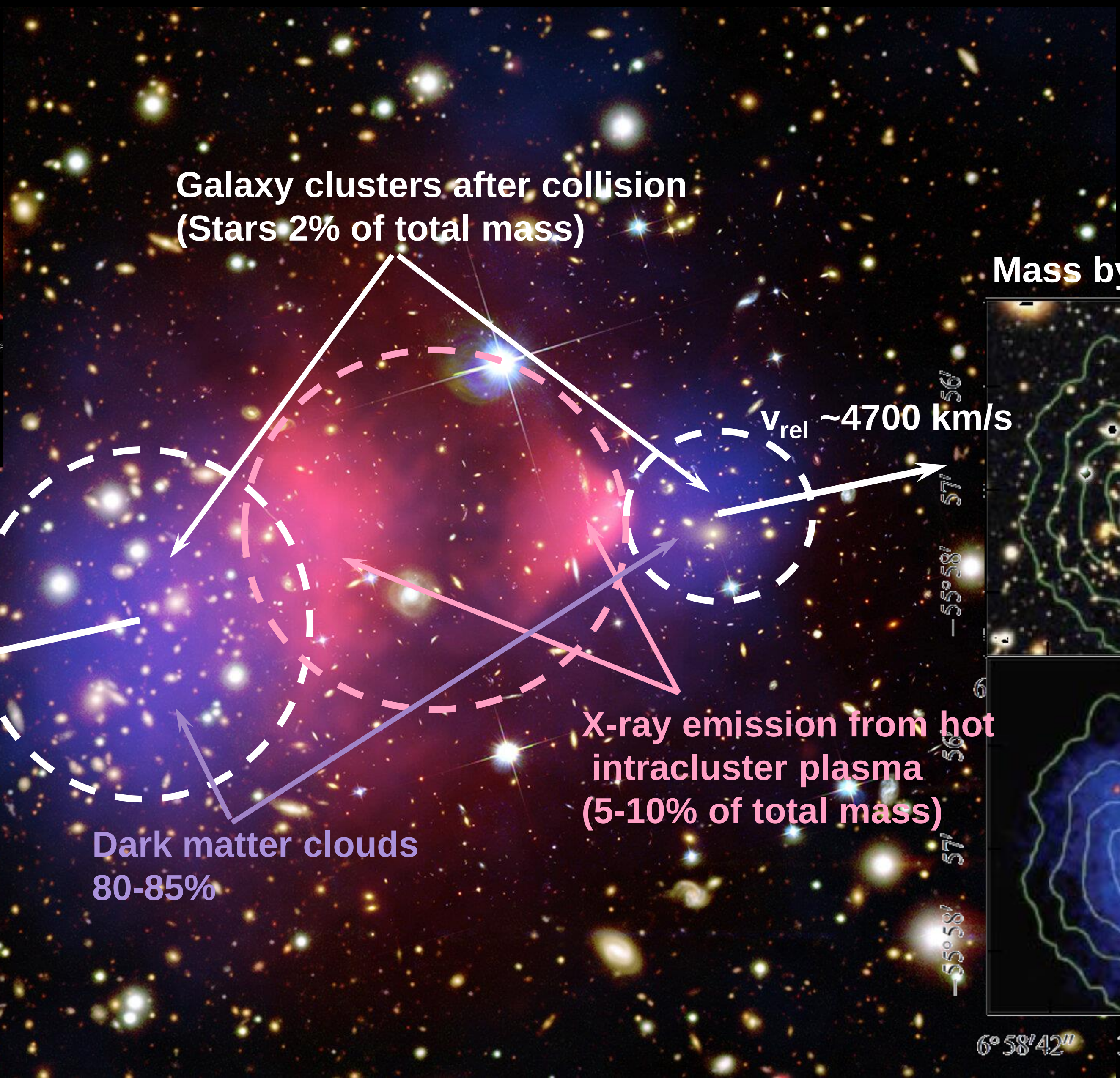
SHiP
Search for Hidden Particles

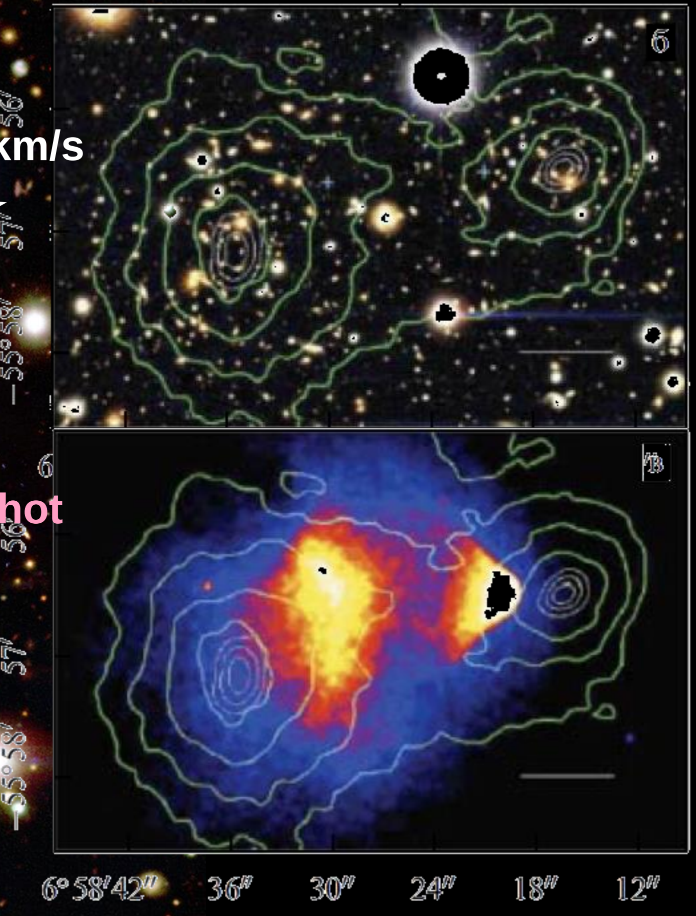
# Target and target complex

## *- The Window to Hidden Sectors! -*

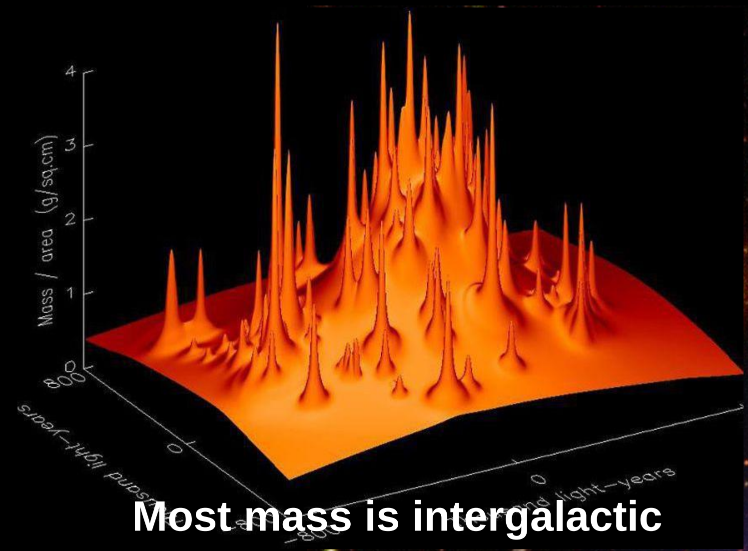
# The game changer on DM (1998 – 100 Myears)

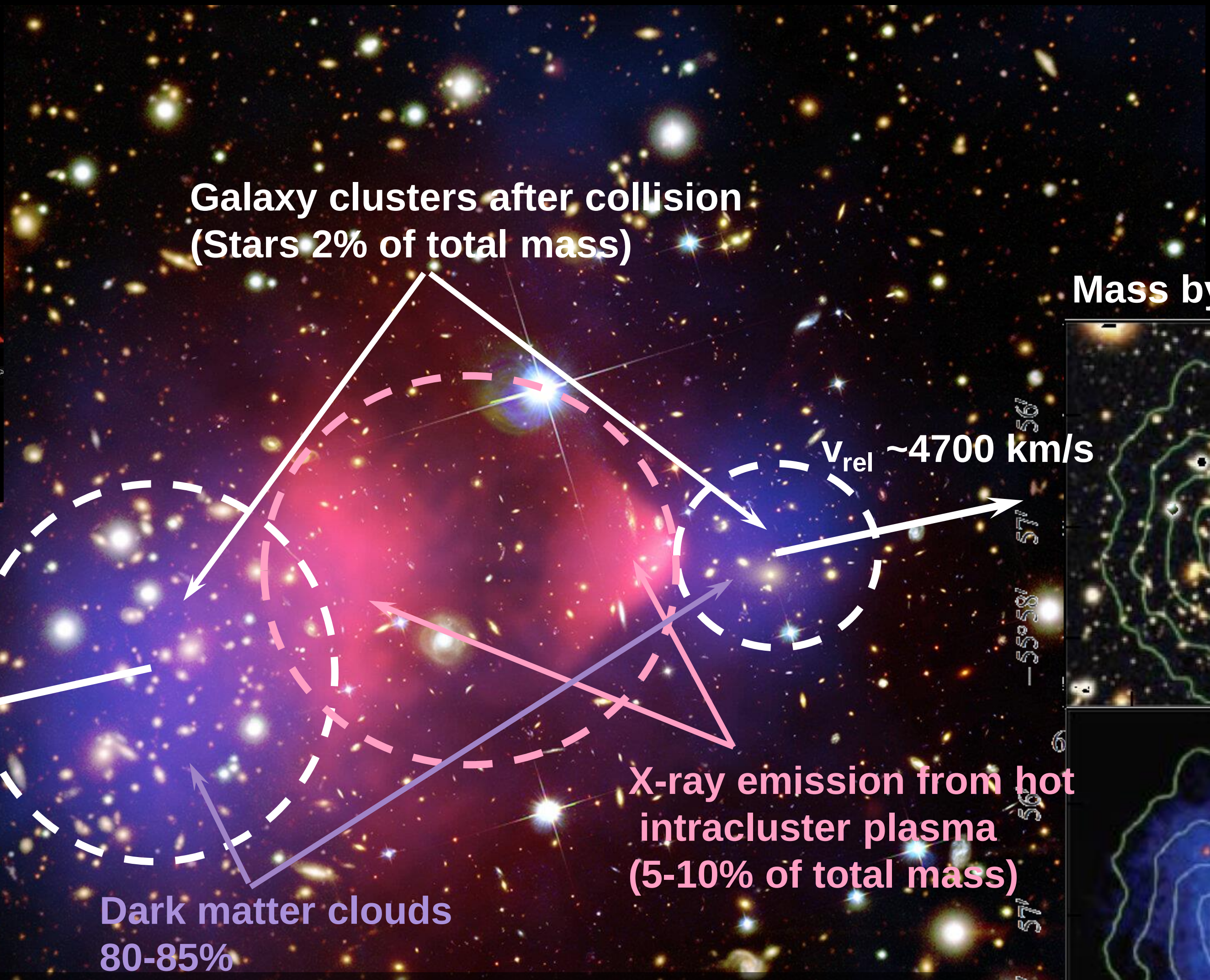


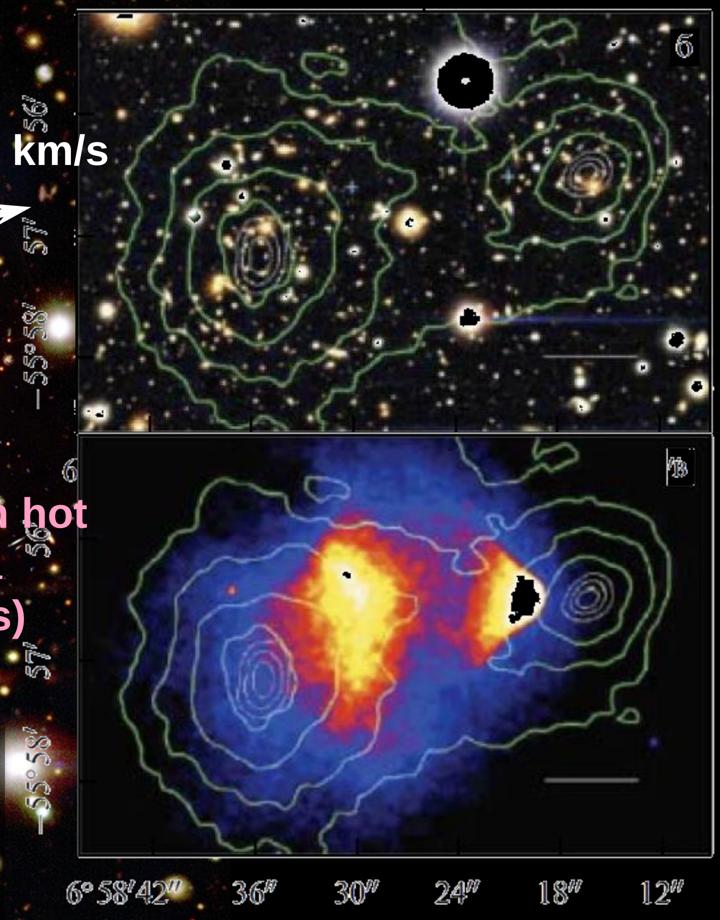



# The game changer on DM (1998 – 100 Myears)



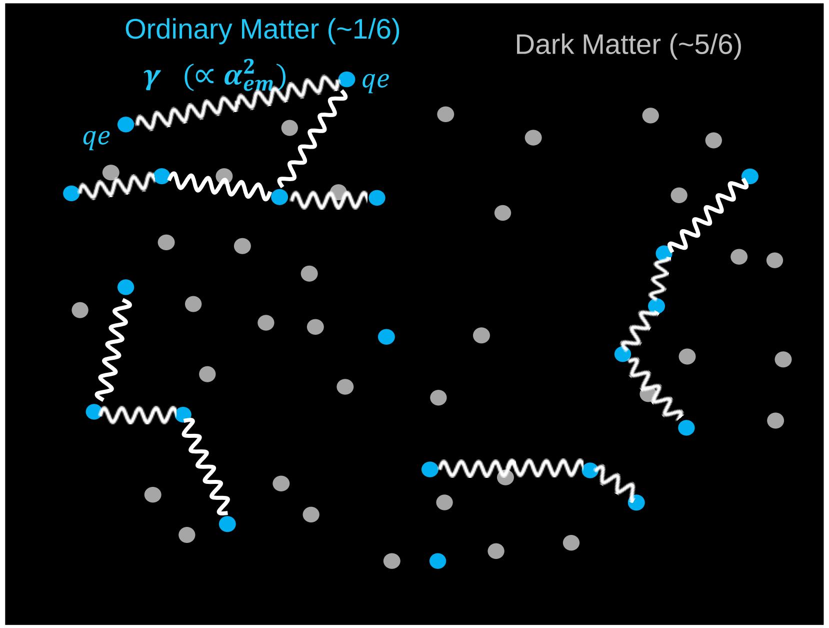



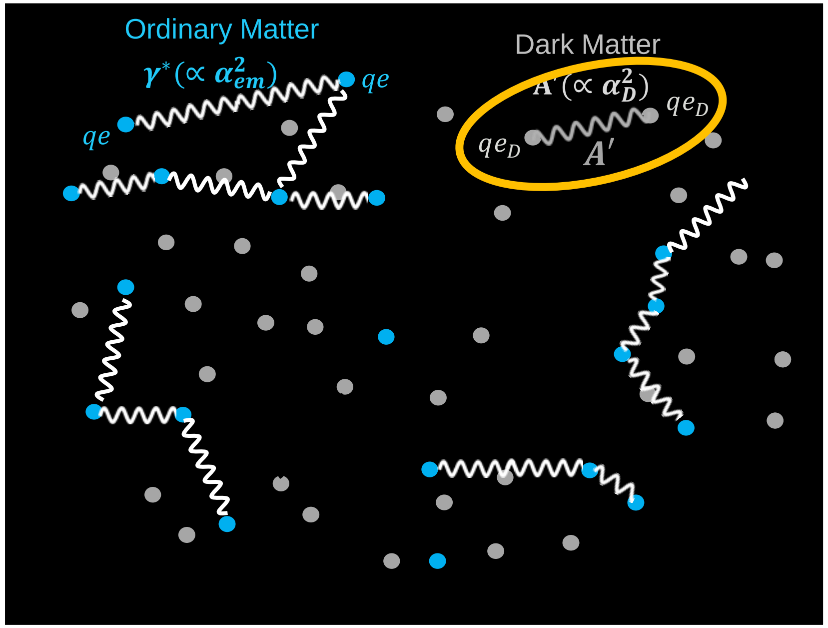



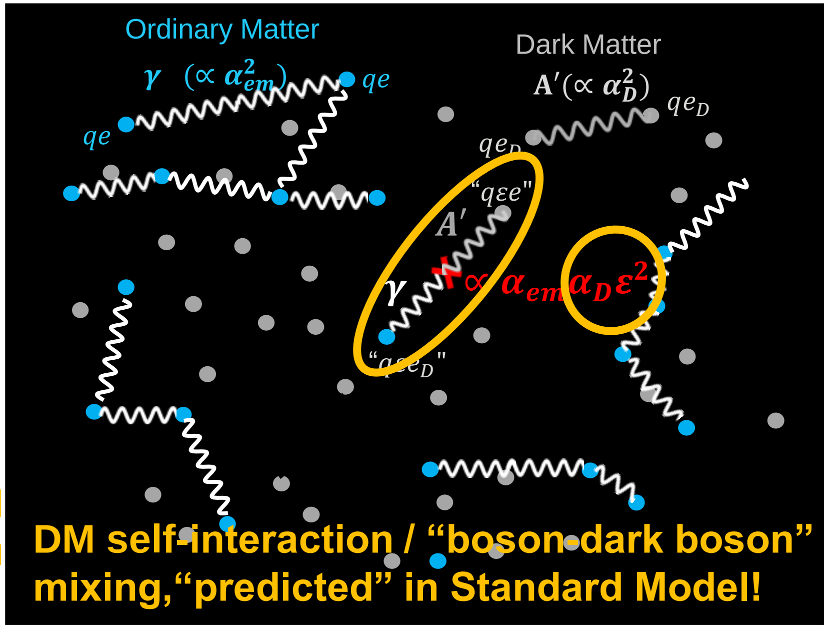

- ➔ Rules out modified gravity for DM
- ➔ DM massive particles to avoid blowing out small galactic structures
- ➔ DM is non-self-interacting above $\sigma/m \sim 1 cm^2 g^{-1}$

# Motivation for intensity and energy

## *Example* of FIP physics case

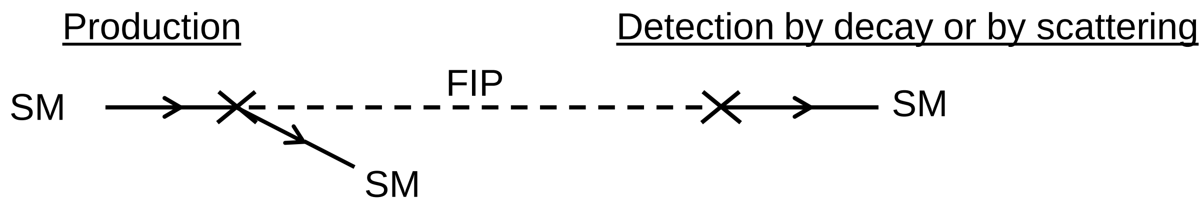


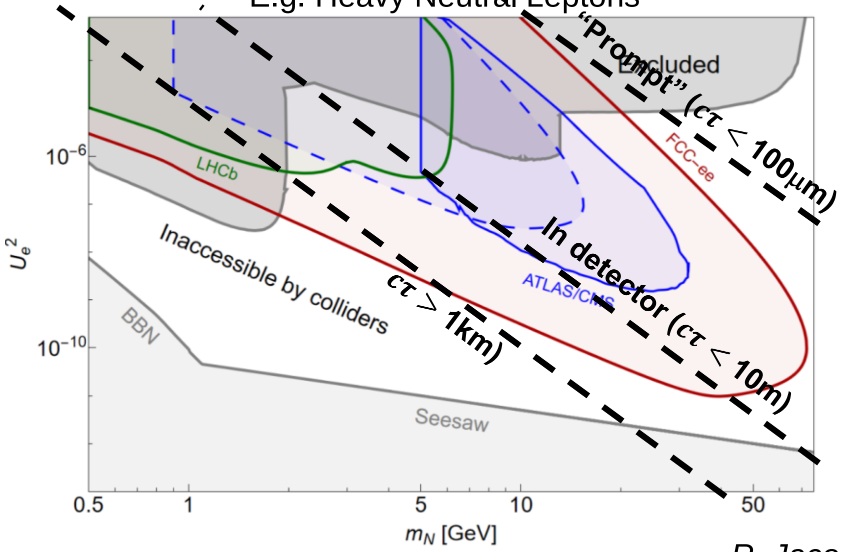

Profiting from "portal" coupling at accelerator!

- ➔ Typical coupling at $10^{-6}$ - $10^{-10}$…
- ➔ Long-lived with cτ ~ metres-kilometres….



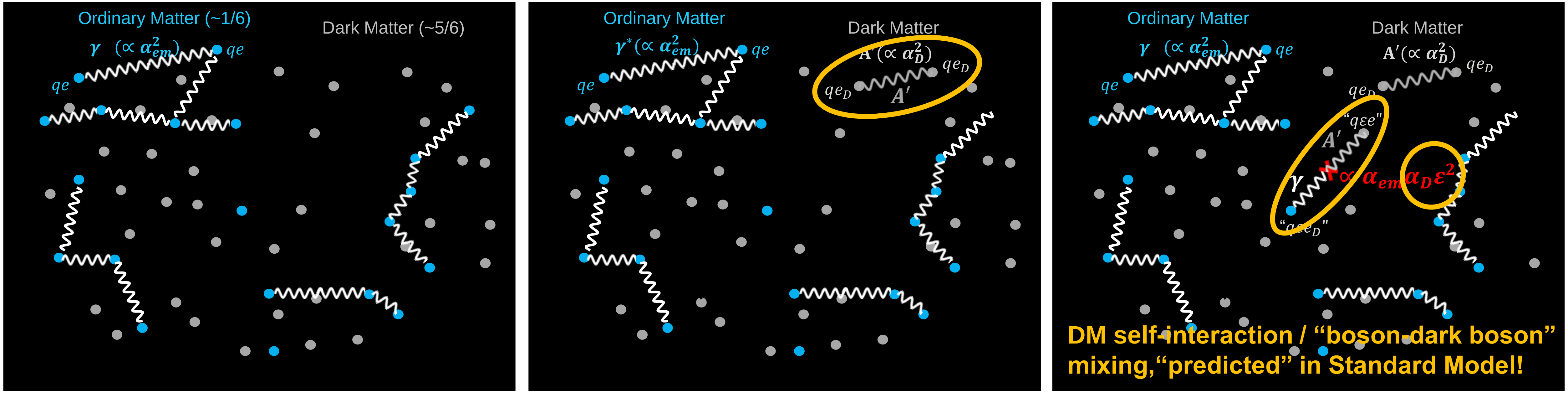

- ➔ Maximize production of $\gamma, q/g, c, b$

E.g. Heavy Neutral Leptons



# Motivation for intensity and energy

***Example*** of FIP physics case



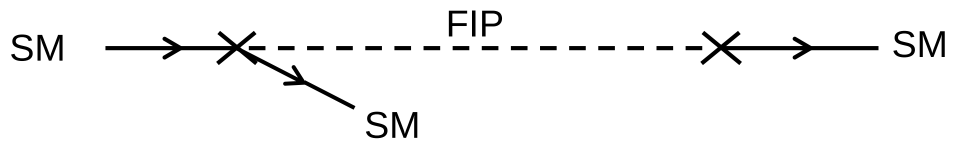

Profiting from "portal" coupling at accelerator!

➔ Typical coupling at $10^{-6}$ - $10^{-10}$…

➔ Long-lived with cτ ~ metres-kilometres….

Production

Detection by decay or by scattering

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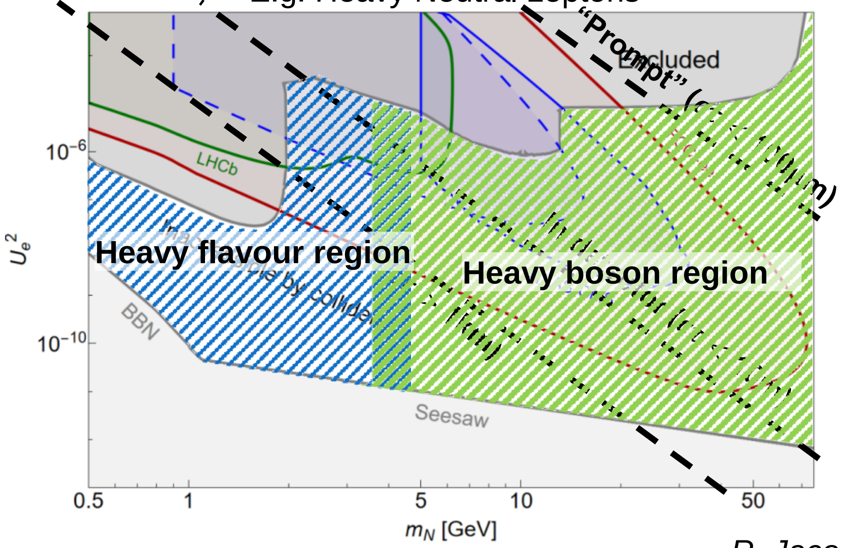
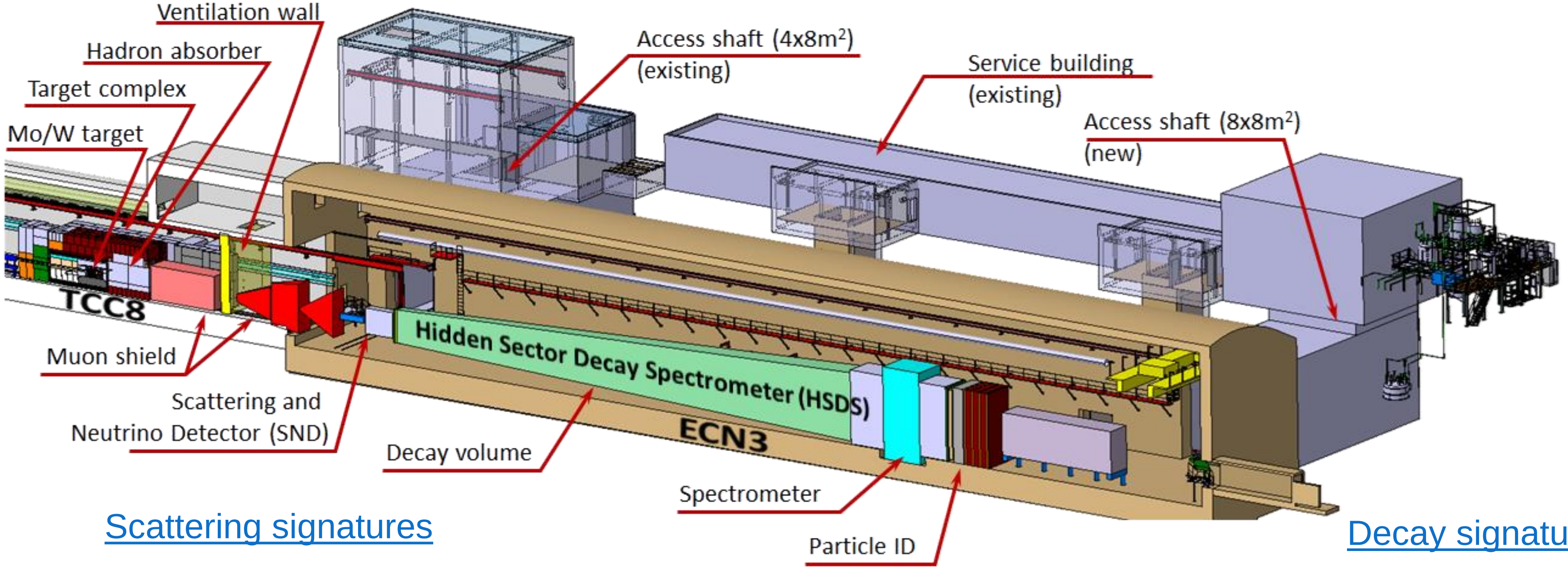
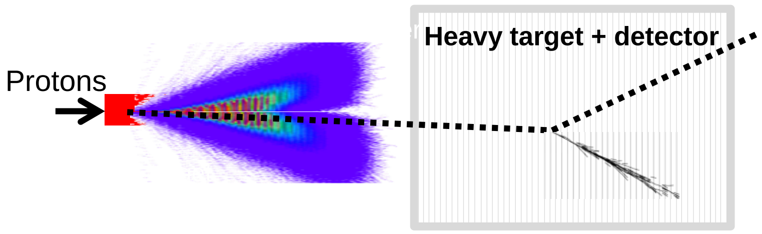


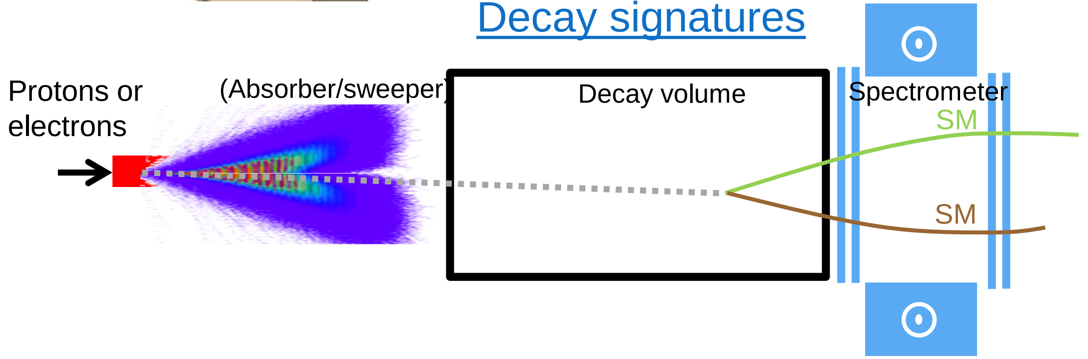
# SHiP: two-in-one




## Scattering signatures




## Decay signatures

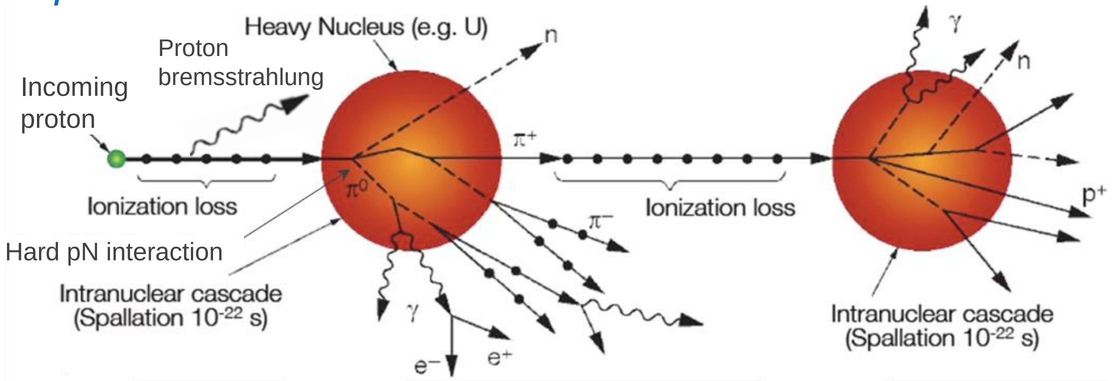



- BDF luminosity with the optimised target and 4x10[19] protons on Mo target per year *currently available* in the SPS
  - BDF@SPS $\mathcal{L}_{int}[year^{-1}]$ = >4 x $10^{45}$ $cm^{-2}$ (cascade not incl.)
  - HL-LHC $\mathcal{L}_{int}[year^{-1}]$ = $10^{42}$ $cm^{-2}$

E.g. ~ $2\times10^{17}$ charmed hadrons (>10 times the yield at HL-LHC)

# Physics FoM of the target

- **Target design for signal/background optimisation:**
  - *“induce hard interactions of all protons and secondaries in the densest possible medium”:*
  - Very thick → use full beam and secondary interactions (12λ)
  - High-A/Z → maximise production cross-sections
  - Short λ → stop pions/kaons before decay




$t_{max}[\lambda_{int}] \approx 0.2\, ln(400\ GeV) + 0.7 \sim 1.9\lambda_{int}$

**95% long. containment:** $L_{95} \approx t_{max} + 2.5(400\ GeV)^{1/3} = 20.3\ \lambda_{int}$

**95% radial containment:** $R_{95} \approx \lambda_{int} + 2\sigma_{beam} + r_{sweep}$

- **Signal**
  - Proton DIS $\sigma_{pN} \propto \sigma_{pp} A^{2/3}$
  - Electromagnetic processes $\sigma_{QN} \propto \sigma_{Qp} Z^2$

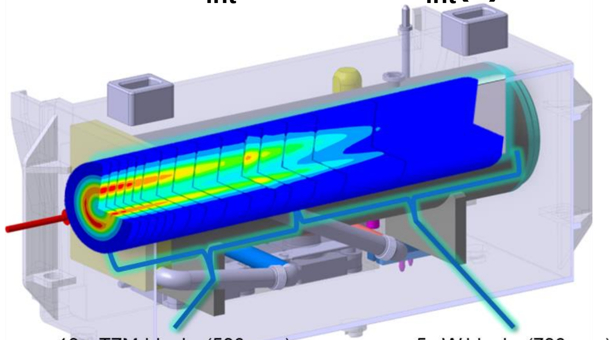
**W: A=184, Z=74, $\lambda_{int}$=9.9cm, $\lambda_{int}(\pi)$=11.3cm**
**Mo: A= 96, Z=42, $\lambda_{int}$=15.2cm, $\lambda_{int}(\pi)$=18.0cm**
**Cu: A= 64, Z=29, $\lambda_{int}$=15.3cm, $\lambda_{int}(\pi)$=18.5cm**
**$H_2$0: $\lambda_{int}$=83.3cm, $\lambda_{int}(\pi)$=115.6cm**

- **Background ($\mu, \nu$ from $\pi$, $K$, and neutrons)**
  - $\pi$, $K$ decay: $c\tau\gamma(\pi)$=7.8$\gamma$ m, $c\tau\gamma$(K)=3.7$\gamma$ m

$N_{dec}(x) = N_0 e^{-x/\gamma\tau}$

$N_{int}(x) = N_0 e^{-x/\lambda_{int}}$

  - Hadronic interaction $\lambda_{int}(\pi) = \frac{1}{n\sigma_{inel}} = \frac{A}{\sigma_{\pi p} A^{2/3} N_a \rho} \propto A^{1/3}$
  - (Electromagnetic) $X_0 \propto \frac{A}{Z^2}$
  - Muon shield will suppress muon flux by six orders of magnitude
  - Neutrino background suppressed by vacuum/helium in decay volume



# Physics FoM of the target

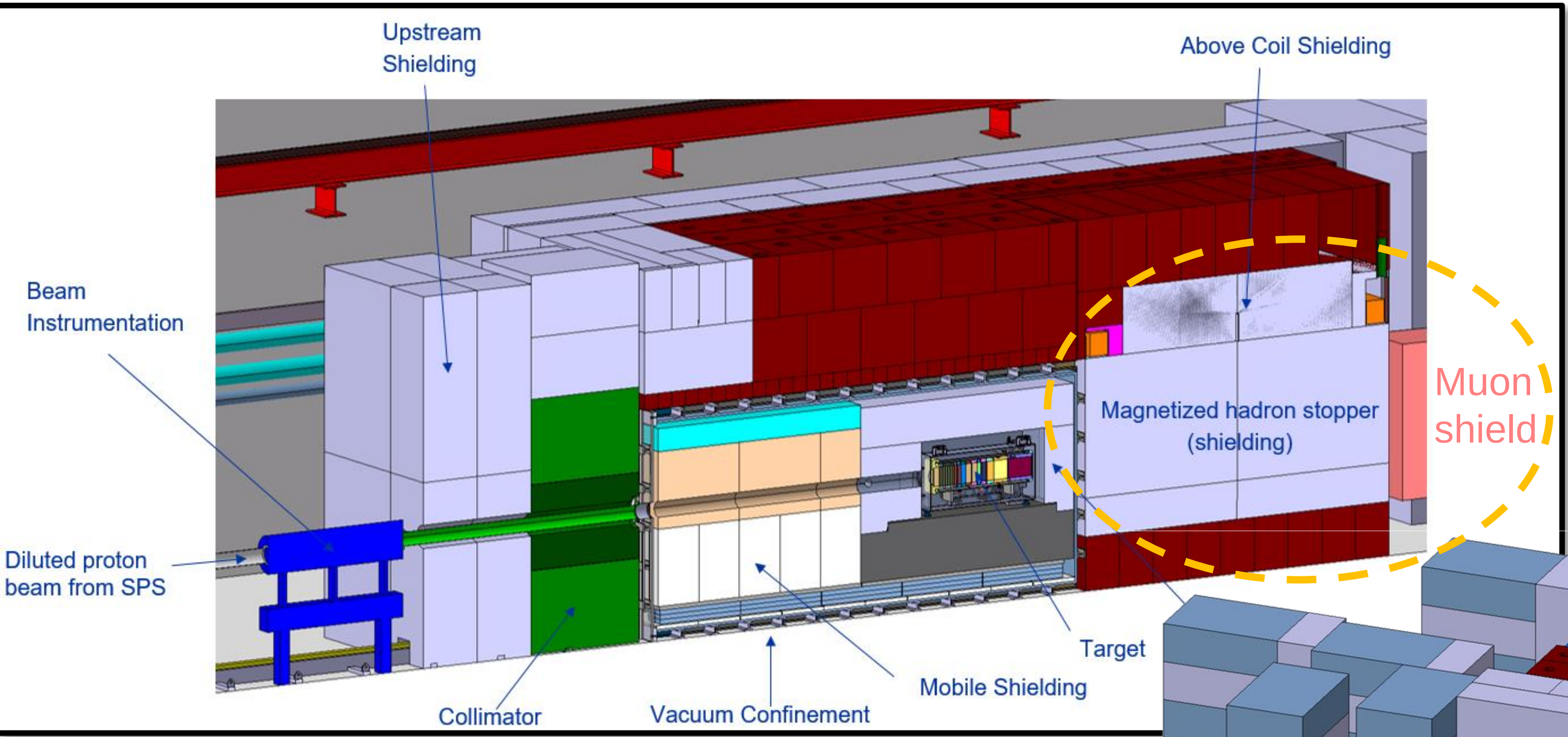
- No simple metric but different target configurations can be quite easily compared for fast exploration

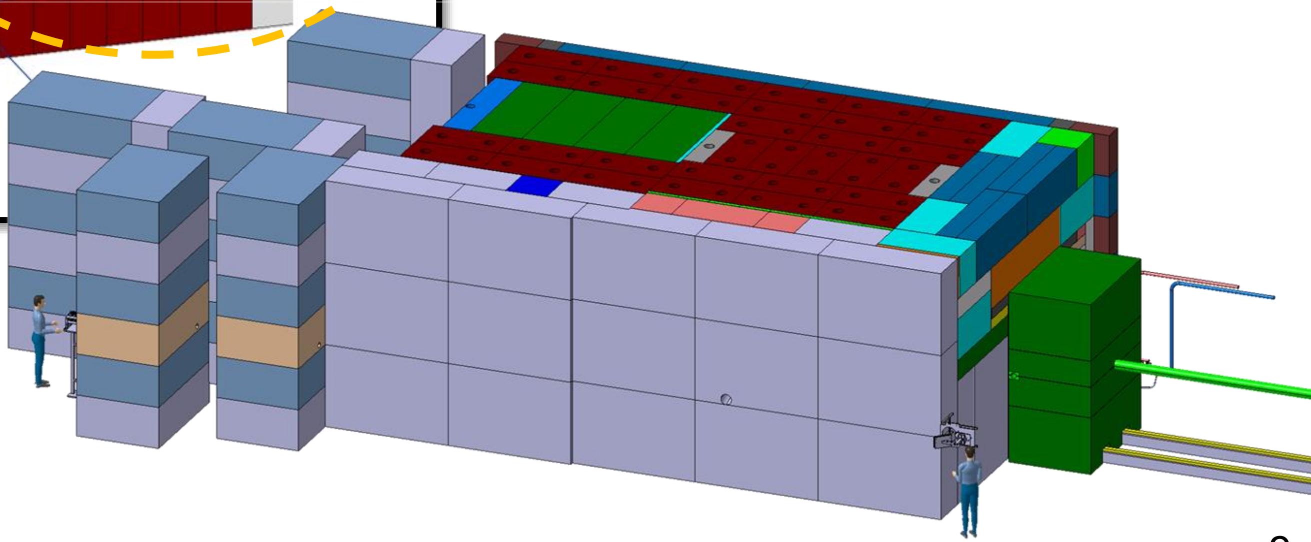
- Guidelines:
  - Highest density is most important
  - Highest density is most important in core of shower, i.e. first interaction lengths!...
  - Shower containment for hadronic comportant is important up to a radius where $\pi/K$ "miss detector"
  - Water gaps are less critical as long as negligible contribution to combined interaction length
  - Beam spot size and sweep radius are secondary, mostly important to check containment
  - Optimise explicitly for signal, background optimisation is implicit (perhaps a longer target...)

- Use FLUKA for checking performance of different options
  - $p$, $\pi$, $K$, $\mu$, $n$ $(x, y, x, \bar{p})$ to check rates and hadronic shower containment at scoring planes per interaction length

# Target complex – SHiP interface

- Hadron stopper magnetization, first muon shield magnet, surrounding shielding blocks
  - Ongoing discussion about possibility of moving first muon shield magnet into the hadron stopper

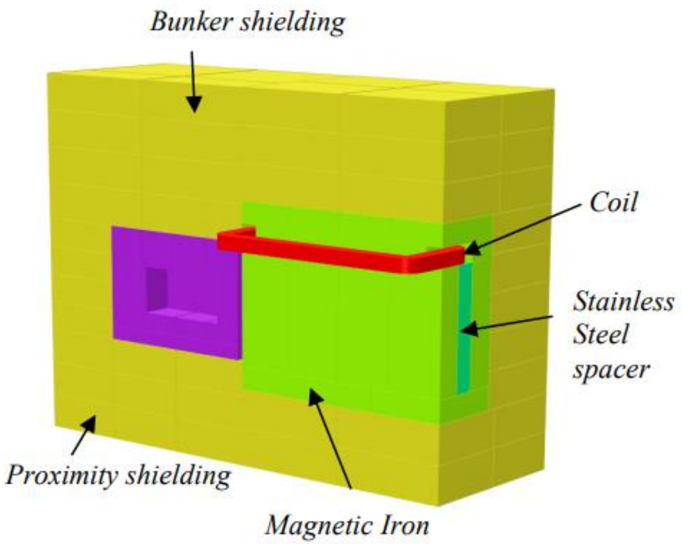


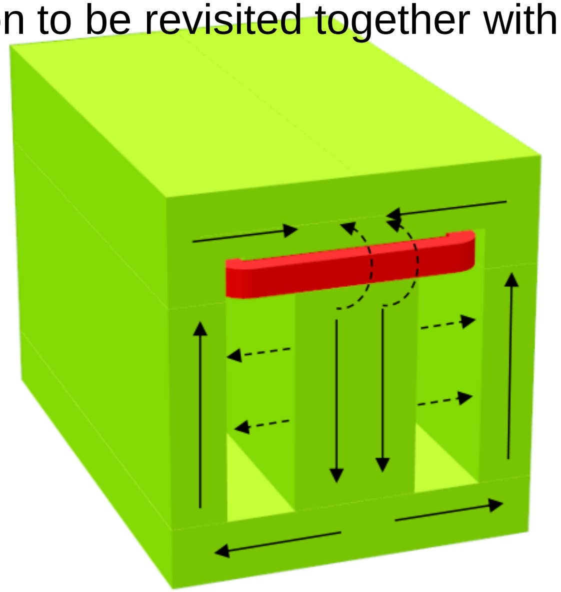



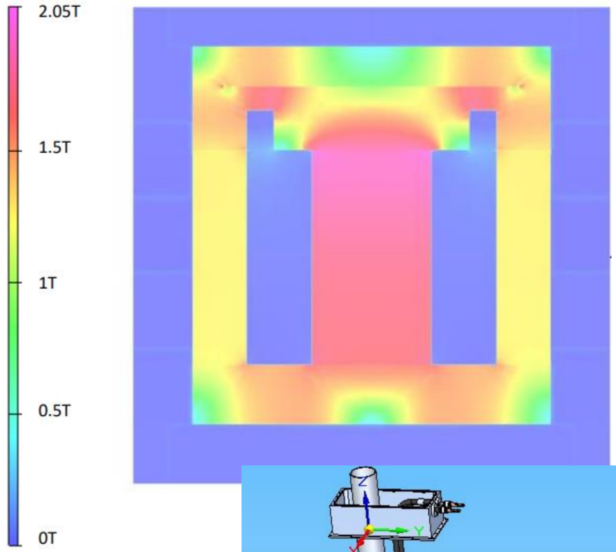
# Hadron stopper magnetisation

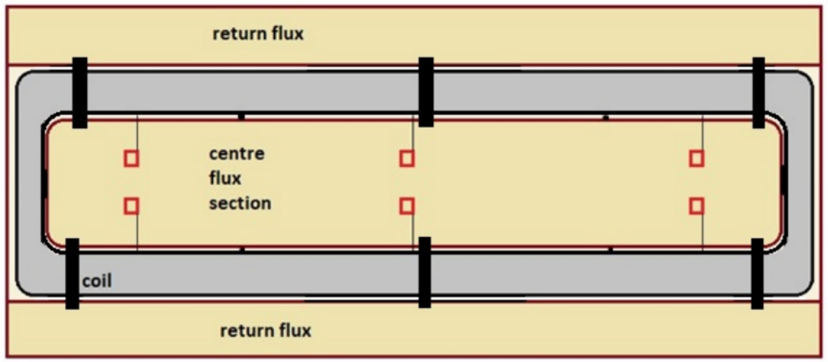
- First fully developed concept by RAL, now taken by TE-MSC
  - First concept based on classical coil from aluminium with helium gas cooling
  - Longitudinal extent of coil/magnetisation to be revisited together with muon shield studies (9-12 months)

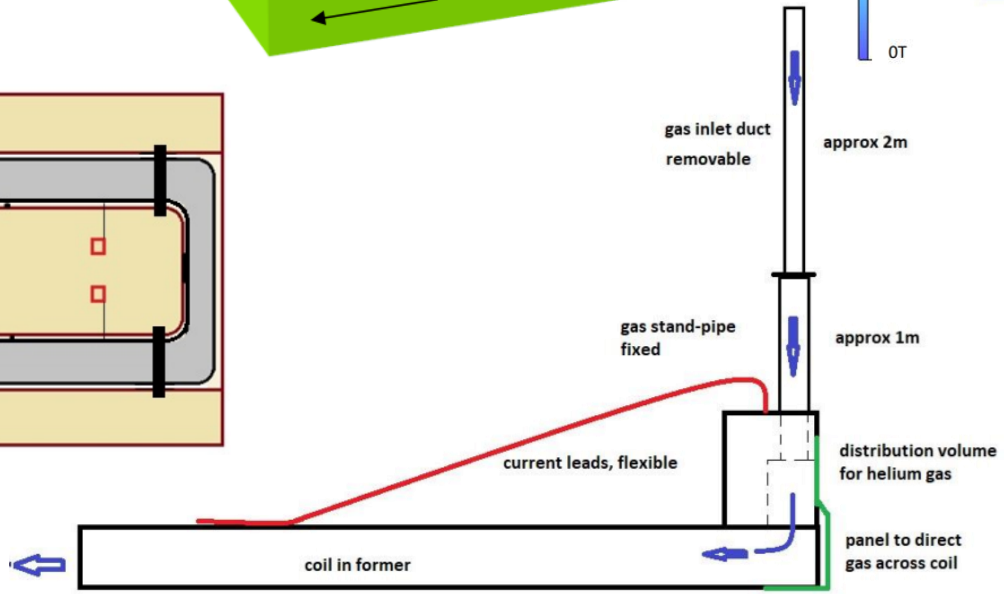
V. Bayliss,J. Boehm, CERN-SHiP-NOTE-2019-004

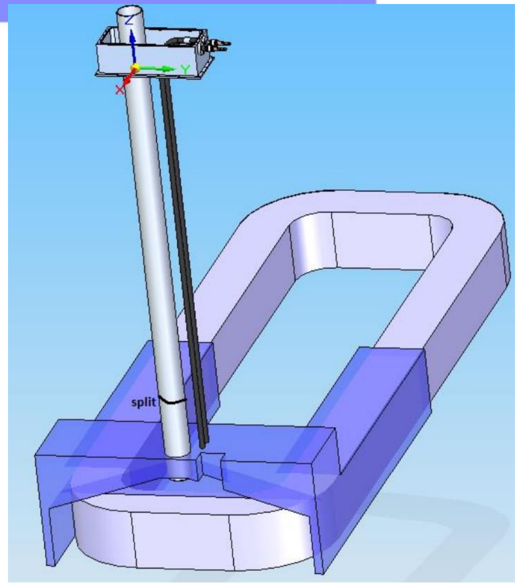


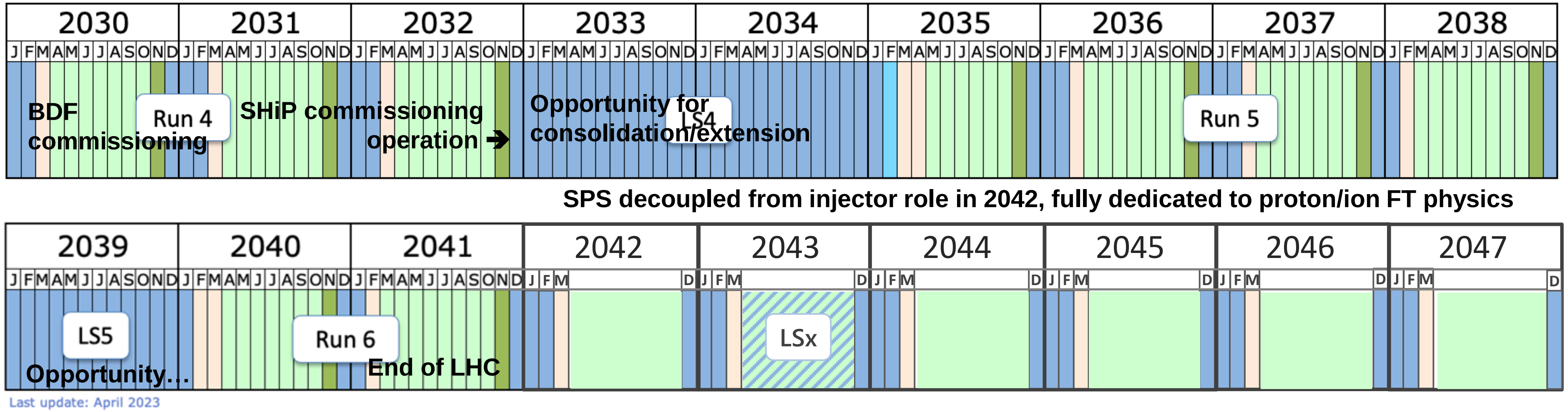


# Overall SHiP operational schedule




- 2031-2032: Start at lower intensity for commissioning and crank up to 4E13 before LS4
- Yearly data taking run with muon shield off at low intensity for calibration/alignment
  - Run with no beam sweep?
- Worth considering spills of 7E13, annually > 4E19, if all goes well….