NA: the future is colourful and dark

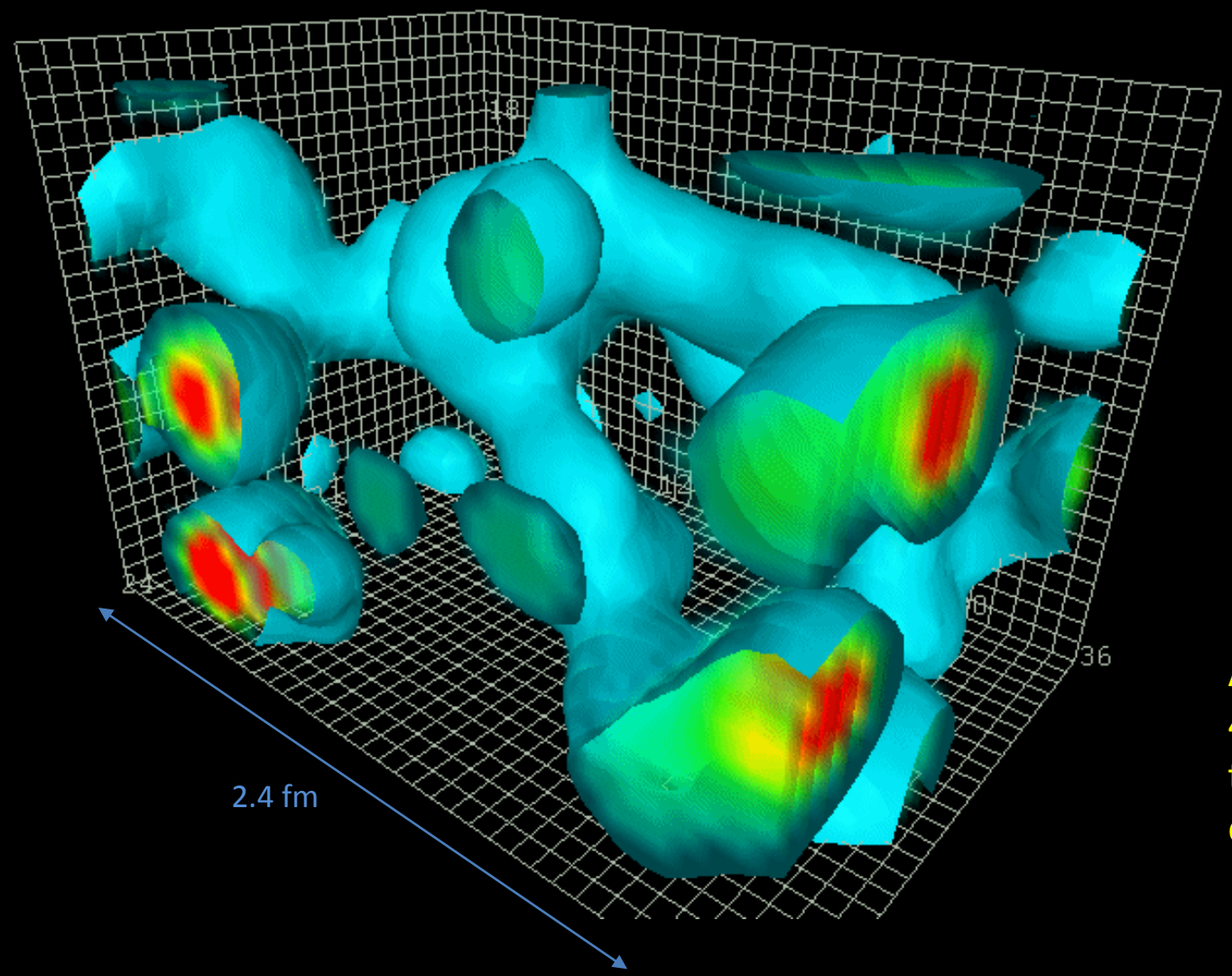
Mike Lamont

40 years SPS NA Physics Celebration

Acknowledgements: Gaia Lanfranchi, Lau Gatignon, Conventional Beams WG

QCD

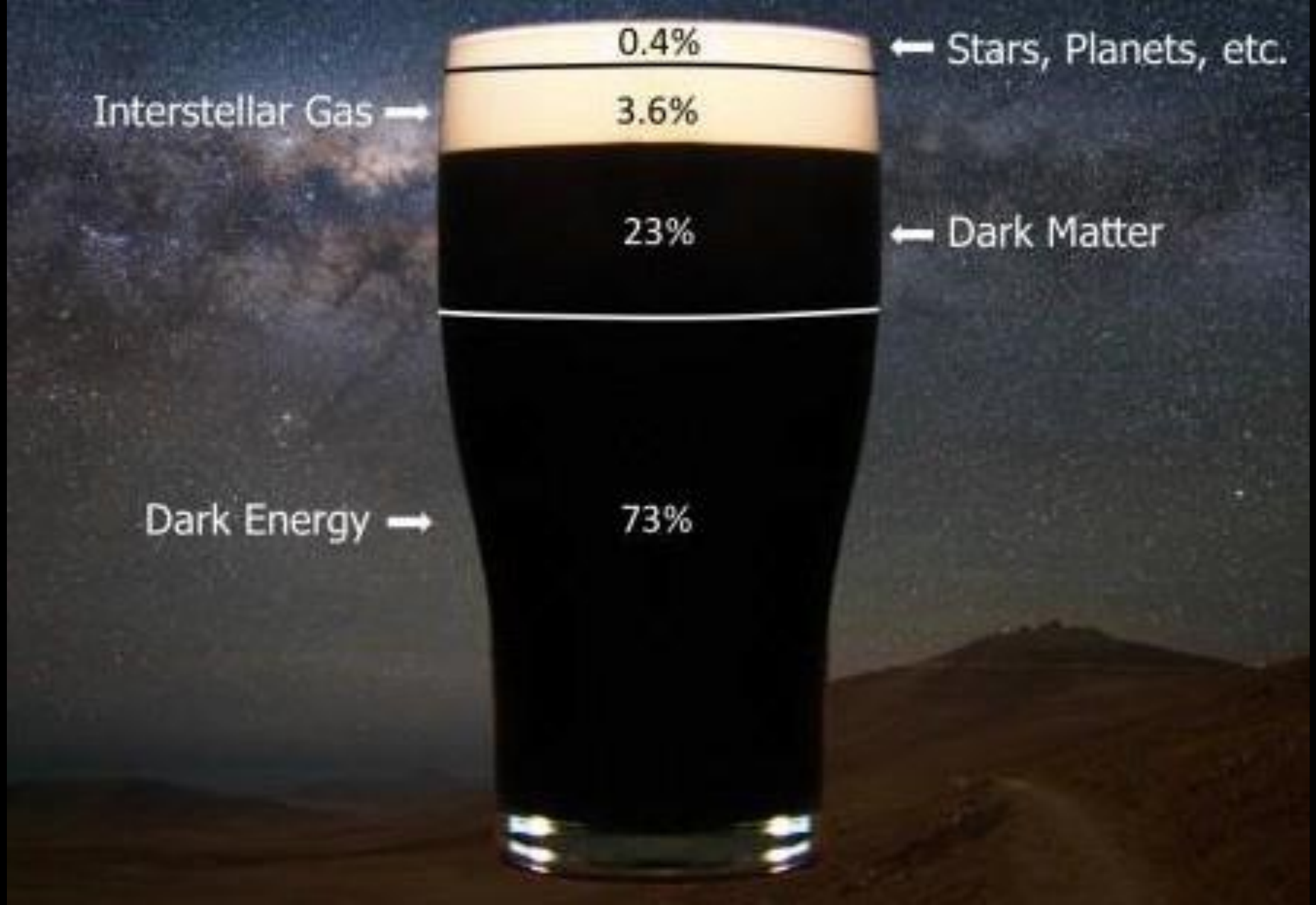
remains wonderfully intriguing



Action density:
4 dimensional structure of the long-distance aspects of the QCD vacuum

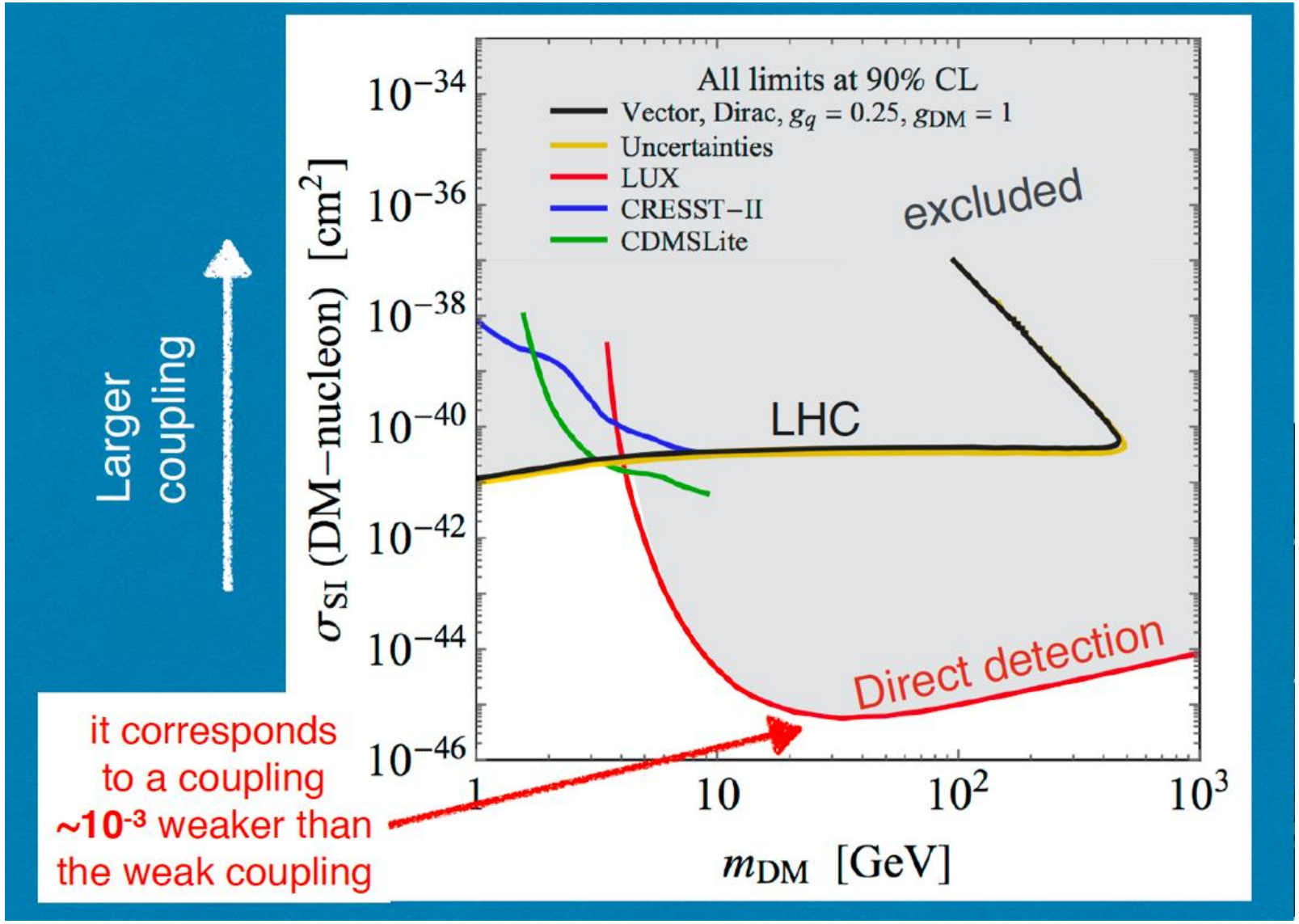
Derek B. Leinweber http://www.physics.adelaide.edu.au

Higgs discovered with mass ~125 GeV.
No new particles found.

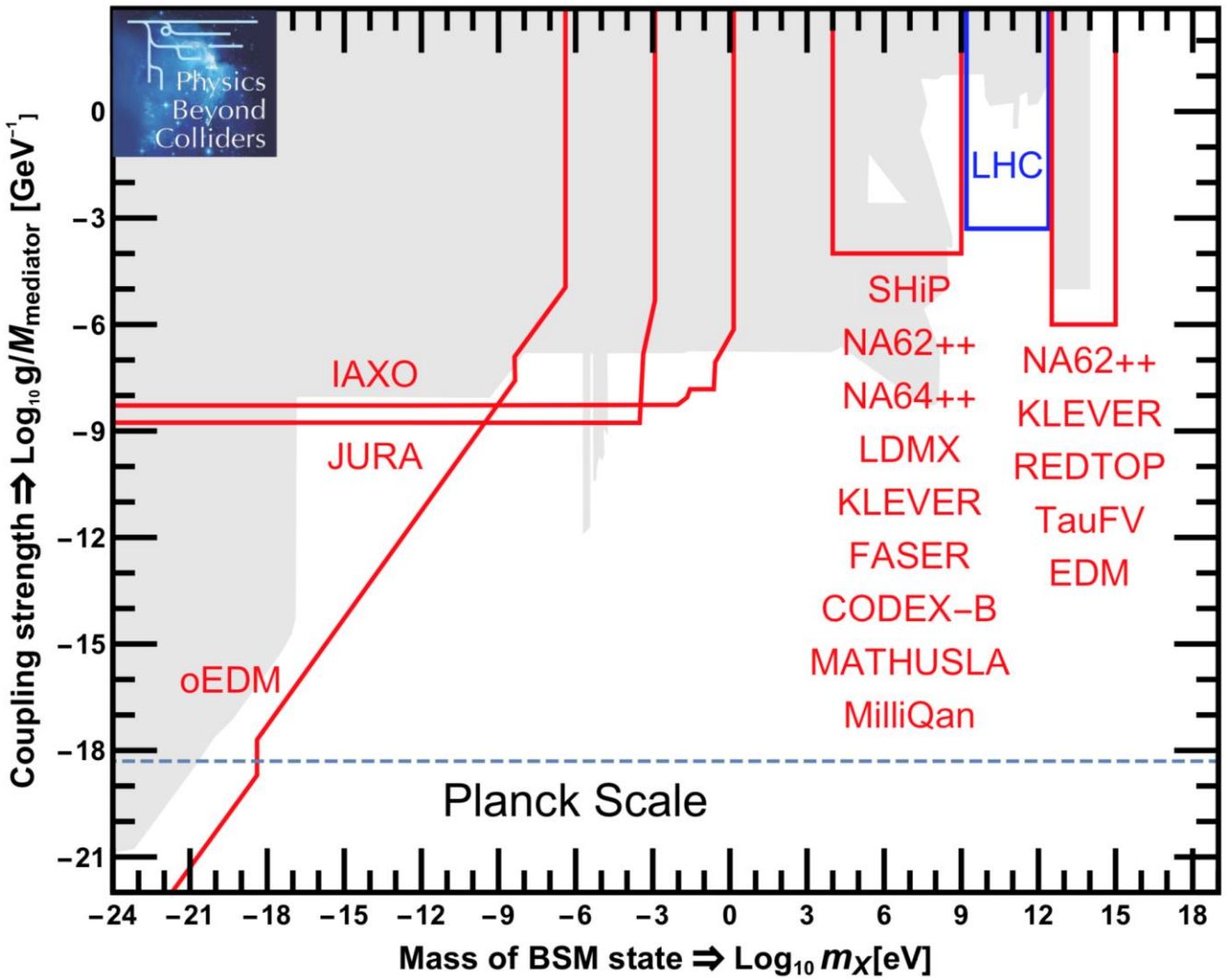


Stefania Gori

Direct detection – WIMP searches



Strong motivation to extend the search



- **Sub-eV:** axions, axion-like particles
- **MeV – GeV:** RH neutrinos below the EW scale, axion-Like Particles, Light Dark Matter
- **>>TeV:** search for NP in clean and very rare flavour processes or in EDMs

Joerg Jaeckel

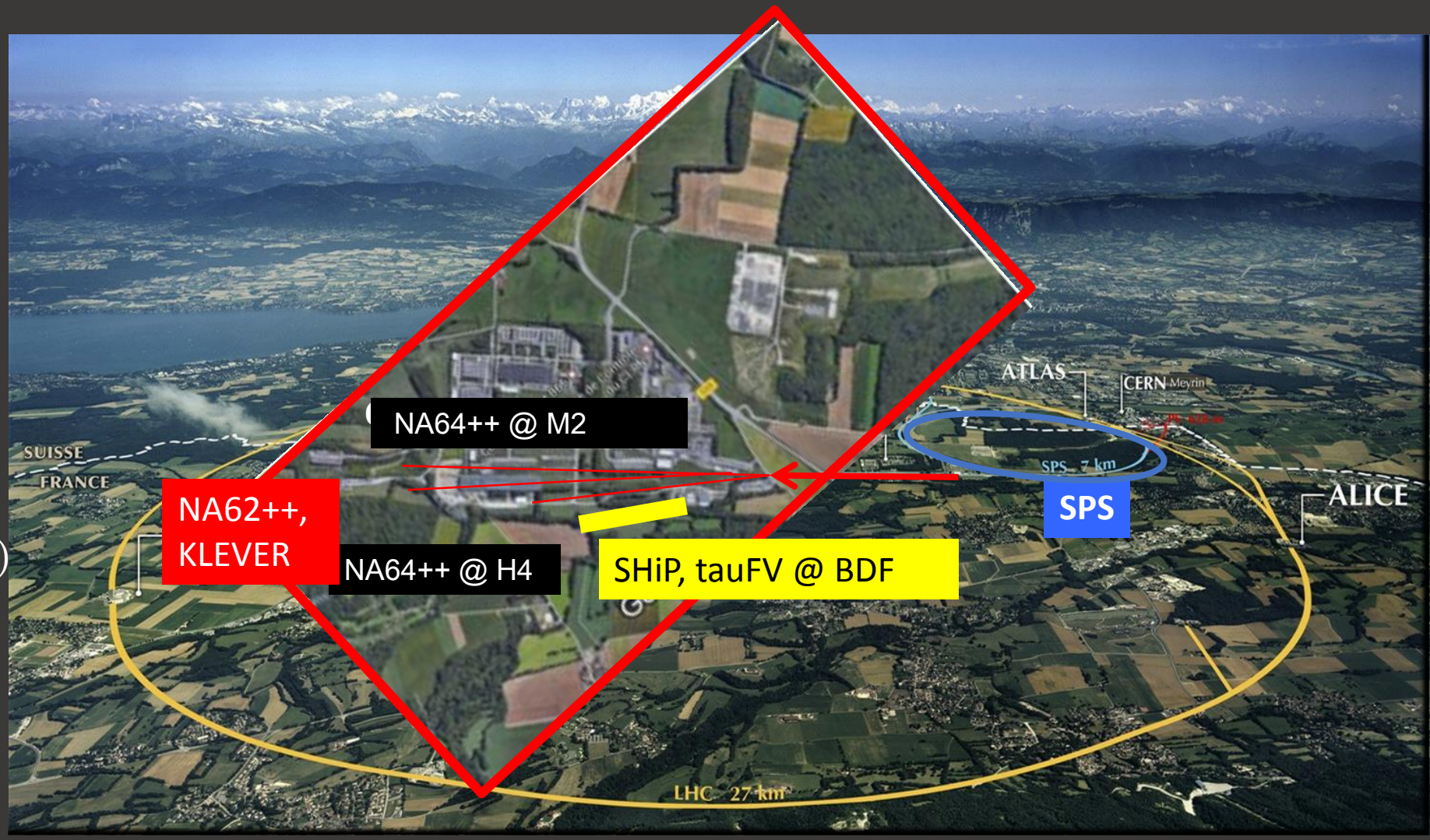
Beam lines available/proposed in the North Area

M2: 100-160 GeV, mu beam
up to 10^{13} μ/year
→ **NA64^{++} (muons)**

H4: 100 GeV e- beam
up to 5×10^{12} eot/year
→ **NA64^{++} (electrons)**

K12: 400 GeV p beam
up to 3×10^{18} pot/year (now)
→ **NA62^{++} (NA62-dump)**
up to 10^{19} pot/year (if upgraded)
→ **KLEVER**

BDF (proposed): 400 GeV p
up to 4×10^{19} pot/year
→ **SHiP, TauFV**



Highest energy proton, electrons and muon beams delivered for fixed target experiments in the world.

Conventional Beams at the North Area

Proposals followed by the CB WG - healthy mix of HS/QCD

NA61++	Run NA61/SHINE at higher intensity and with better protection
NA64++ (e,h)	Increase electron flux and optimise hadron beams in the H4 line
NA64++ (u)	Study the possibility to install and run a NA64-like experiment with muons in EHN2
COMPASS++	Study new requests from COMPASS, including a RF separated beam
MUonE	Study the possibility to implement the MuonE experiment in the M2 beam for operation with μ and e beams
NA62++	Optimise conditions for NA62 in beam dump mode for Hidden Sector searches
KLEVER	Study a new beam for a $K_L \rightarrow$ pi0nunu experiment at very high proton flux in ECN3
DIRAC++	Study implementation options for a DIRAC follow-up experiment at the SPS
NA60++	Study implementation options for a NA60 follow-up experiment with heavy ion beams

D.Banerjee, J.Bernhard, M.Brugger, N.Charitonidis, G.L.d'Alessandro, N.Doble, M.van Dijk,
L.Gatignon, A.Gerbershagen, E.Montbarbon, M.Rosenthal
on behalf of the Conventional Beams working group

Report in support of ESPP update

CERN-PBC-REPORT-2018-002 17 December 2018

PBC CONVENTIONAL BEAMS

Report from the Conventional Beams Working Group to the Physics beyond Collider Study and to the European Strategy for Particle Physics

D.Banerjee, J.Bernhard, M.Brugger, N.Charitonidis, G.L.d'Alessandro, N.Doble, M.van Dijk, L.Gatignon, A.Gerbershagen, E.Montbarbon, M.Rosenthal
on behalf of the Conventional Beams working group

Contact person: Lau Gatignon, email Lau.Gatignon@cern.ch

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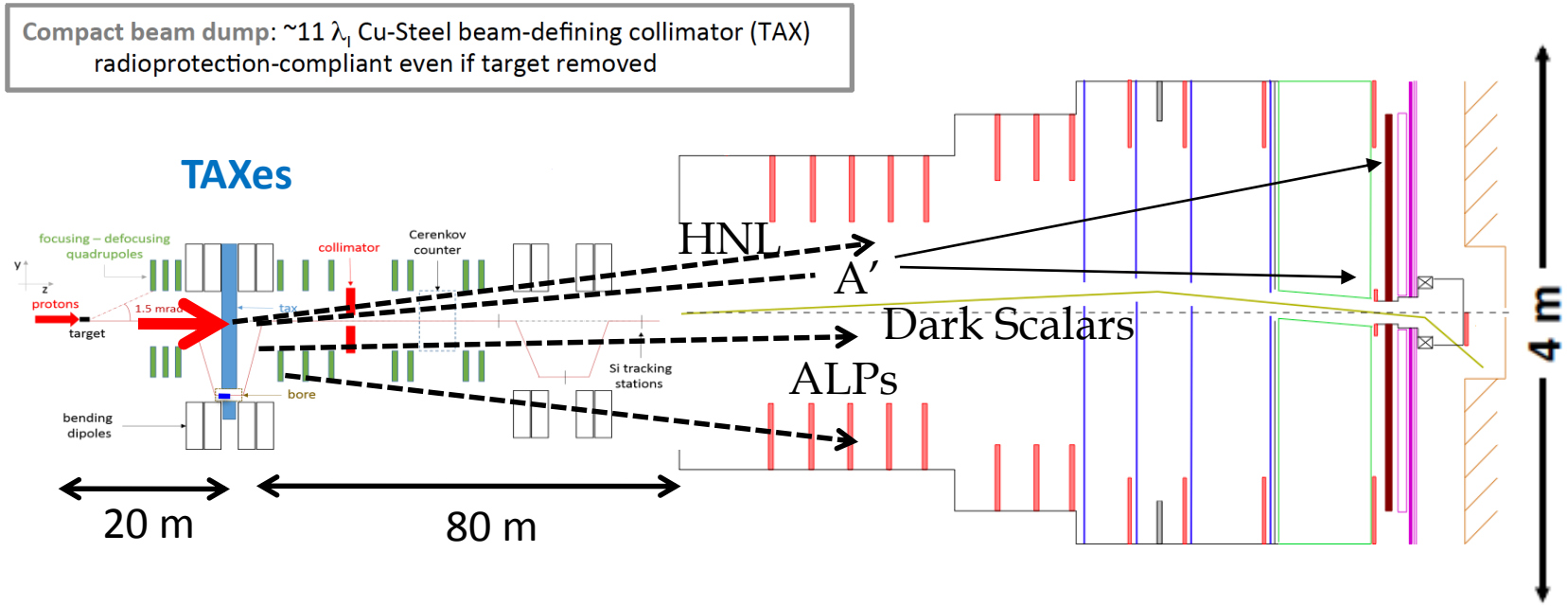
NA62++: dump mode

Transfer full proton intensity on TAX with T10 out and reduce flux of upstream pion and kaons decaying to muons.

Muons need to be efficiently swept as zero background from SM required.

Successful benchmarking of simulation with experimental data performed.

Configuration with closed TAXes and modified 1st achromat for optimum muon sweeping.



Marcel Rosenthal

NA64++: electrons, muons and hadrons

NA64++ (electrons): extension beyond 2021 to accumulate up to 5×10^{12} eot in H4

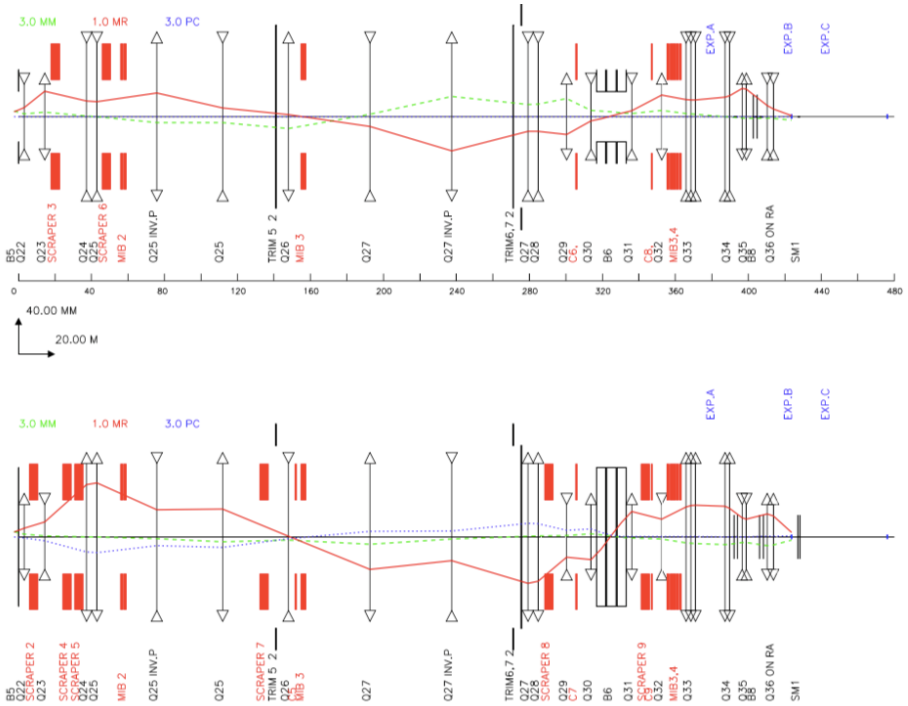
NA64++ (muons): use the 100-160 GeV muon beam in COMPASS area to study hidden sector with muon couplings. Preliminary test done in 2017 with the COMPASS setup show that the purity of the muon can be kept under control. Interplay between NA64, COMPASS and MUonE under study.

NA64++ ($K_{L,S}$, $\pi^0, \eta, \eta' \rightarrow$ invisible): produced via charge exchange reactions $\pi(K)\ p \rightarrow M^0\ n + E_{miss}$

NA64-mu - Phase 1:

- Upstream location identified in PPE211, compatible with current downstream COMPASS installations.
- Calculated optics that fulfil well user requirements.
- Study for optimisation of beam momentum measurement completed.
- Preliminary cost estimate ready for possible installation in ≧ 2021.

Phase 2: Optics ready, integration study continues…



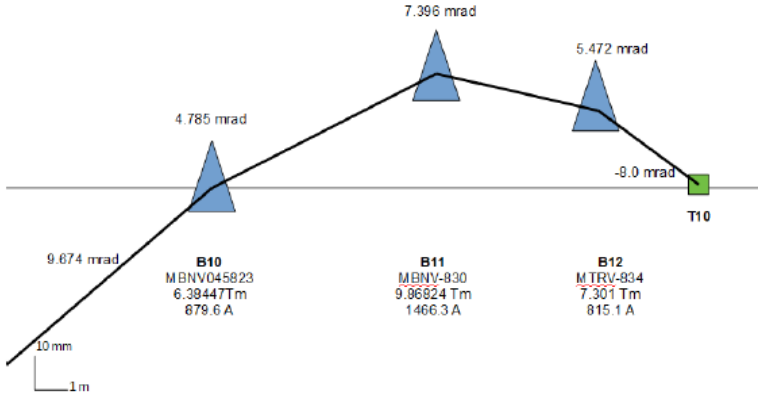
Dipanwita Banerjee
Johannes Bernhard

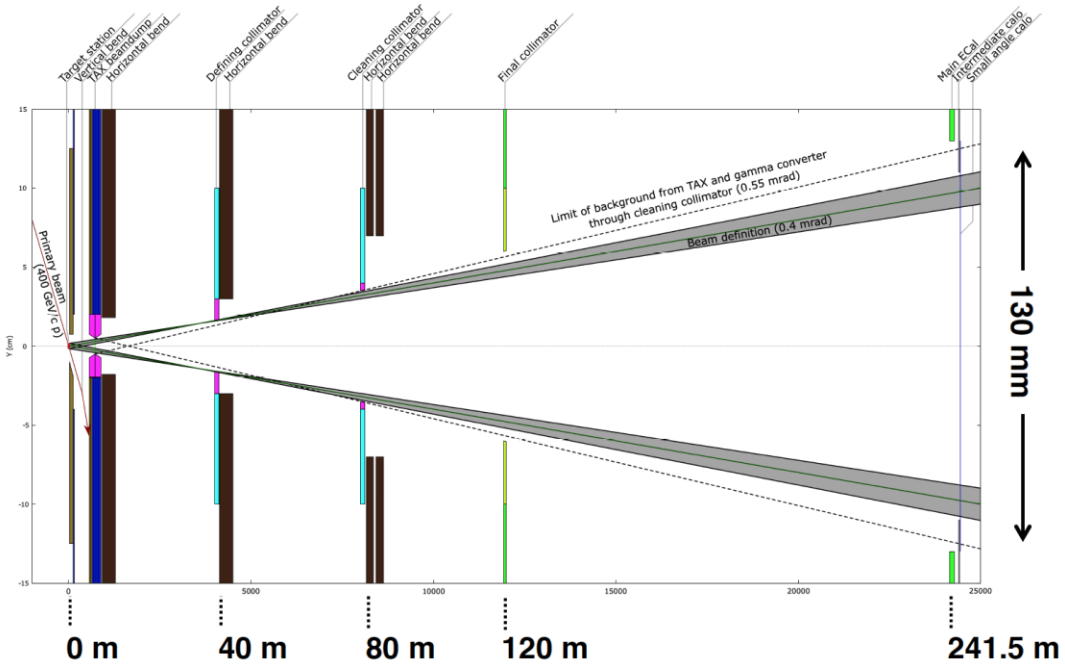
KLEVER

$K_L \to \pi^0 \nu \bar{\nu}$ BR = (3.4 ± 0.6) × 10^{-11}

Maarten van Dijk et al

Neutral beam line – decidedly non-trivial





Modification and optimization of the proton beam transport in P42 to the T10 target.
Intense target production studies:

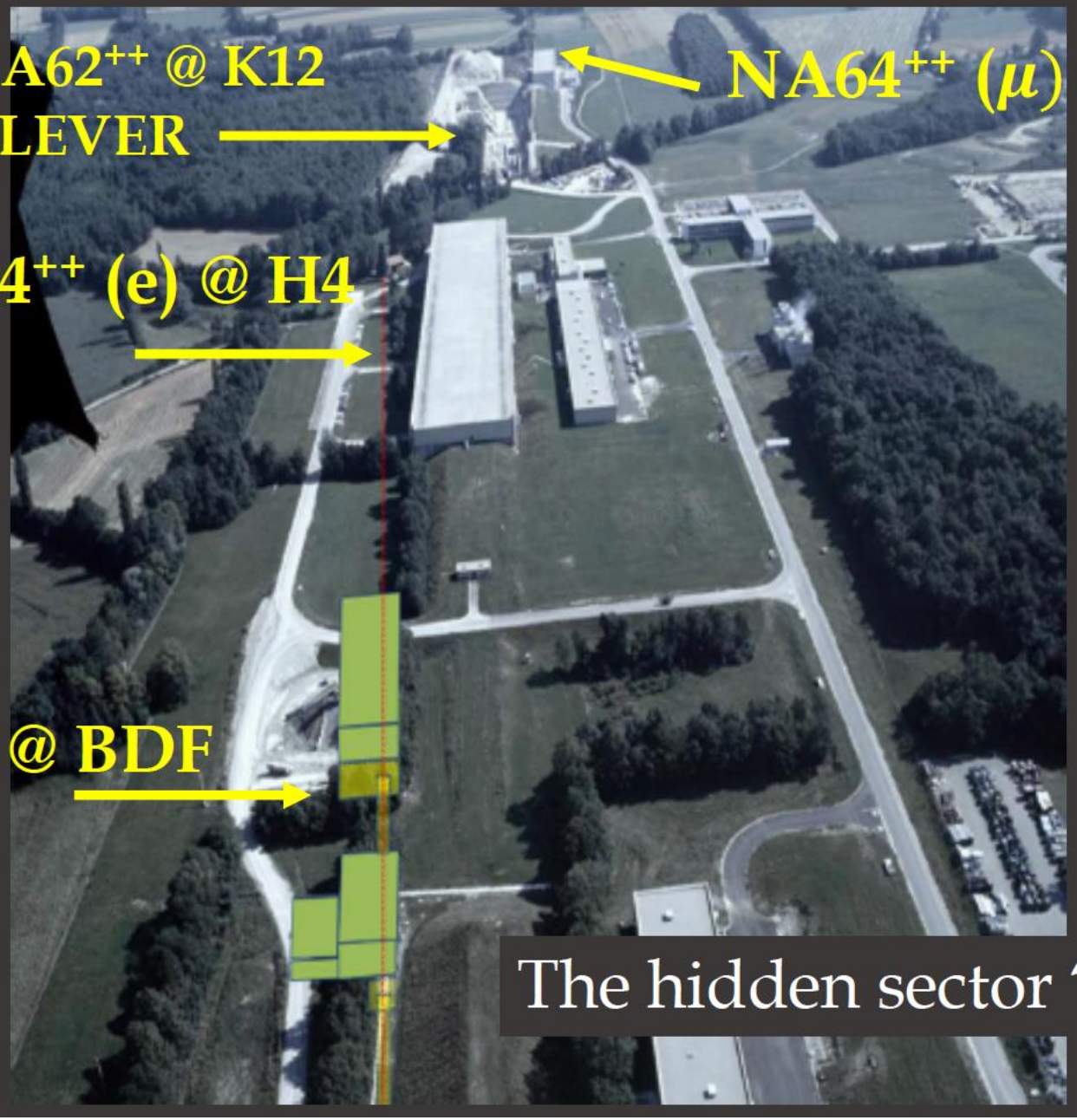
- Production angle on T10 target increased from 2.4 to 8 mrad. Λ production suppressed. Loss in K_L production compensated.

- Reduce photon background by pair conversion in photon converter, material and thickness study in FLUKA.
- Optimize configuration of 3 groups of bending magnets for reduction of muon background with full FLUKA model including magnetic fields etc…

For 60 SM events, need:
5 × 10^{19} pot
e.g. 2 × 10^{13} ppp/16.8 s × 5 yrs

7 times higher than NA62:
upgrades to target area and transfer lines (RP, target, TAXes…) required

Aerial picture of the North Area



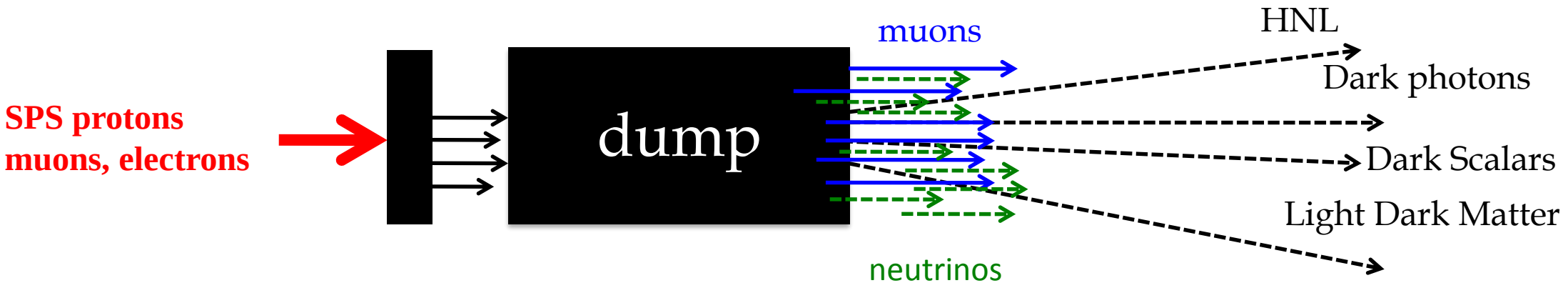
HSC

The hidden sector "campus"

Gaia Lanfranchi

Beam Dump Facilities

- BDFs ideal for exploring light super-weakly interacting particles and Light Dark Matter
  - **Luminosity** (yield of π, K, D, B decay and photons):
    - HL-LHC: ~10^{35} $cm^{-2}s^{-1}$ x 10^7 s = **10^{42} cm^{-2}**
    - SPS (1 m long high A/Z target): $4*10^{13}$ x $6*10^{24}$ cm^{-3} x 10^2 cm x 10^6 ~ **$2*10^{46}$ cm^{-2}**
    - Superior luminosity compensates for lower energy (e.g. yield of charm hadrons ~10^{16}@HL-LHC vs ~10^{18}@SPS)
  - **Geometrical acceptance**
  - **Long lifetimes**
  - **Background suppression**



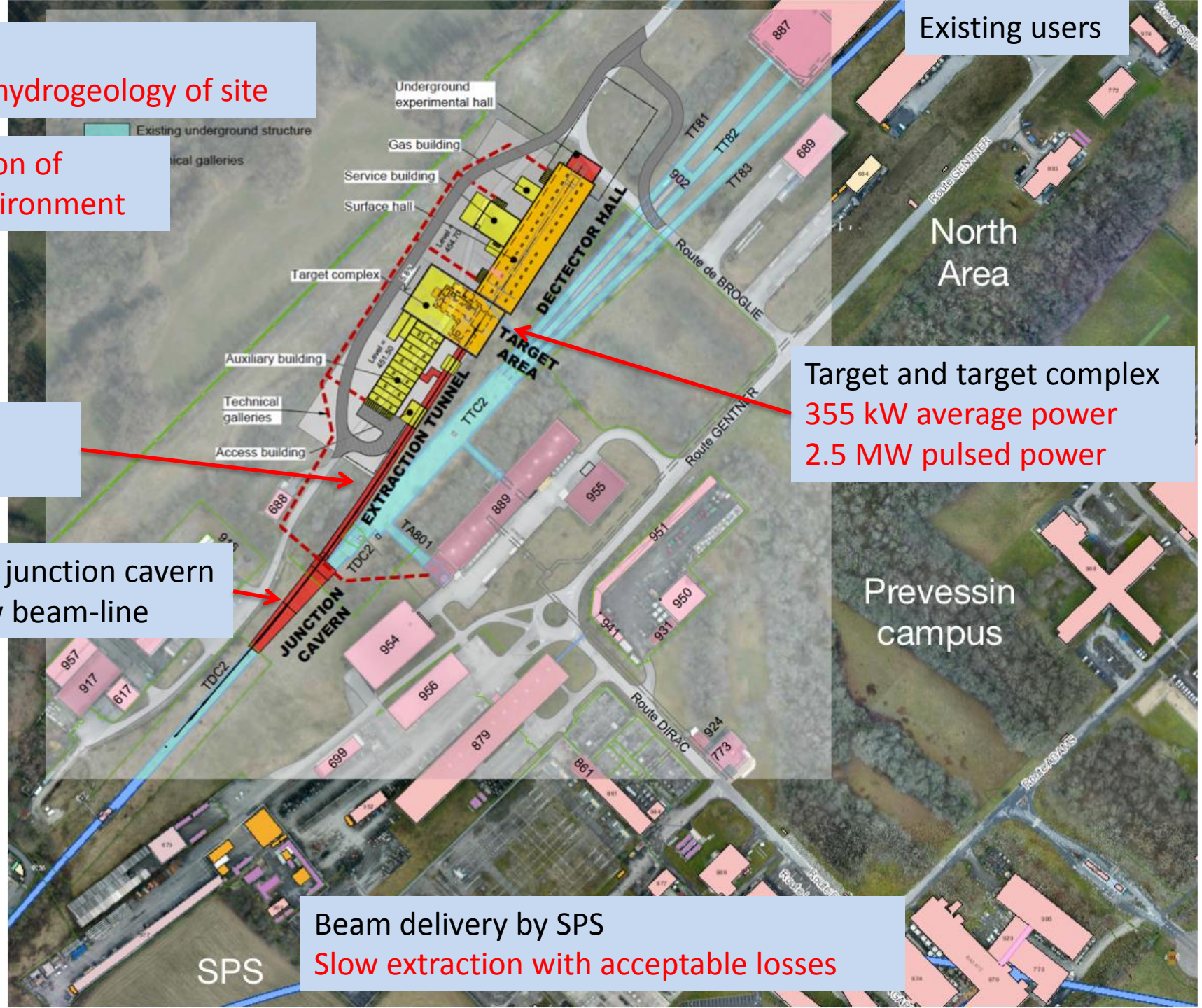
Civil engineering
Geotechnical and hydrogeology of site

Radiation protection of personnel and environment

New beam line
Beam dilution

Re-construction of junction cavern
Switching into new beam-line

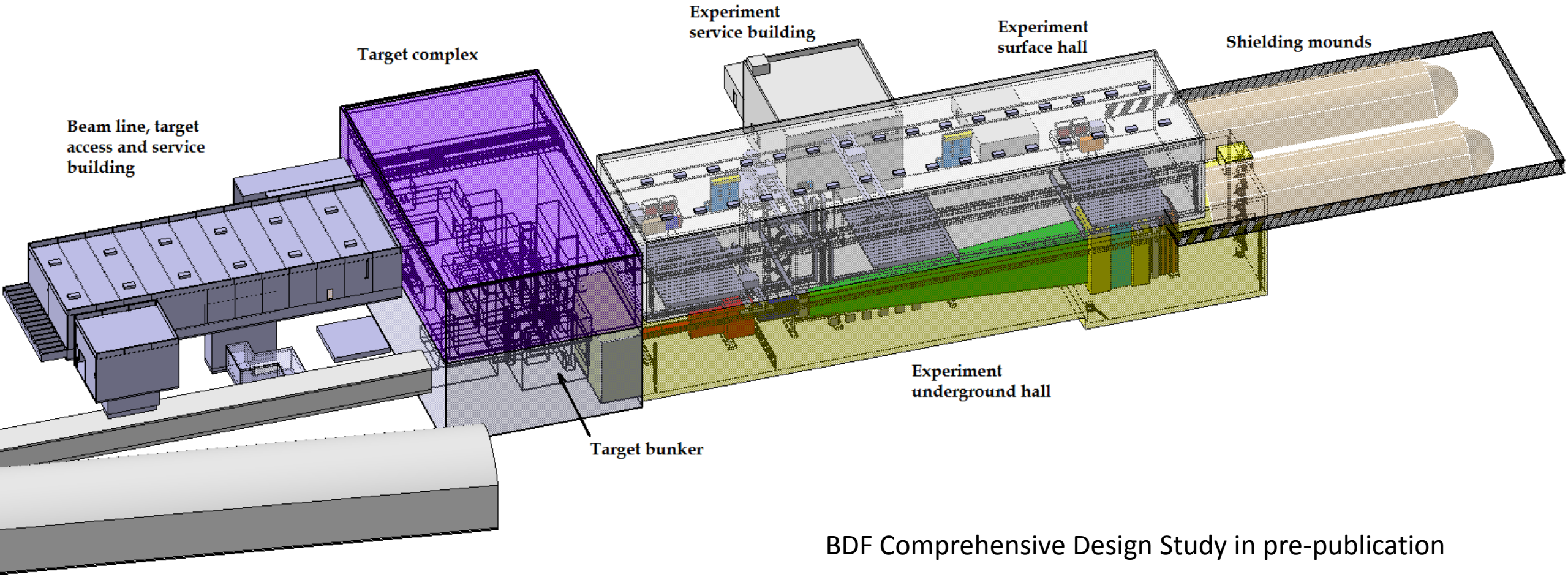
BDF



Target and target complex
355 kW average power
2.5 MW pulsed power

Beam delivery by SPS
Slow extraction with acceptable losses

Target Complex & Experiment Hall



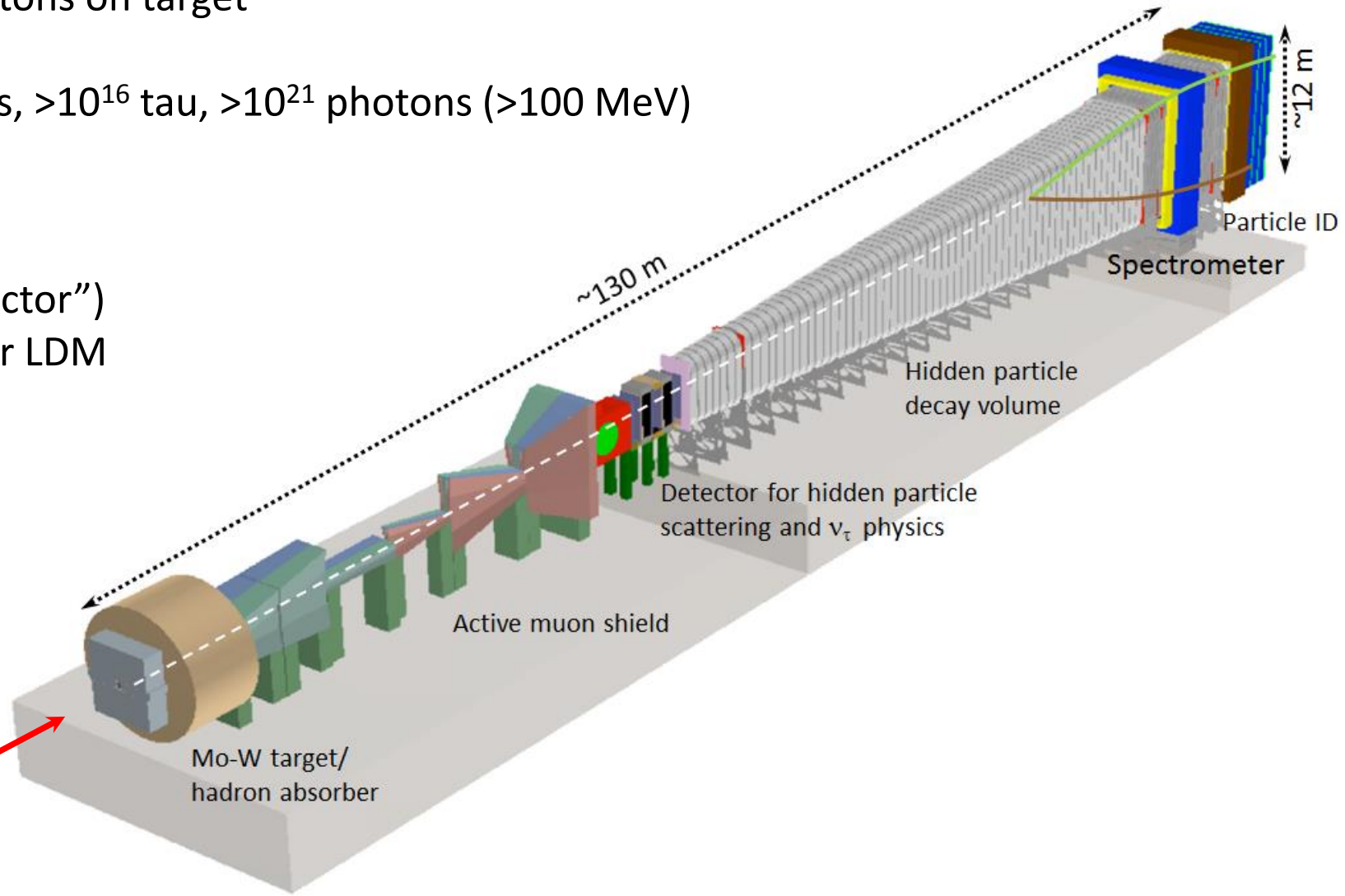
BDF Comprehensive Design Study in pre-publication

Pablo Santos Diaz

SHiP

Physics case based on $2x10^{20}$ protons on target
(5 years of nominal operation)
Signal yields from $>10^{18}$ D mesons, $>10^{16}$ tau, $>10^{21}$ photons (>100 MeV)

Dual detector system:
1. Search for HS decays ("HS detector")
2. Neutrino physics and search for LDM recoil signatures ("SND")

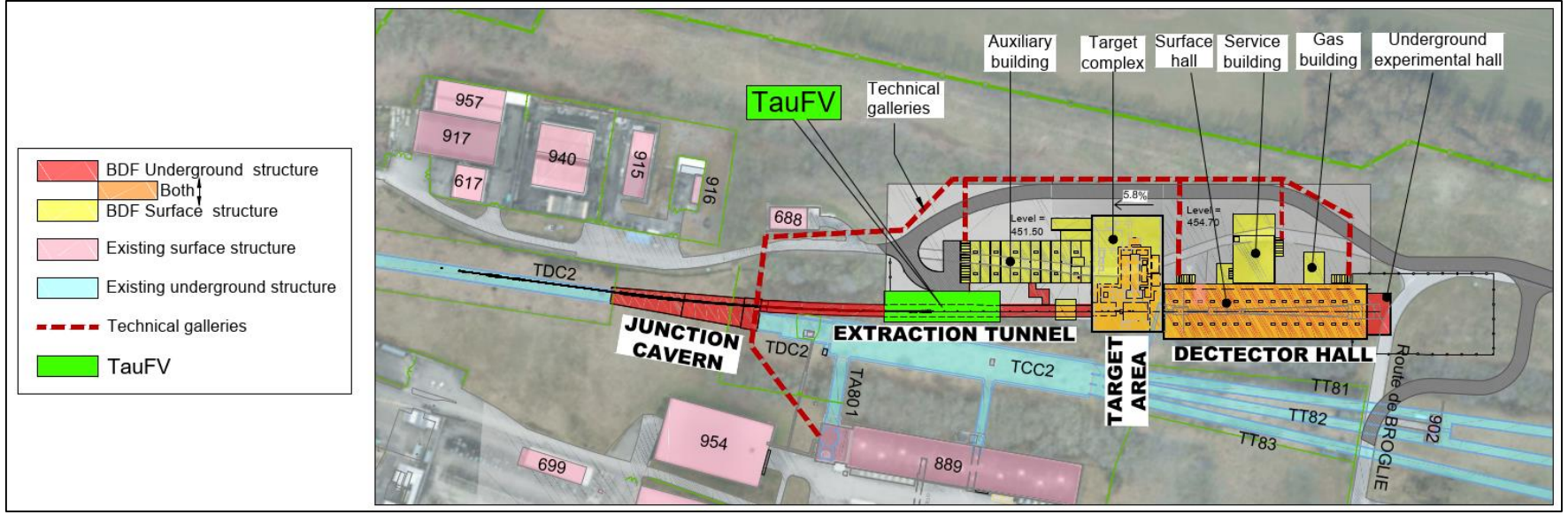


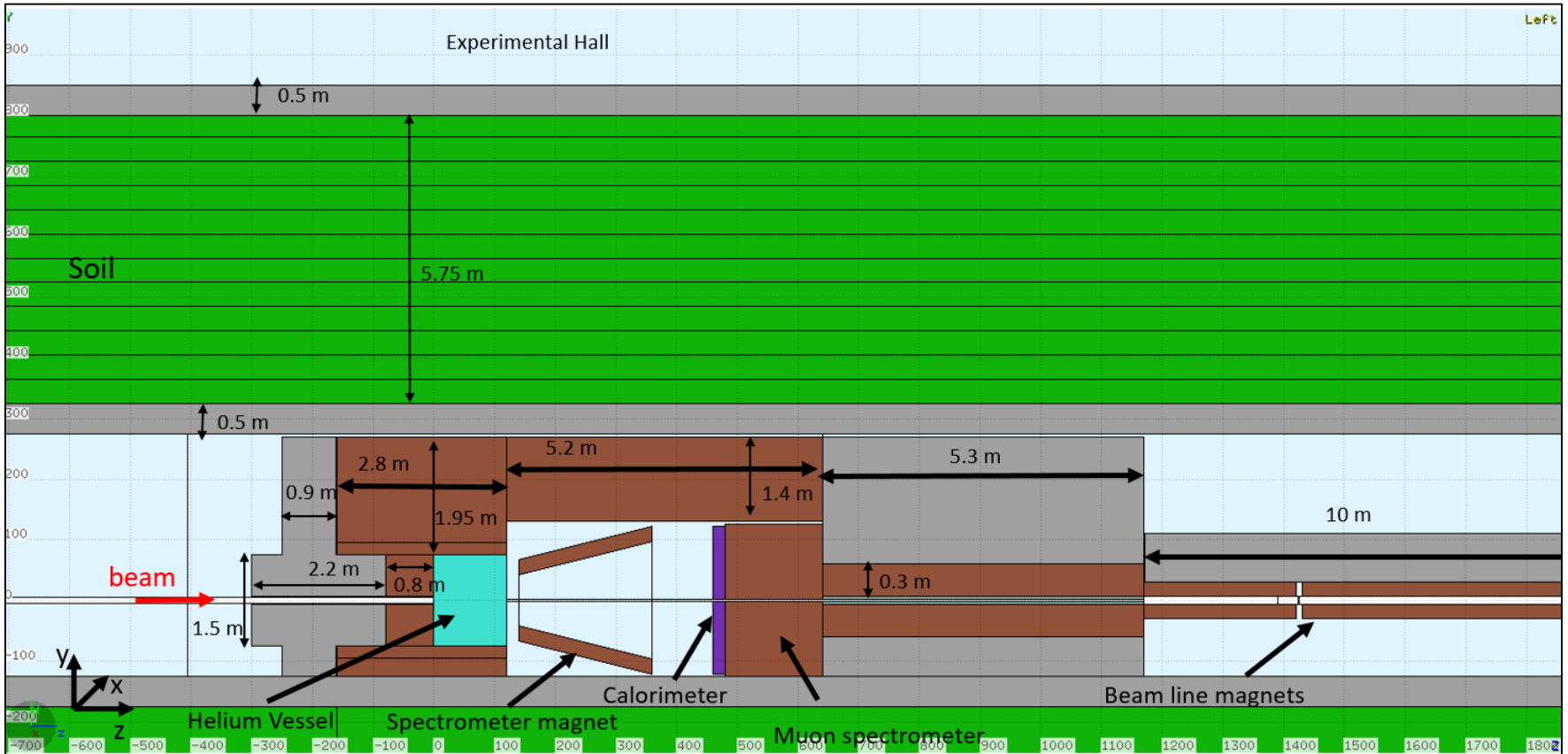
4e13 PoT/ 1 s spill

TauFV

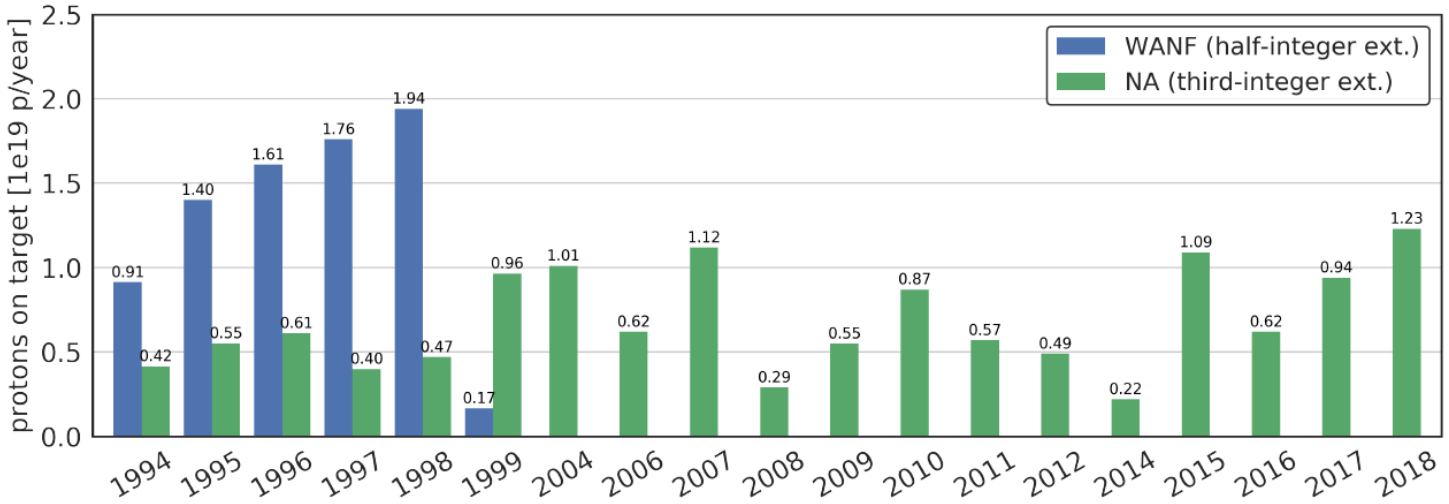
Search for Lepton Flavour Violation and rare decays

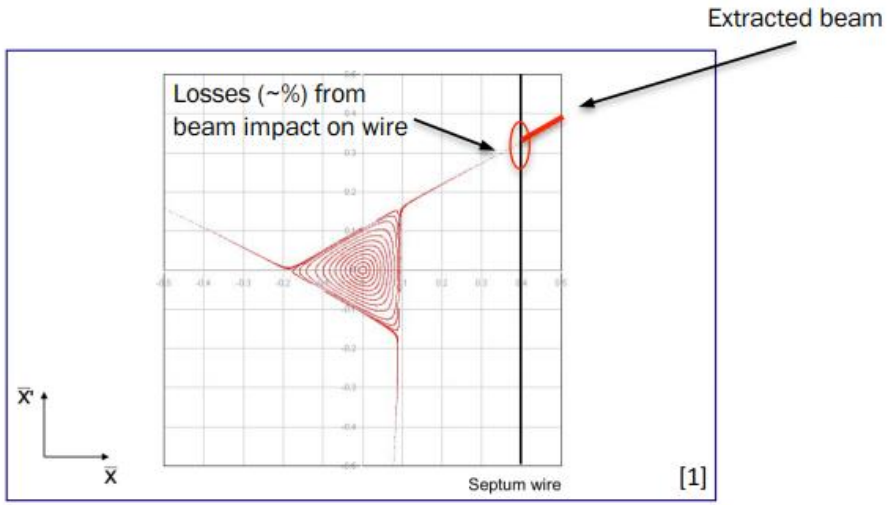
Using a thin in-line target to intercept about 2% of the intensity delivered to the SHiP target, would have access to close to 8e13 tau lepton and 5e15 D_0 meson decays

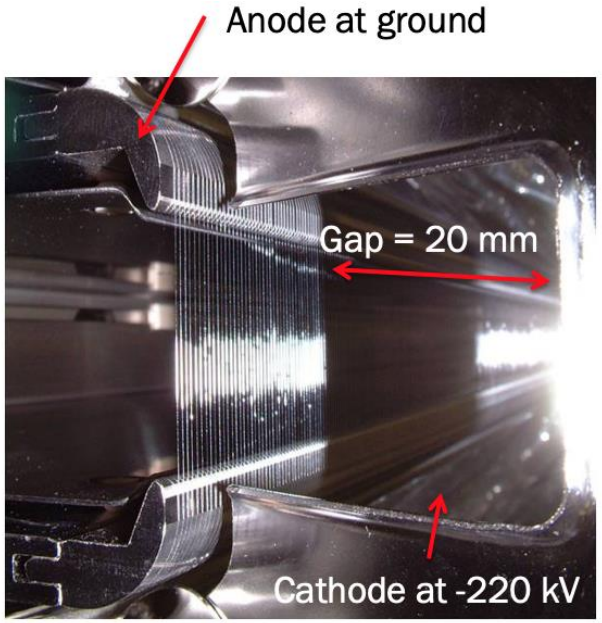




SPS beam – slow extraction



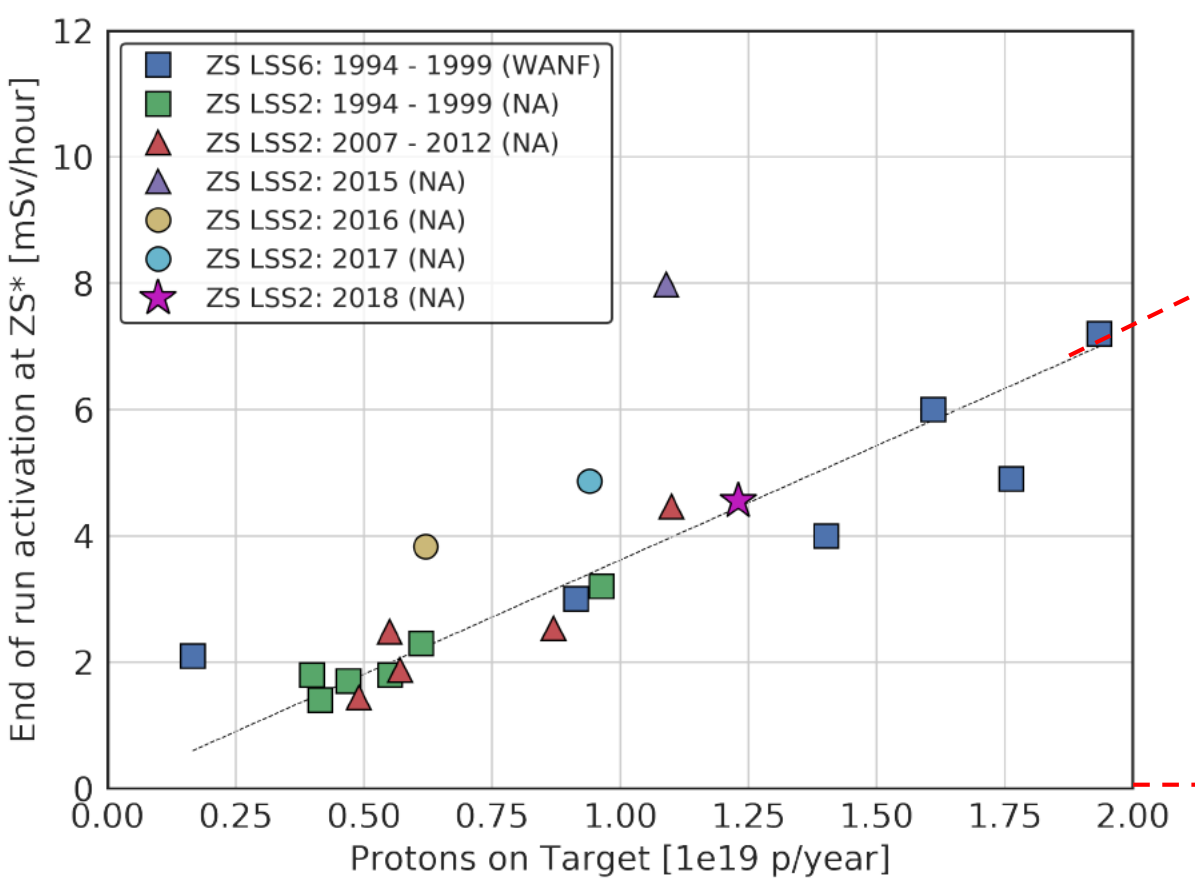




Beam loss from slow extraction is **unavoidable** and has to be **controlled and optimized**:

Induced activation in Long Straight Section 2 (LSS2) increases in direct proportion to the beam loss on the septum

Losses/activation during slow extraction



* Measured ~30h after shutdown at ~1 m from beam line, peak at ZS plotted.

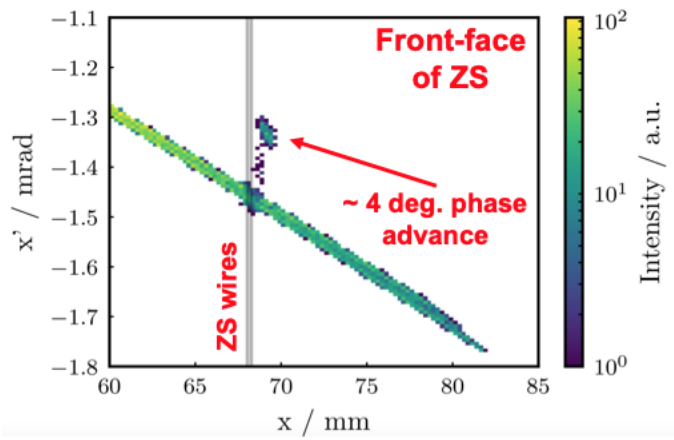
SHiP request for POTs demands a **factor of x 4 - 5 loss reduction** to keep future activation levels in LSS2 comparable to today:

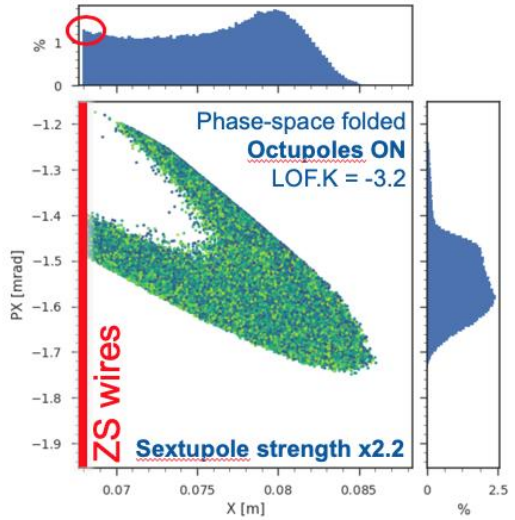
- 4E19 POT for SPS BDF and ~ 1E19 POT for North Area parallel operation

4e19

Major effort to reduce losses

- Implementation of dynamic optics control (COSE) to hold separatrix stationary during spill
- Thin bent crystal installed upstream ZS
  - Crystal channeling creates depleted density region at ZS wires
- Apply higher-order multipole fields during extraction:
  - Reduce density of beam impinging the ZS wires: **35 – 45%**
  - At the expense of increasing extracted beam emittance





Driven and supported by the members of SPS-CASE WG and SLAWG

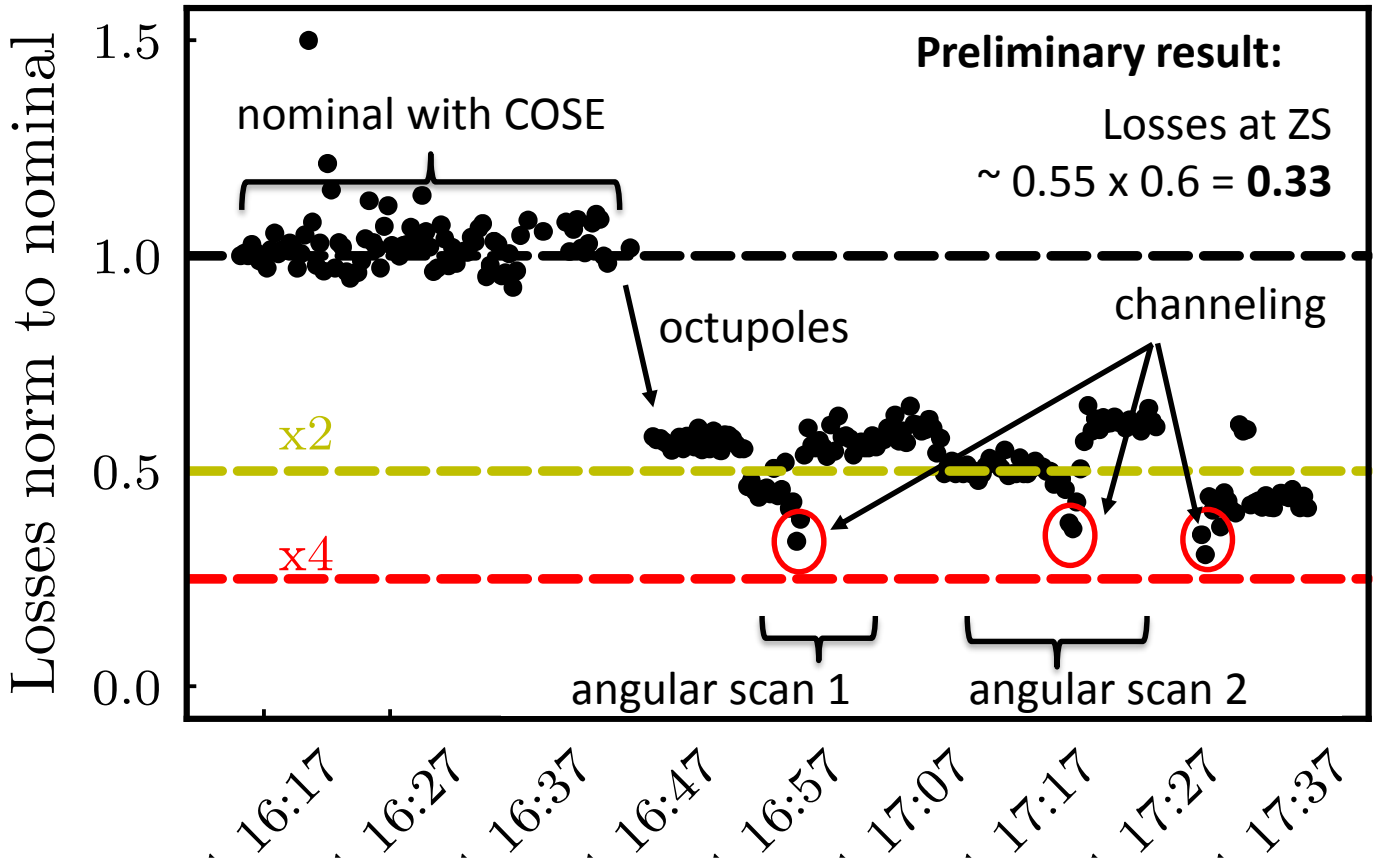
Fruitful collaboration between a large number of groups and experimental collaborations!

Dedicated R&D effort including 2 PhD thesis topics

Brennan Goddard, Matthew Fraser et al

Combining techniques

Crystal inserted and aligned with **octupoles** during afternoon of 1st November 2018:



In 2018, different loss reduction concepts were validated in MD tests:

- Included passive and active diffusers (crystal shadowing of ZS) and phase space folding
- Factor of ~ 3 - 4 loss reduction at ZS demonstrated
- Scope for further loss reduction improvement

The magic factor of 4 - 5 reduction to accommodate SHiP/BDF does appear to be in reach!

THE EXTERNAL PROTON BEAM LINES

AND THE SPLITTER SYSTEMS OF THE CERN SPS

L. Evans, A. Hilaire, A. Ijspeert, B. de Raad, N. Siegel, E. Weisse

Paper presented at the 1977 Particle Accelerator Conference - Chicago
March 16 - 18, 1977.

3. The North Area Beam Transfer Lines

The beam lines to the North Area have been designed for 400 GeV/c. The geometry is shown in Figure 3.

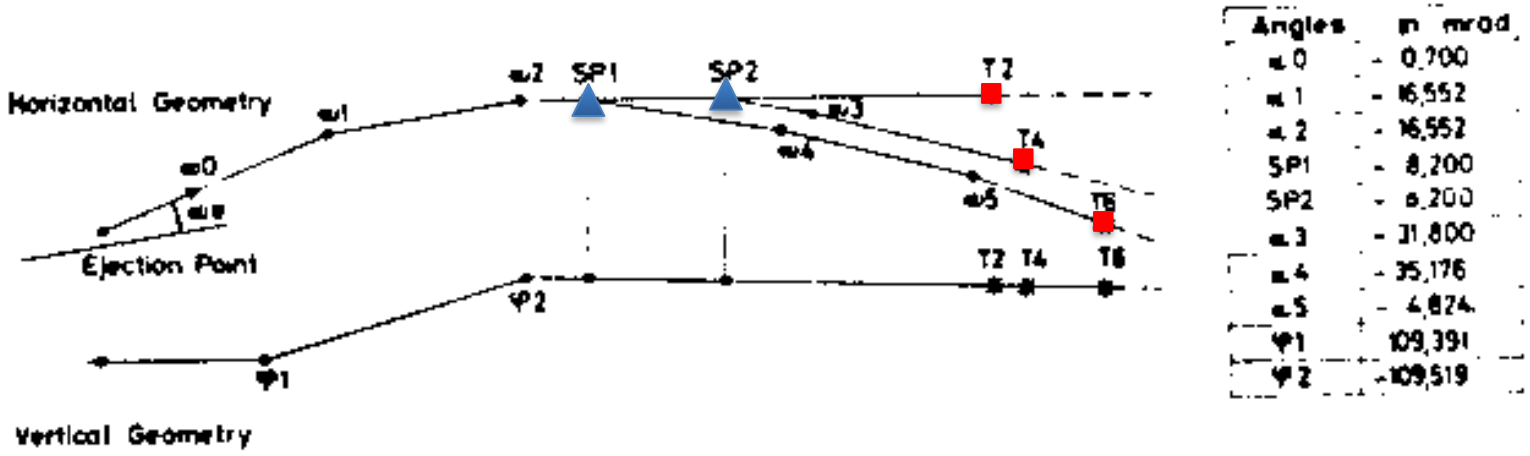


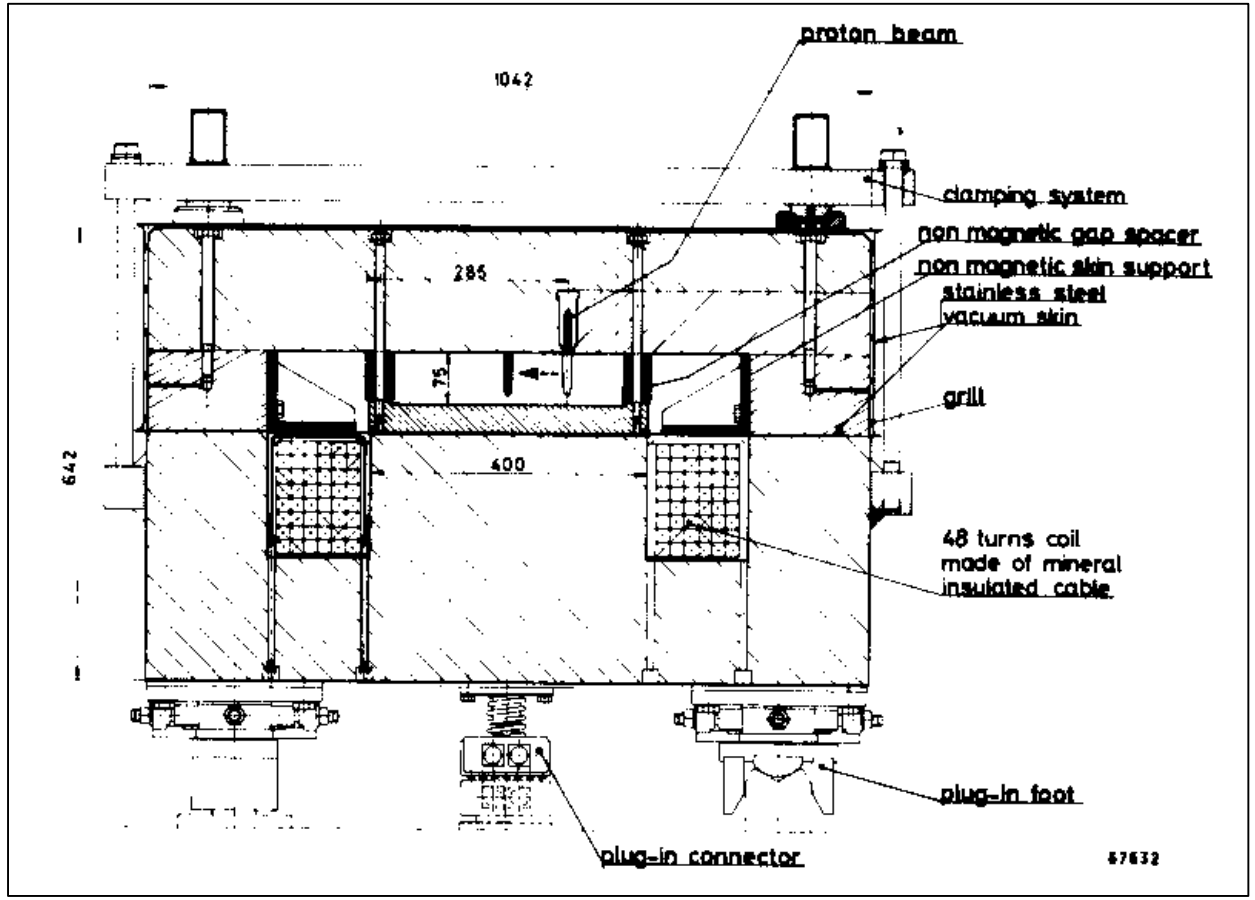
Fig. 3 Geometry of the proton beam lines to the North Area

THE STEEL SEPTUM MAGNETS FOR BEAM SPLITTING AT THE CERN SPS

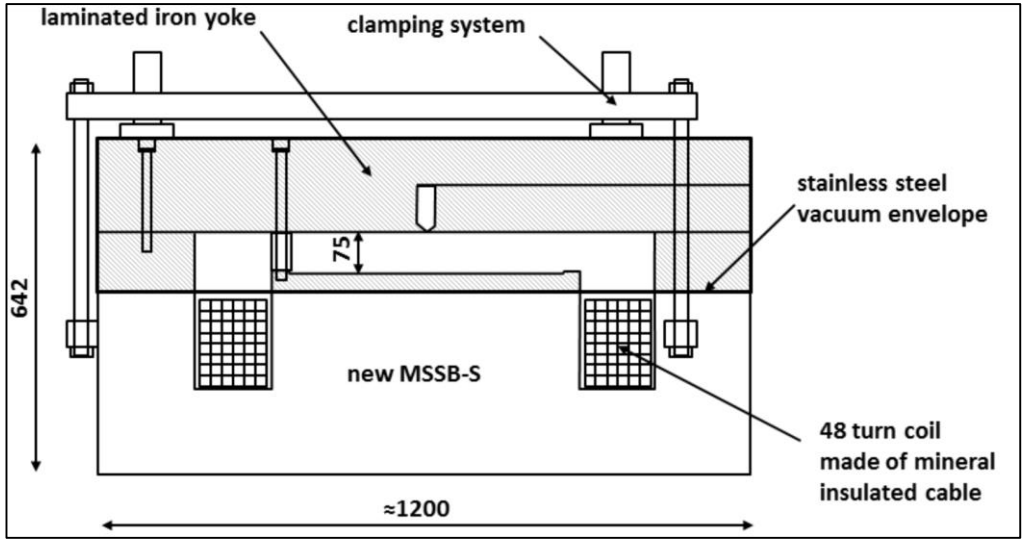
by

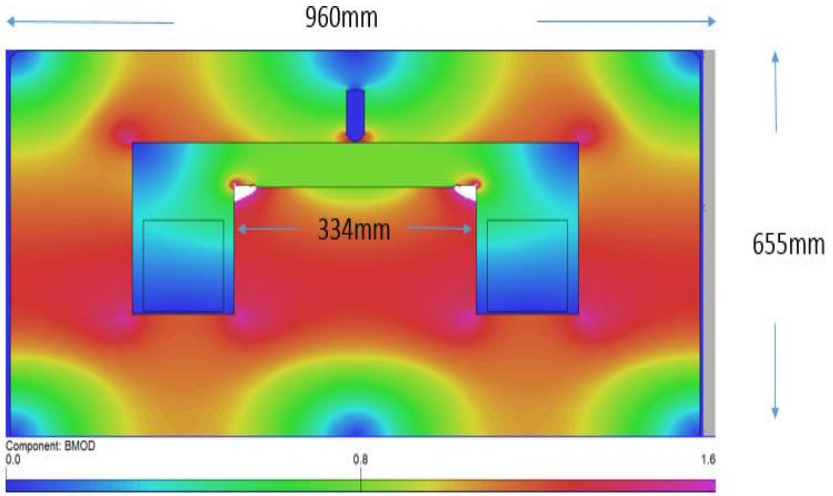
L. Evans, A. Ijspeert, B. de Raad, W. Thomi, E. Weisse

CERN-SPS/ABT/77-13

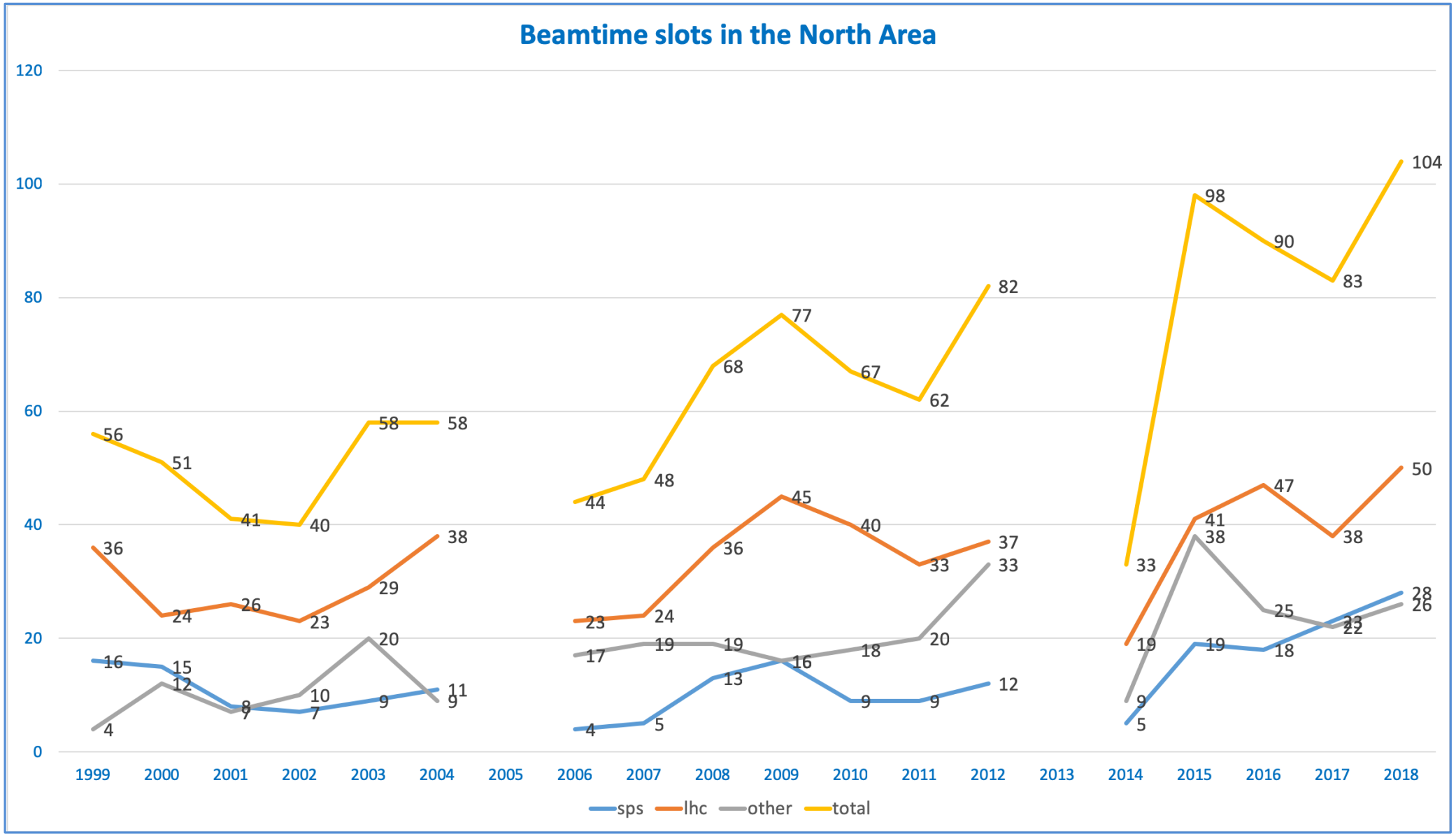


New laminated bipolar splitter/switch with reduced saturation



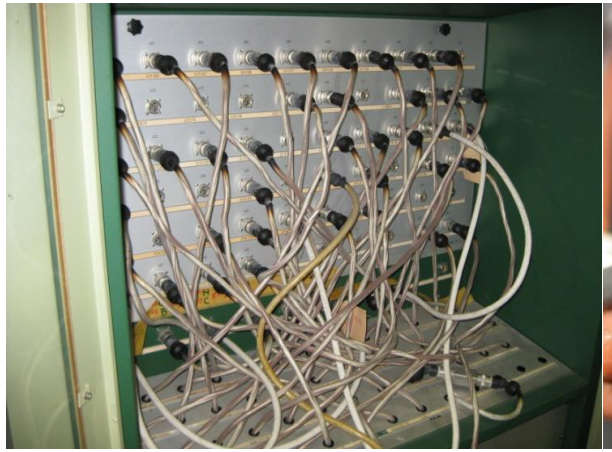


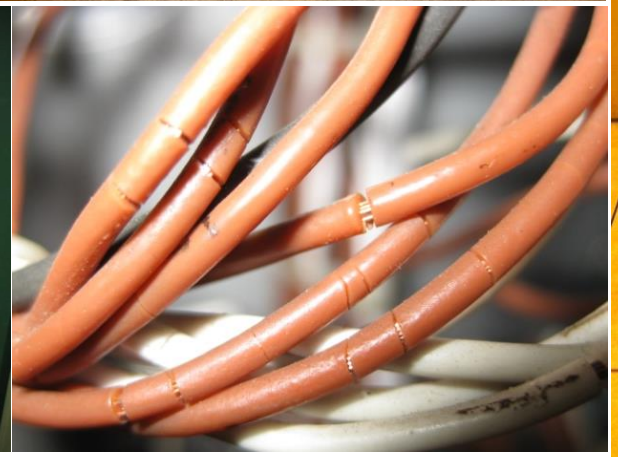
Jakub Kurdej

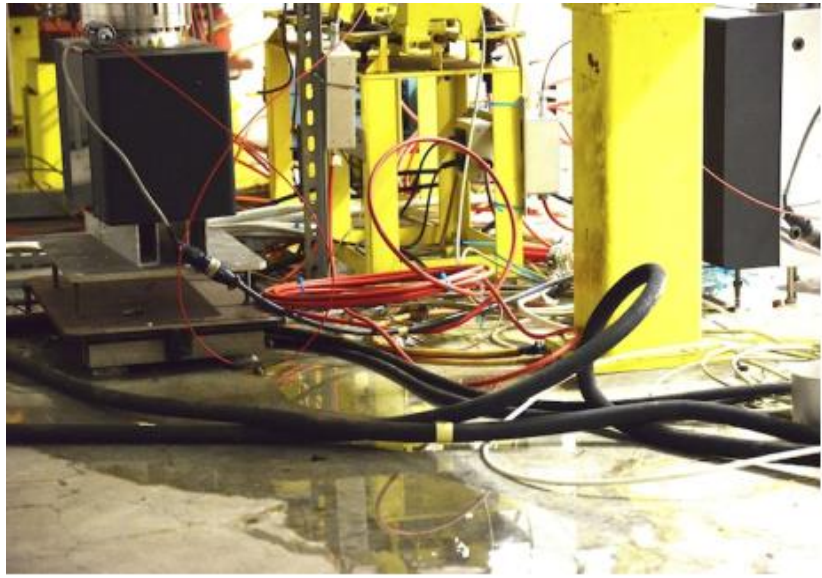


Henric Wilkens

Some loving care and attention required!







Yacine Kadi

NA: the future is colourful and dark and interesting!

Physics motivation remains strong

- The North Area is an ideal place to search for Hidden Sector at with NA62, NA64, SHiP etc. in < O(10) GeV range
- Unique QCD possibilities

SPS is adapting well to the foreseen challenges

NA remains vitally important as a test facility