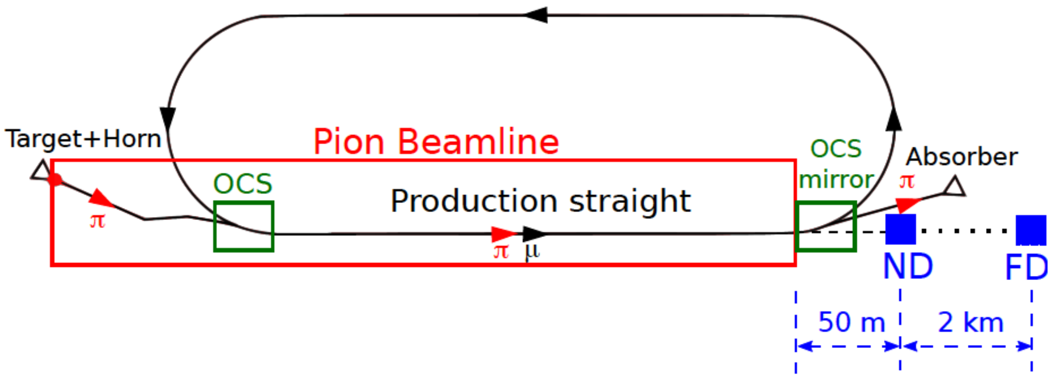


nuSTORM
and the Physics Beyond Colliders workshop

Joerg Jaeckel, Mike Lamont, Claude Vallée
16th February 2017

Three main scientific pillars

Full exploitation of the LHC → over the period of this MTP:

- ❑ successful Run 2, LS2, and Run 3 start-up
- ❑ construction and installation of LIU; on-track construction of HL-LHC

Scientific diversity programme serving a broad community:

- ❑ ongoing experiments and facilities at Booster, PS, SPS and their upgrades (ELENA, HIE-ISOLDE)
- ❑ participation in accelerator-based neutrino projects outside Europe (presently mainly LBNF in the US) through CERN Neutrino Platform

Preparation of CERN's future:

- ❑ vibrant accelerator R&D programme exploiting CERN's strengths and uniqueness (including superconducting high-field magnets, AWAKE, etc.)
- ❑ design studies for future accelerators: CLIC, FCC (includes HE-LHC)
- ❑ future opportunities of diversity programme (new): "Physics Beyond Colliders" Study Group

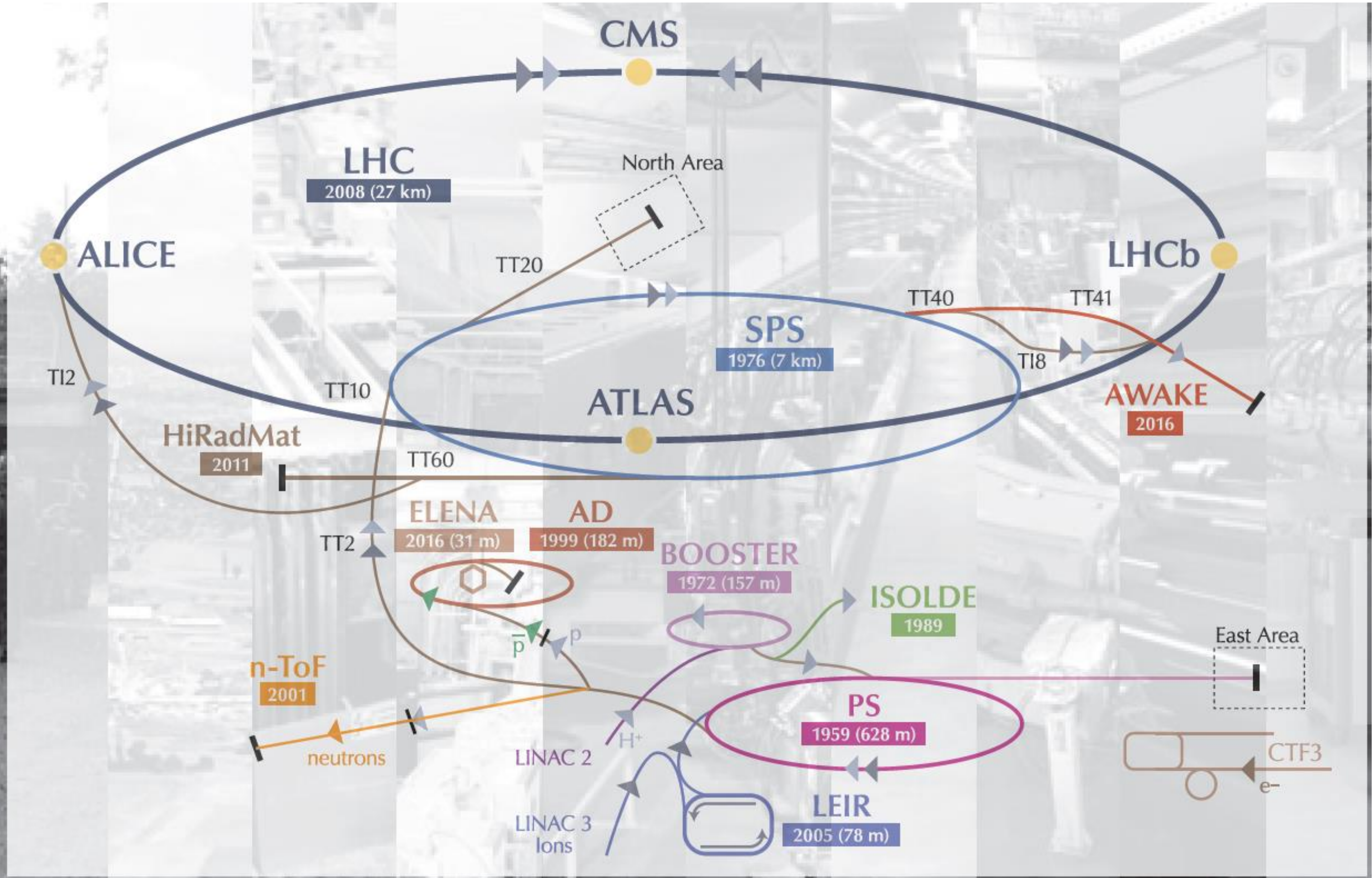
Important milestone: update of the European Strategy for Particle Physics (ESPP): ~ 2019-2020
→ 10-year view has uncertainties beyond 2020 for part of programme other than LHC upgrade

Fabiola Gianotti SPC May 2016

PBC - scientific goal

- Explore the opportunities offered by the CERN accelerator complex to address some of today's outstanding questions in particle physics
- These experiments would typically:
  - enrich and diversify the CERN scientific program,
  - exploit the unique opportunities offered by CERN's accelerator complex and scientific infrastructure,
  - complement the laboratory's collider programme (LHC, HL-LHC and possible future colliders).
  - Examples of physics objectives include searches for rare processes and very-weakly interacting particles, measurements of electric dipole moments, etc.

This study should provide input for the future of CERN's scientific diversity programme, which today consists of several facilities and experiments at the Booster, PS and SPS, over the period until ~2040.



What’s not in!

Medical applications
Beta beams
ADSR
Short baseline neutrino
Long baseline neutrino
g-2
Mu2e
AWAKE (as a project)
Neutrino platform
FCC era variations

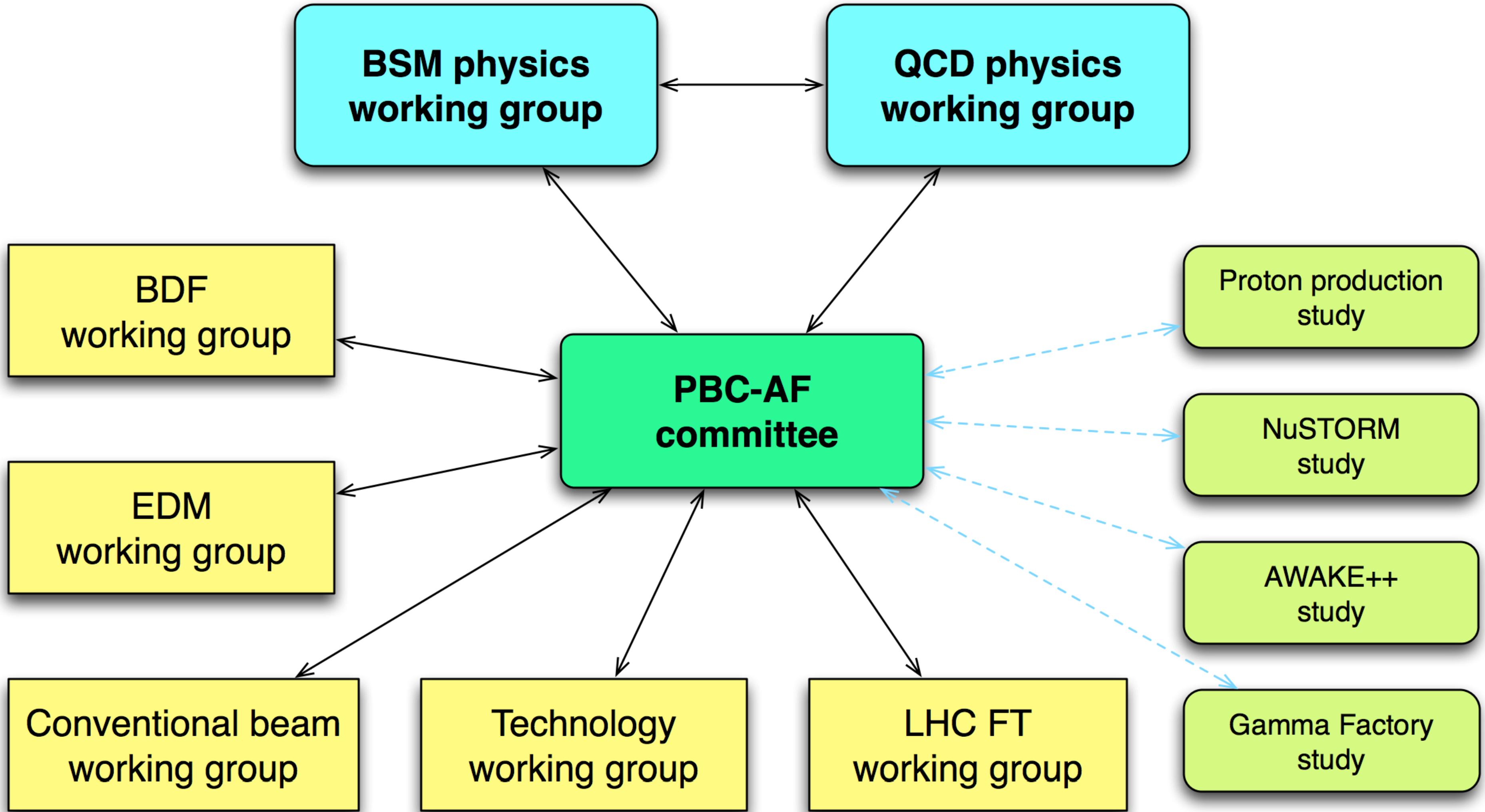
Working groups

- Working Groups have been set up to address:
  - the physics case of the proposed projects in the worldwide landscape
  - their feasibility and possible implementation at CERN (or elsewhere)

… with involvement being tuned to the level of maturity of the projects

- First general working group meeting 1-2 March
  - Present plans, deliverables, timeline, resources
- Follow-up PBC workshop foreseen in autumn 2017.

Organization



Please bear in mind the competition for resources at CERN

Foreseen deliverables

COMPLEX	Fully developed proton performance plan – post LIU
BDF	Complete technical feasibility studies – input to SHIP CDS
EDM	Fully developed proposal including preliminary costing
CONV. BEAMS	Establish requirements, initiate feasibility studies
LHC FT	Preliminary conceptual design report
GAMMA	Exploratory study, initiate initial tests
nuSTORM	• **Exploratory study of implementation at CERN** • **Review potential scientific impact**
AWAKE+	Exploratory study

Technology	• Explore possible technological contributions by CERN to externally hosted facilities • Document actual use of CERN infrastructure • Facilitate potential use of CERN infrastructure • Study physics case and technical requirements as input to ESU

Physics domain

- For each proposed project deliverables will include:
  - evaluation of the physics case in the worldwide context;
  - possible further detector optimization;
  - and, for new projects, investigation of the uniqueness of the CERN accelerator complex for their realization.
  - The subgroup core members include theory and experimental experts of the corresponding domains as well as representatives of the projects.
- **Physics sub working groups:**
  - **BSM subgroup:** current projects: SHIP/NA64++/NA62++/KLEVER/IAXO/LSW/EDM
  - **QCD subgroup:** current projects: COMPASS++/μ-e/LHC FT (gas target+crystal extraction) / DIRAC++/ NA60++/NA61++

Felt that nuSTORM physics case has been well elucidated

Deliverables

- Final deliverable due end 2018: summary document as input to the European Strategy Update process (2019-20).
- Will gather and summarize the status and potential of the projects (no ranking!) to help facilitate the update of the ESPP by the ESG group.

The remit of the ESG is to establish a proposal for an Update of the medium and long-term European Strategy for Particle Physics, for approval by the Council.

nuSTORM…

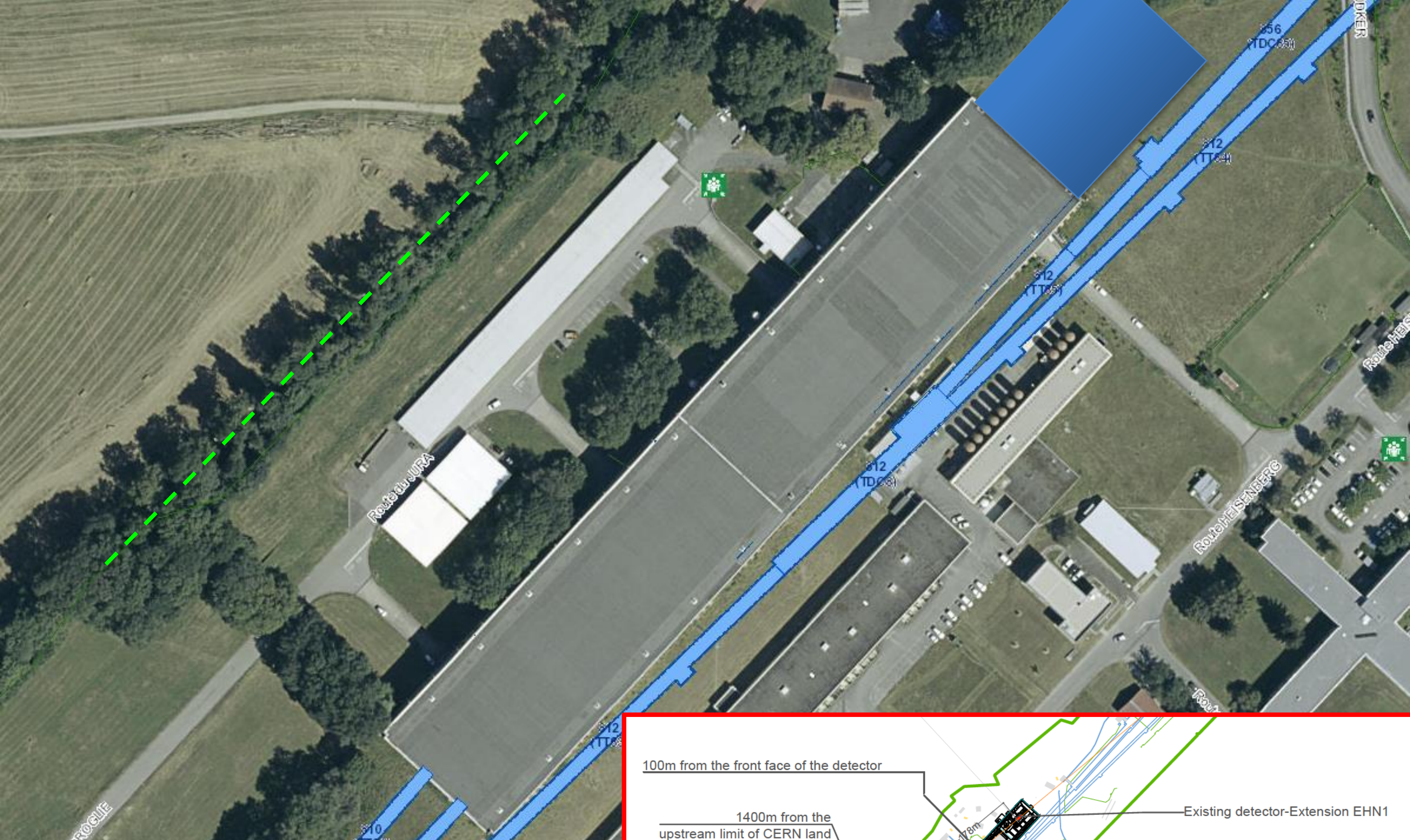
- The program is well developed – little to add CERN side in the short term
- **Exploratory study of implementation at CERN**
- We're time limited – end 2018
  - Preliminary feasibility – no given level (this is not a CDR)
- Minimal resources
  - CERN would be willing to host if required
  - But established network of experts…
- Possible synergies
  - ENUBET, AD target (re-design ongoing)
  - Material R&D
  - CENF, BDF

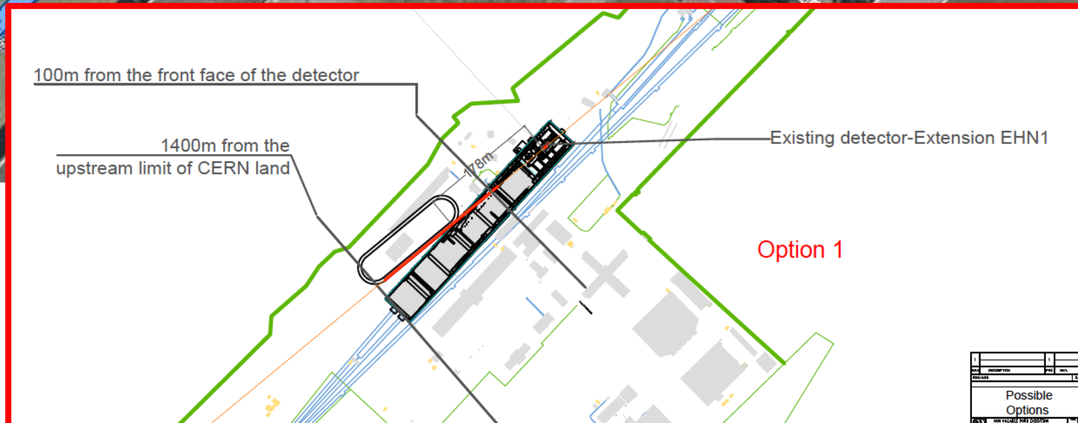
“Exploratory study”

- A credible proposal for siting at CERN taking into account:
  - SPS requirements POT/year, beam parameters, other potential users
  - Fast extraction, beam-line
  - Target and target complex, absorber
  - Horn: engineering, simulation, energy deposition
  - Siting of target and target complex, ring
    - radiation protection considerations…, interference...,
  - Civil engineering
    - preliminary study might be possible – resources required
  - RP implications, target, environment, muon fluxes near surface etc. etc.

Probably not…

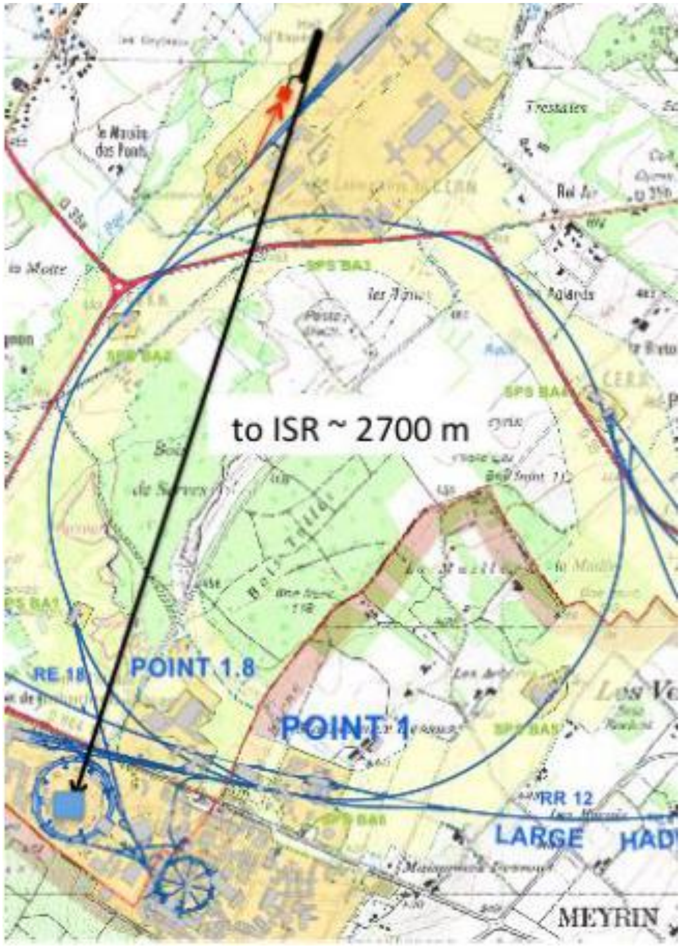
- Services
  - Cooling, ventilation, electricity…
- Components
  - Power supplies, Instrumentation, Vacuum, Magnets
- Site specific infrastructure
- Cost

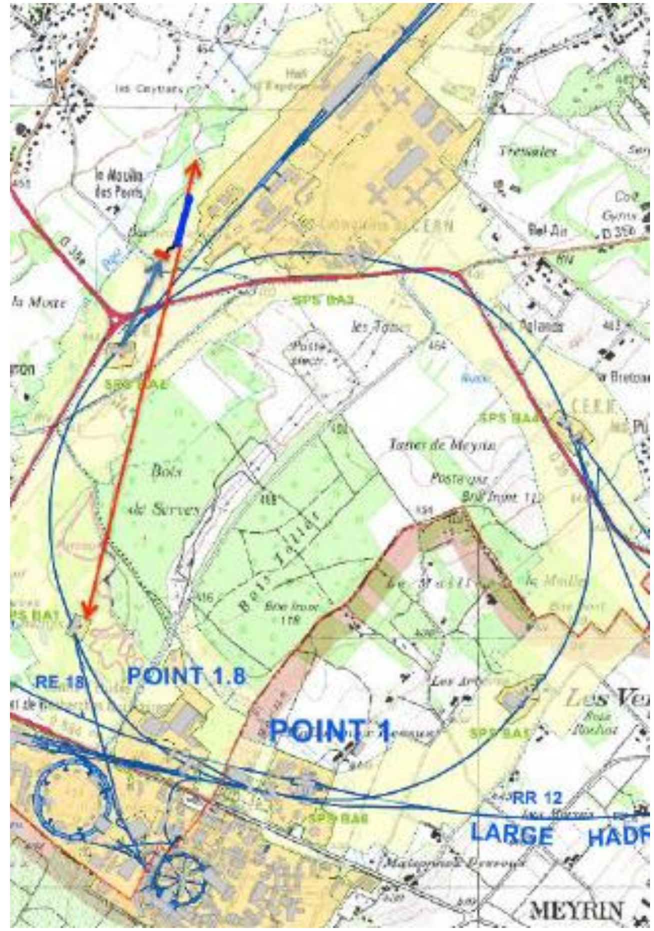




“Ring “just” below surface provides shielding”

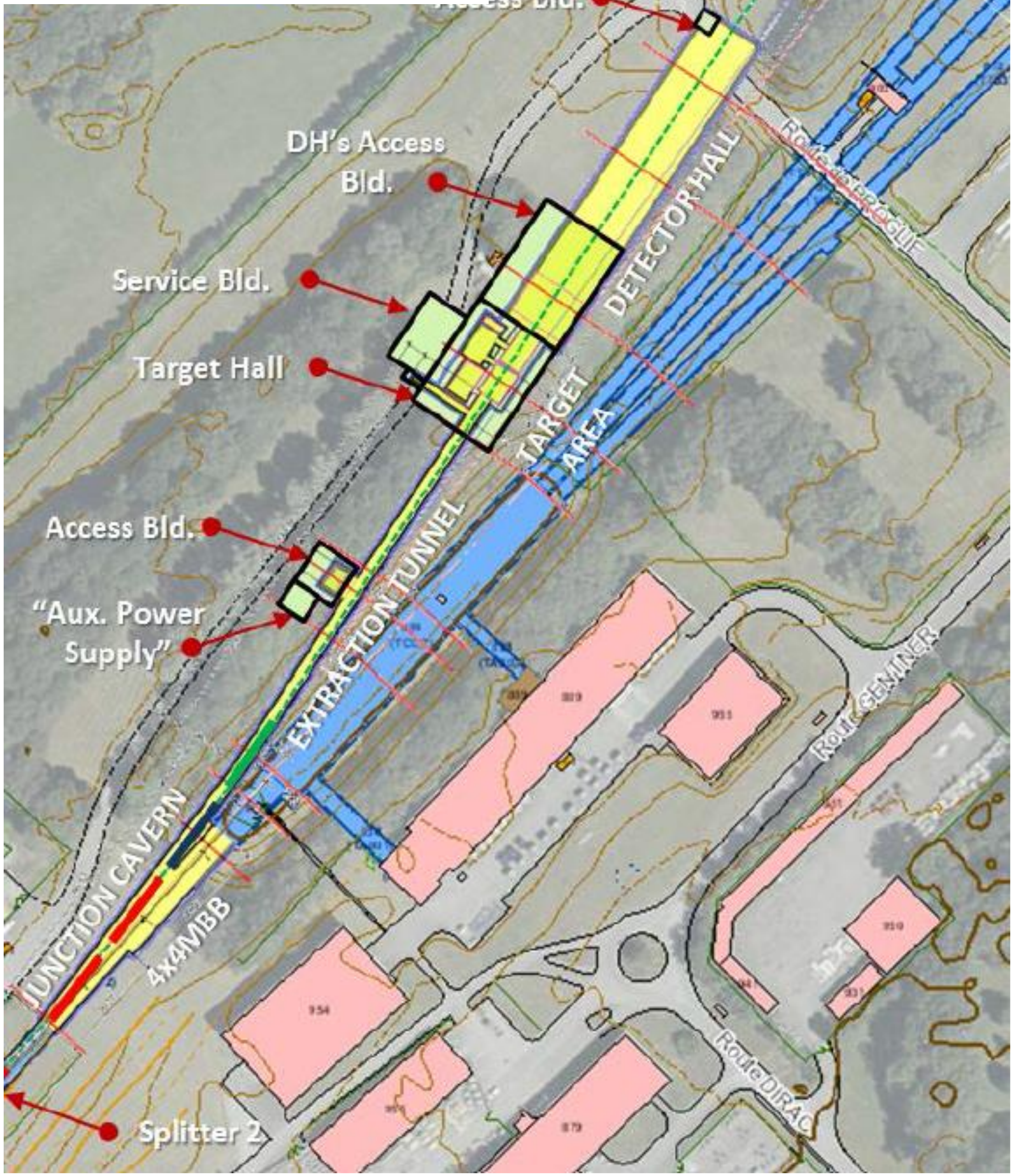
Options 2013



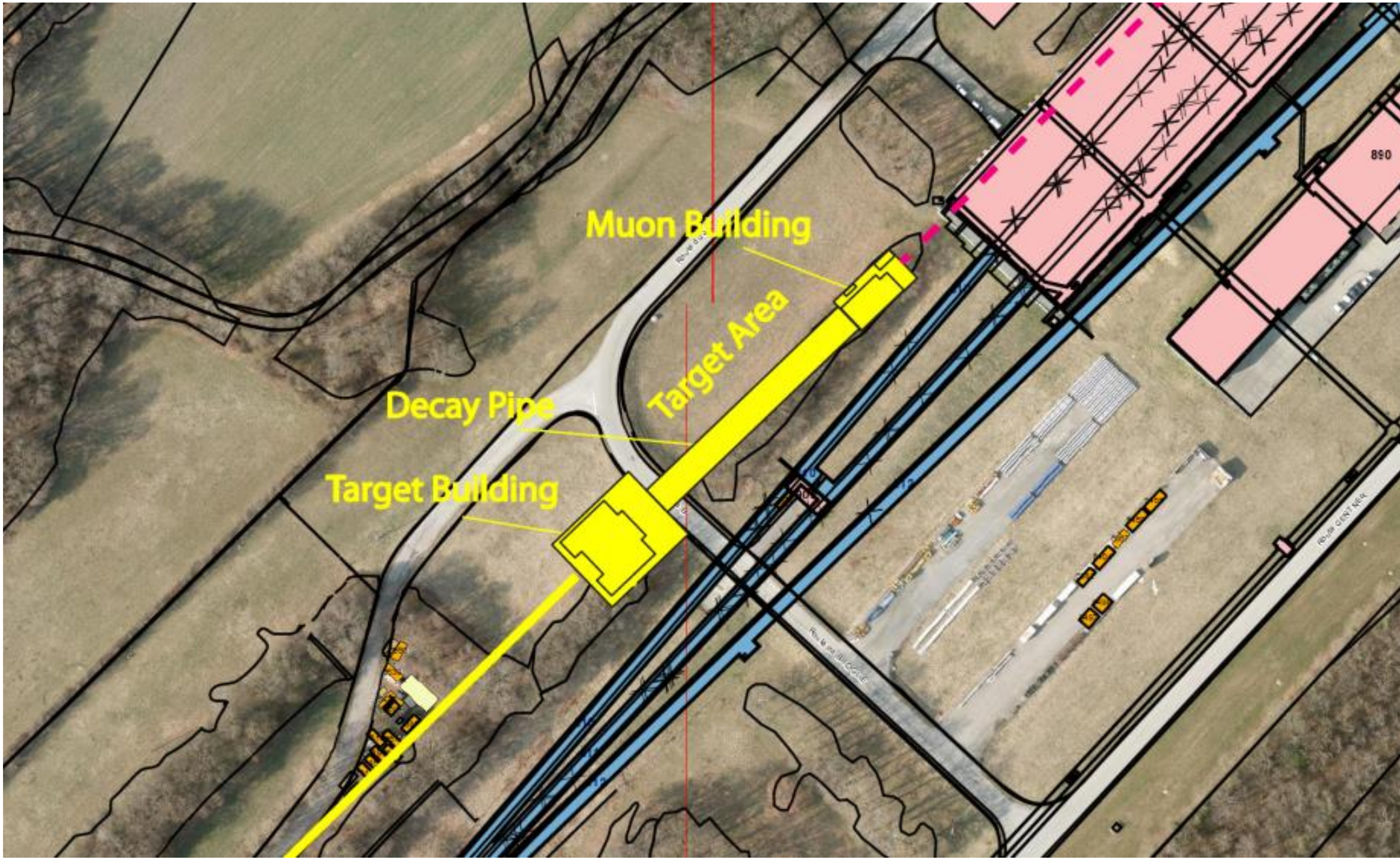


First Considerations to implement nuSTORM on the CERN site
"North Area Neutrino Hub" E.Wildner, CERN 2013

BDF NEW FACILITIES



CENF



Conclusions

- Physics Beyond Colliders study group to look at CERN’s non-collider options out to 2040
  - Report to ESPP in 2019
- A number of options on the table and now actively being pursued
- Process offers the option for nuSTORM to present a “feasibility study for possible implementation at CERN at end 2018”
- The level of detail of this study is to be decided but resource constraints at CERN must be factored in

Parameter list, draft

Neutrino characteristics	Fermilab	CERN
Aimed neutrino energy [GeV]	1.0 to 3.0	1.0 to 3.0
Flux measurement precision [%]	1.0	1.0
Protons on target (POT)	10^{21}	$2.3 10^{20}$
Useful μ decays [10^{18}]	1.00	100/60 = 1.67
Production, horn and injection		
Target (Ta) diameter/length [m], material	0.01/0.21	- / -
Pulse length [μs]	1.0	10.5
Proton energy [GeV/c]	60	100
Pion energy [GeV/c]	$5.0 \pm 10\%$	$5.0 \pm 10\%$
Horn diameter/length [m]	- / 2.0	- / -
Reflector diameter/length [m]	-	- / -
Current Horn/Reflector [kA]	300	- / -
Estimated collection efficiency	0.8	0.8
Estimated transport efficiency	0.8	0.8
Estimated injection efficiency	0.9	0.9
Acceptance [mm rad]	2.0	2.0
π/pot within momentum acceptance	0.11	$0.11 \times \frac{100}{60} = 0.187$
Length of target [m]	0.21	0.21
Distance between target and horn [m]	inside	inside
Length of horn [m]	2.0	-
Distance between horn and injection [m]	20	20
The muon storage ring		
Momentum of circulating muon beam [GeV/c]	3.8	3.8
Momentum of circulating pion beam [GeV/c]	$5.0 \pm 10\%$	$5.0 \pm 10\%$
Circumference [m]	350	350
Length of straight [m]	150	150
Ratio of Lstraight to ring circumference [Ω]	0.43	0.43
Dynamic aperture, A_{dyn}	0.7	0.7
Acceptance [mm rad]	2.0	2.0
Decay length [m]	240	240
Fraction of π decaying in straight (F_s)	0.41	0.41
Relative μ yield ($A_{dyn} \times (\pi$ per POT$) \times F_s \times \Omega$)	0.014	
Detectors		
Distance from target [m]	20/1600	300/1800-2700

Energy of p-beam at CERN 100 GeV
(could be also 400 GeV)

Table 3: Summary of the SPS beam characteristics at present and after the LS2 upgrade.

Parameter	SPS operation		SPS record		After LIU 2020	
	LHC	CNGS	LHC	CNGS	LHC	νSTORM
Energy [GeV]	450	400	450	400	450	100
Bunch spacing [ns]	50	5	25	5	25	5
Bunch intensity [10^{11}]	1.6	0.105	1.3	0.13	2.2	0.17
Number of bunches	144	4200	288	4200	288	4200
SPS intensity [10^{13}]	2.3	4.4	3.75	5.3	6.35	7.0
PS intensity [10^{13}]	0.6	2.3	1.0	3.0	1.75	4.0
SPS Cycle length [s]	21.6	6.0	21.6	6.0	21.6	3.6
PS Cycle length [s]	3.6	1.2	3.6	1.2	3.6	2×1.2
PS beam mom. [GeV/c]	26	14	26	14	26	14
Beam Power [kW]	77	470	125	565	211	156

Based on SBLNF, LOI January 2013

https://edms.cern.ch/nav/P:CERN-0000096725:V0/P:CERN-0000096728:V0/TAB3