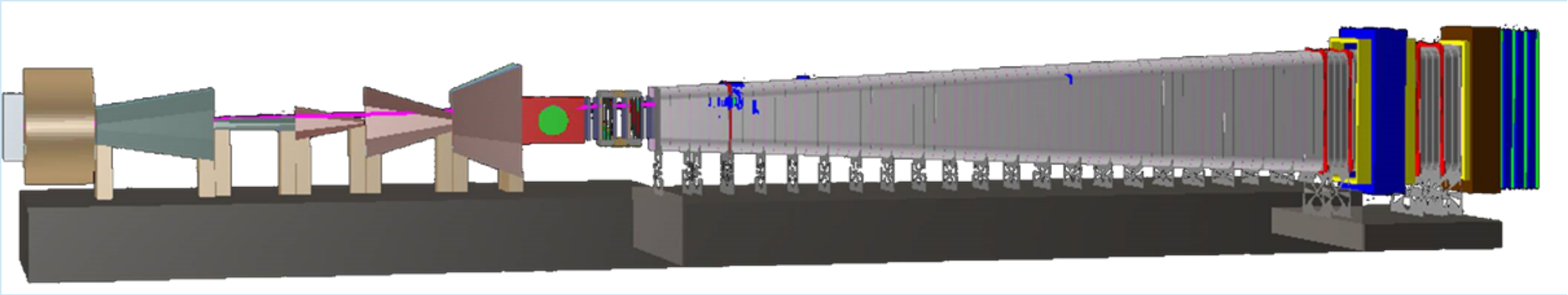
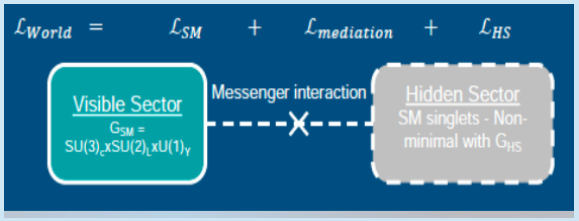
Search for Hidden Particles (SHiP): an experimental proposal at the SPS

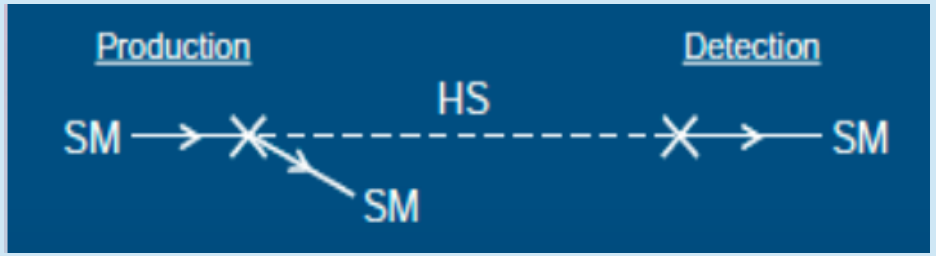
ship.web.cern.ch/ship
Mario Campanelli (UCL)



The “hidden sector” approach to new physics

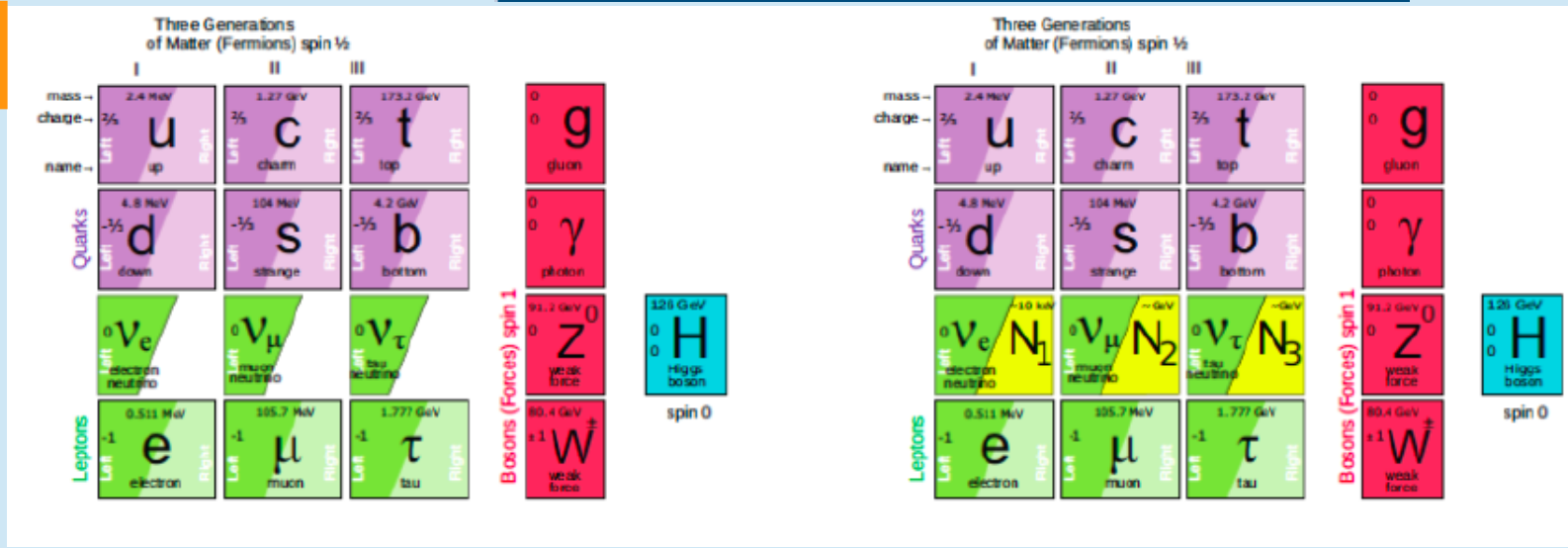
- Searches for new particles at the LHC so far unsuccessful, maybe new physics has a very small coupling?
- If an additional, weakly interacting, term to the Lagrangian could lead to particles very difficult to observe, but contributing to dark matter.





Example: νMSSM

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



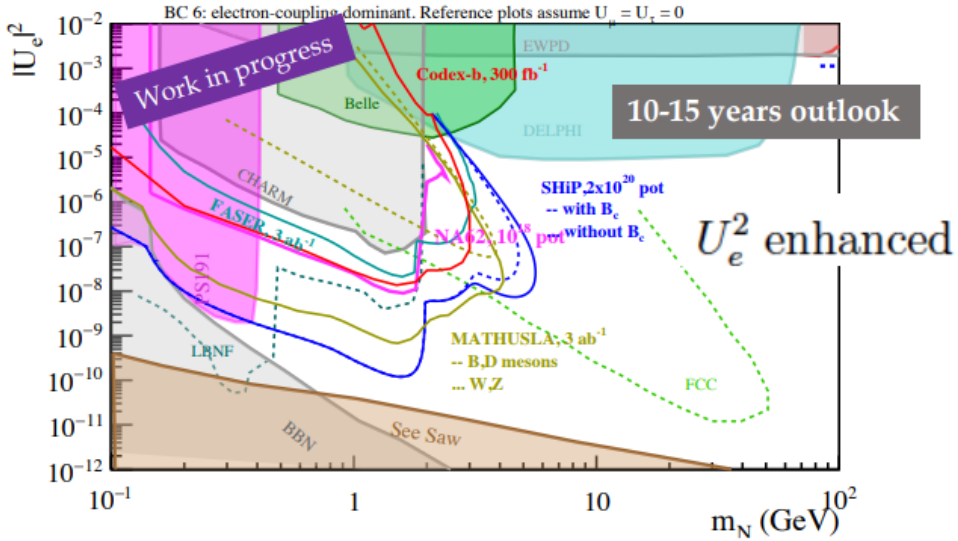
Particle content of SM made symmetric by adding 3 HNL: N_1, N_2, N_3

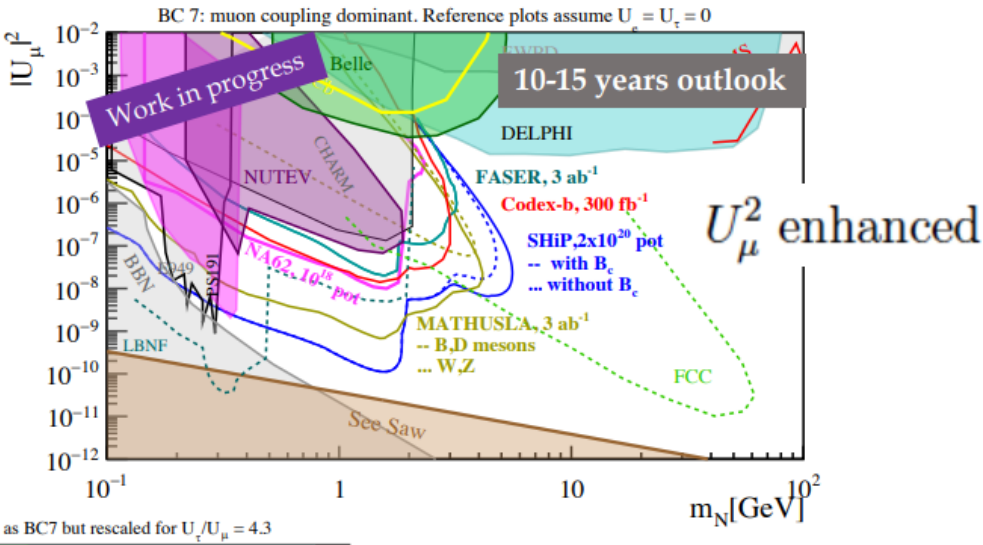
With $M(N_1)$ ~ few KeV, it is a good DM candidate, $M(N_2, N_3)$ ~ GeV, could explain Barion Asymmetry of Universe (via leptogenesis), and generate neutrino masses through see-saw.

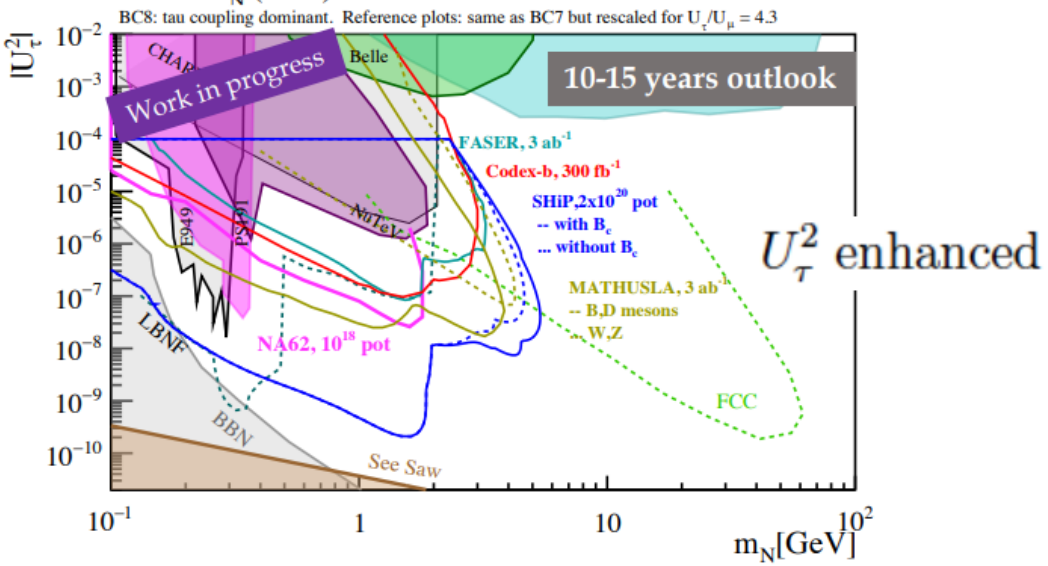
Just an example: SHiP has a unique sensitivity to most common Hidden Sector models

RH neutrinos below the EW scale: PBC projects in 10-15 years

Benchmark Cases n. 6,7,8





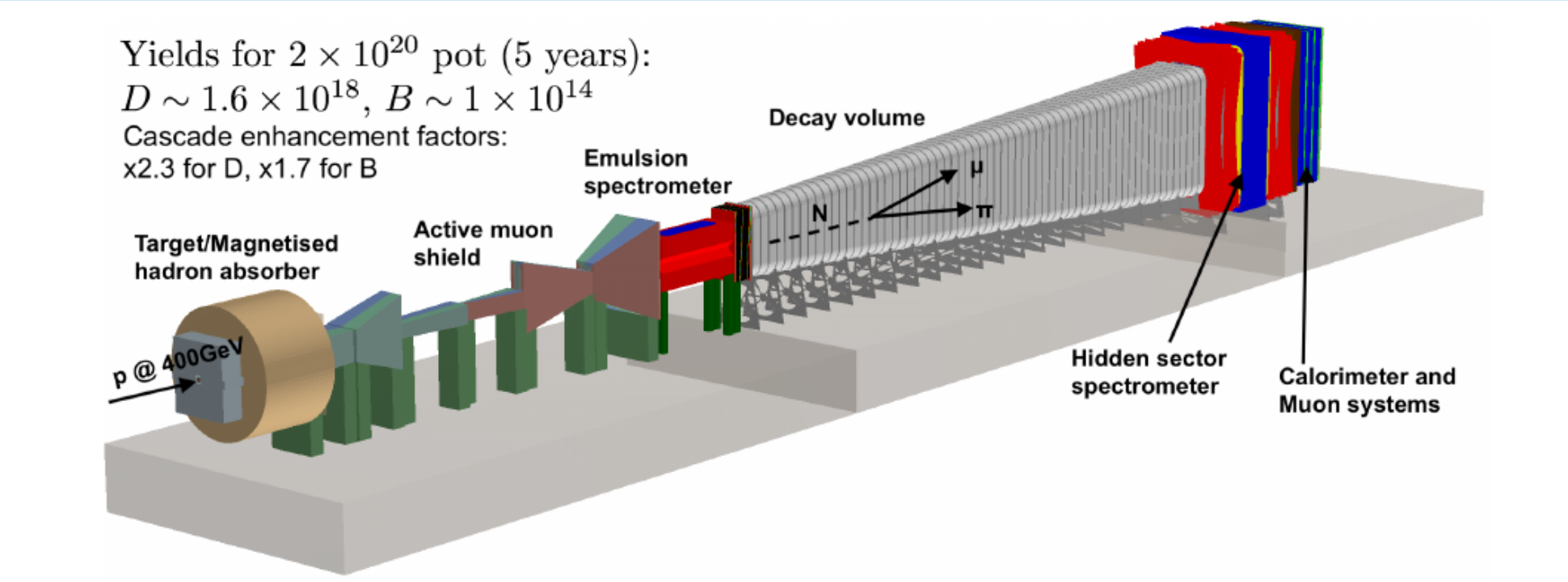


From G. Lanfranchi's talk at PBC workshop June 2018

https://indico.cern.ch/event/706741/contributions/2955719/attachments/1666878/2682637/PBC_BSM_June2018.pdf

The SHiP detector after optimization for the Comprehensive Design Study

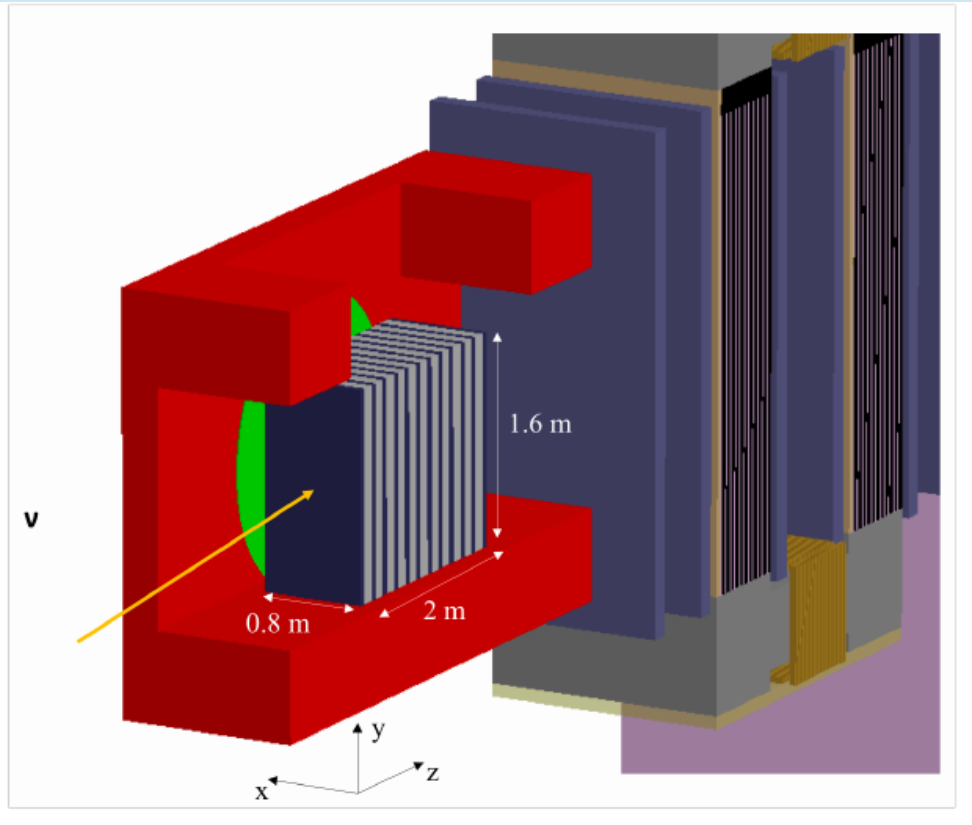
- ✓ *Further optimization of the target*
- ✓ *Configuration of the muon shield, including magnetization of the hadron stopper*
- ✓ *PROTOTYPE TEST AND TEST-BEAM WITH TARGET TO MEASURE MUON SPECTRUM*
- ✓ *Shape, dimension and evacuation of the decay volume*

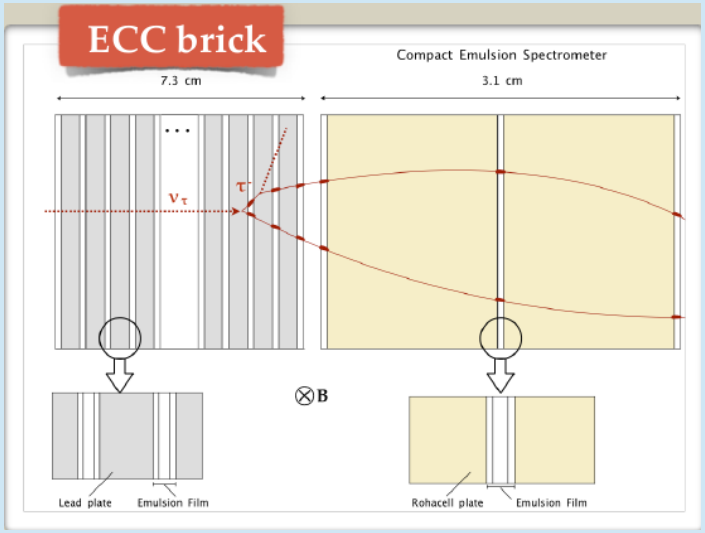


- ✓ *Optimization of the emulsion detector to search for LDM*
- ✓ *Optimization of physics performance for various sub-detectors*
- ✓ *Revisit detector technologies, including new sub-detectors, to further consolidate background rejection and extend PID*

Updated background estimates and signal sensitivities, and cost

Neutrino detector and dark matter searches

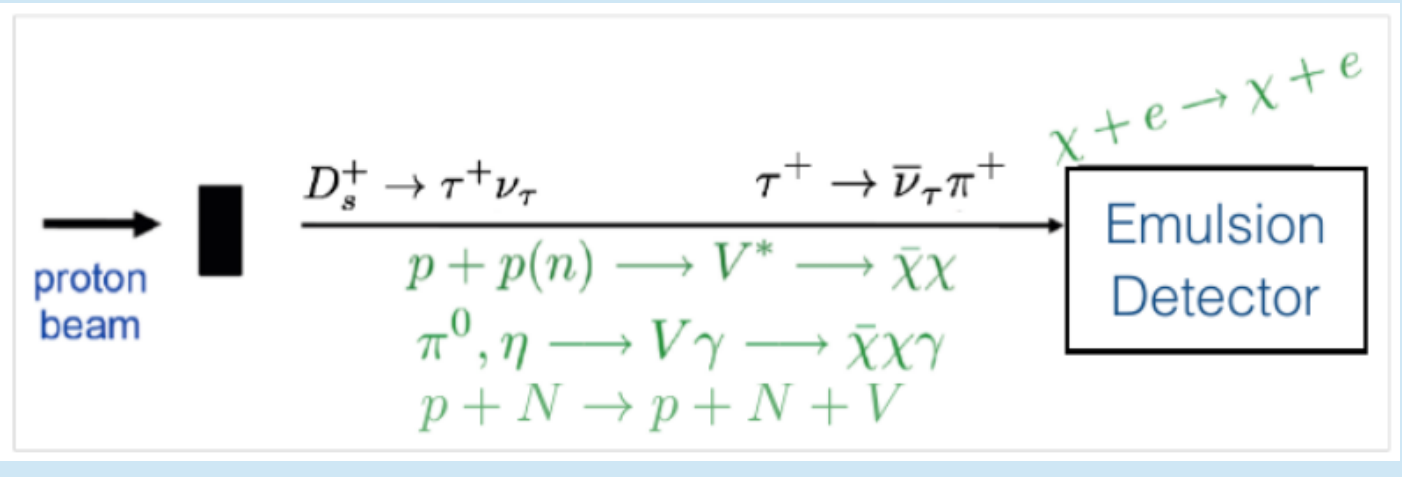




Exploit production thousands of of tau neutrinos to study its properties and structure function

Discovery of tau-antineutrino (only missing SM particle)

Muon spectrometer after target needed to suppress charm BG:



Also, search for direct dark matter via scattering off electrons

Status of SHiP

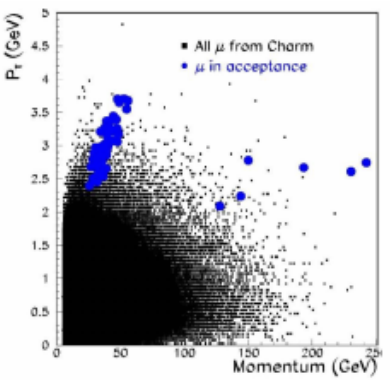
- Currently finalising CDS; SHiP is part of CERN's medium term planning, pending ES update
- PBC initiative set up to inform CERN's planning towards ES strategy: mandate to investigate options at intensity frontier and come up with coherent plan complementary to collider programme. SHiP is the main experiment in this plan (other significant project: proton EDM)
- SHiP has generated interest in hidden sector more generally: e.g. Mathulsa/Codex-B proposals; however SHiP remains unique in it's ability:
  - multiple subsystems to beat a wide range of backgrounds down to the <0.1 event as calculated with large simulation studies.
  - Redundancy will allow us to select background events and test our understanding.
  - We can track origin of signal, and measure particle ID and mass

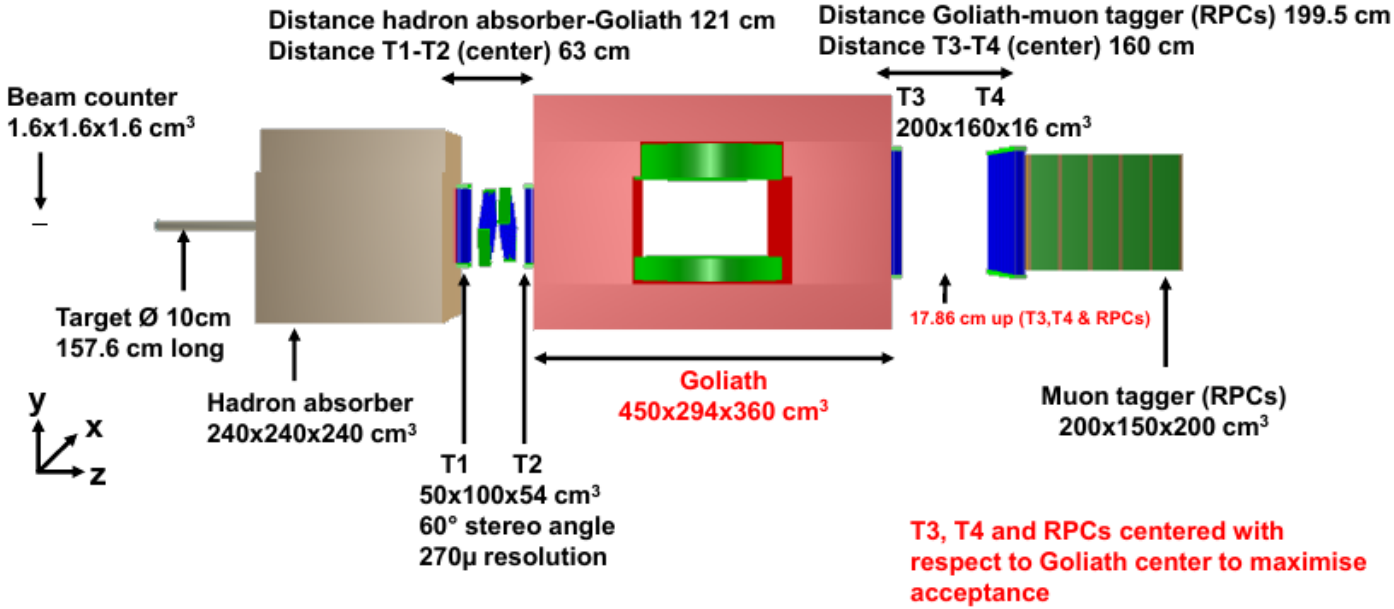
Current activities

- SHiP is taking shape through major prototyping and engineering design effort from all other collaborating institutes
- SHiP is an officially recognised project in Italy Switzerland and Russia (who already contributed at the level of >300k euro each) Germany has also provided significant contribution
- all sub detectors systems have detailed prototyping on-going
- test-beam activities ongoing this month
- CERN accelerator division is conducting detailed modelling of techniques to reduce the beam losses and activation during the slow-extraction process required for SHiP. Current status confirms intensity reaching within a factor 2 and further techniques are being deployed in order provide the additional intensity

Muon spectrum measurement SHiP-EOI-016

- Validate simulations in difficult corners of muon phase space
  - Measure momentum and charge of muons produced from replica of SHiP's target using 4×10^{11} pot
- Detector geometry finalised
- Assembly schedule in place, with data taking starting second week of July

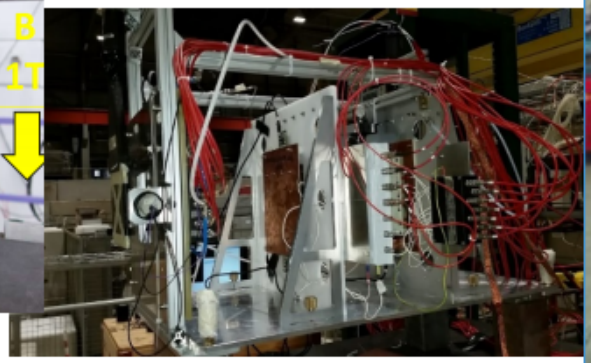


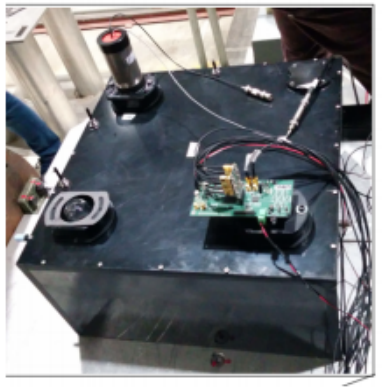


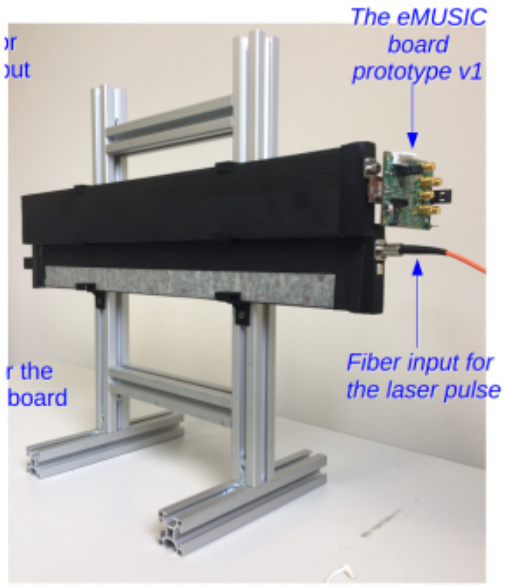
From: K. Petridis' talk PBC June 2018
https://indico.cern.ch/event/706741/contributions/3017540/attachments/1667786/2674408/PBCSHiPUpdateJune2018.pdf

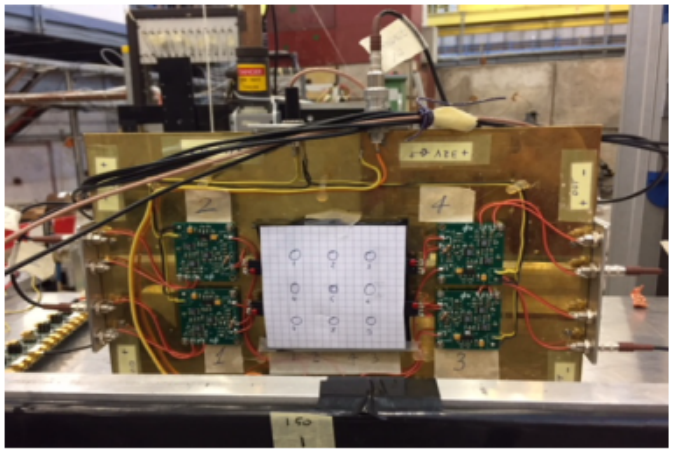
Other news

- All sub-detectors with at least a first level of prototyping







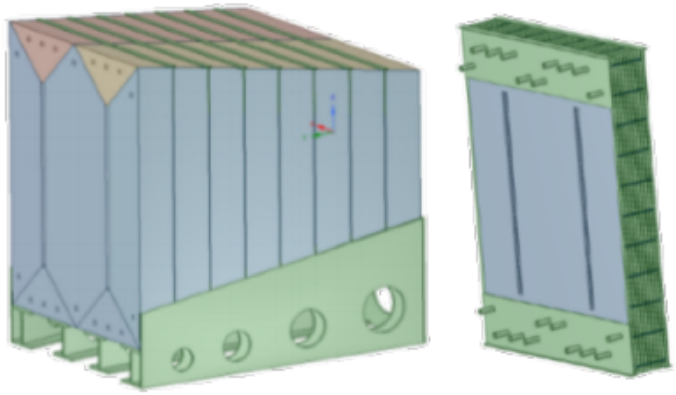


+ electronics

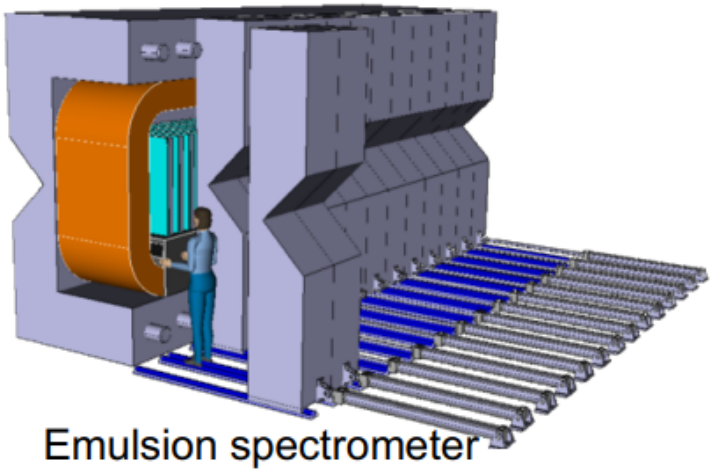
- Prototyping of the shield also well underway

Other news

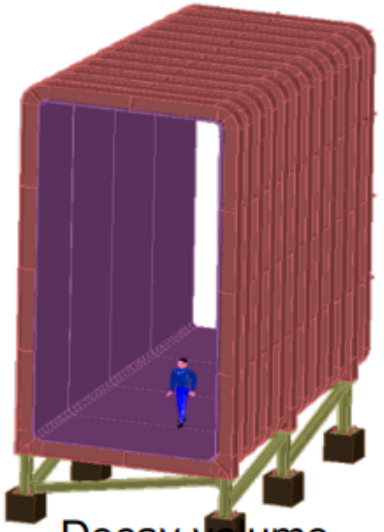
- Engineering designs progressing well including CAD and FEA
  - Detector is becoming increasingly real



Muon shield

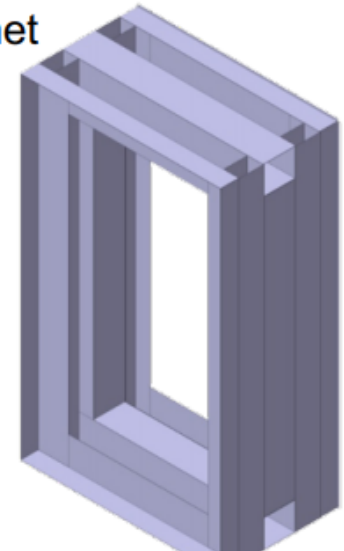


Emulsion spectrometer



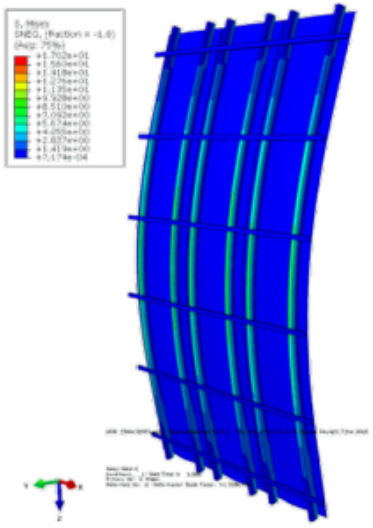
Decay volume

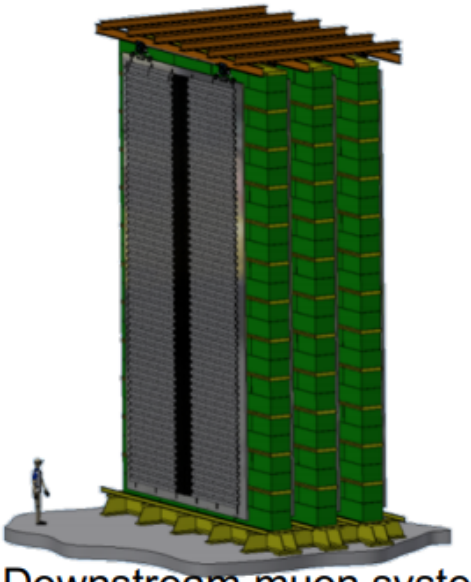
Main spectrometer magnet



Straw tracker tandem box

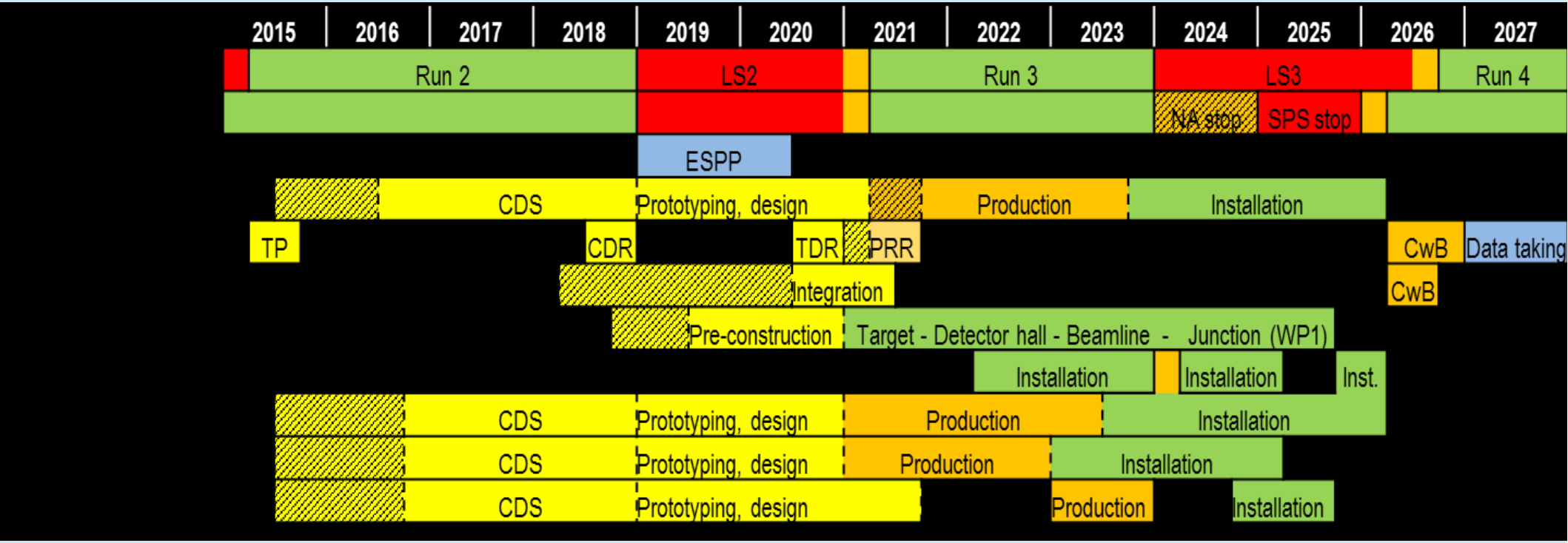
Timing detector





Downstream muon system

Global SHiP schedule



- ✓ ***Planning very well aligned with***
  - *CERN scientific strategy*
  - *Update of European strategy 2019/2020*
  - *Accelerator schedule (to be followed closely)*
  - *Production Readiness Reviews (PRR) 2020Q1*
  - *Construction / production 2020*
  - *Data taking (pilot run) 2026 (start of LHC Run 4)*

- ✓ ***Main current priority: Comprehensive Design Study by 2018***
- ✓ ***Validation of MC studies with dedicated test-beams already this year!***

UK contribution

- UK collaborators from ICL, UCL, Bristol, Warwick, RAL
- Efforts focused on muon shield that it is critical to deflect muons coming from charm, strange decays in the dump
- Muon shield is an ~8M CHF project that will primarily be built by industry
- The free-standing part of shield will most probably be funded through common fund, while the magnetization of the hadron stooper will be covered by the CERN budget. UK groups are involved in both projects.
- Very innovative technique for magnet design can have wide industrial spinoffs beyond the specific SHiP magnet
- Potentially O(millions) benefit to manufacturing in the UK
- Machine-learning techniques used to simulate interactions of particle with shield- prohibitive computing time otherwise
- Also minor involvement in target design and TDAQ system

Status of UK funding and conclusions

- A SHiP SOI was submitted to the Science Board in May. Outcome:
- Science Board agreed that the UK had leadership in this area and the experiment would result in interesting science. In addition, the novel construction of the magnetic system offered some opportunities for UK industry. However, Science Board noted that there was currently no funding available in the STFC core programme for the support of the SHiP experiment. In the light of this, Science Board agreed not to invite a full proposal at this time. STFC will undertake a detailed programme evaluation for the particle physics area in 2018 and it was agreed that the proposal will be considered and prioritised as an element of this evaluation.
- In the meantime, Russian collaborators are advancing muon shield engineering design together with Russian steel suppliers and manufacturing industry

Consequences of current funding situation

- Despite having identified a UK manufacturer that could use specialist UK electrical steel to develop magnets for the shield, we have no engineering or postdoctoral effort to take UK prototyping forward. UK industry will shortly be in a terminally weakened position for any eventual tender
- Although we retain the spokesperson, the UK have subsequently lost one of three project leadership roles in the experiment that we held. We will clearly lose leadership of the muon shield project if we are unable to put any resources in. Our leadership of physics groups can also not be retained without postdoctoral effort.
- In the medium / long term, our funding aspiration would be several engineering FTEs with associated postdoctoral support for simulation, test-beams etc., prototype funding, travel; together with postdoctoral effort for physics at a level that is commensurate with the five UK institutes in the SHiP collaboration.