νSTORM @ CERN

First Considerations to implement nuSTORM
on the CERN site “North Area Neutrino Hub”

E.Wildner, CERN

From: "Proposed Update of the European Strategy for Particle Physics" (Draft)

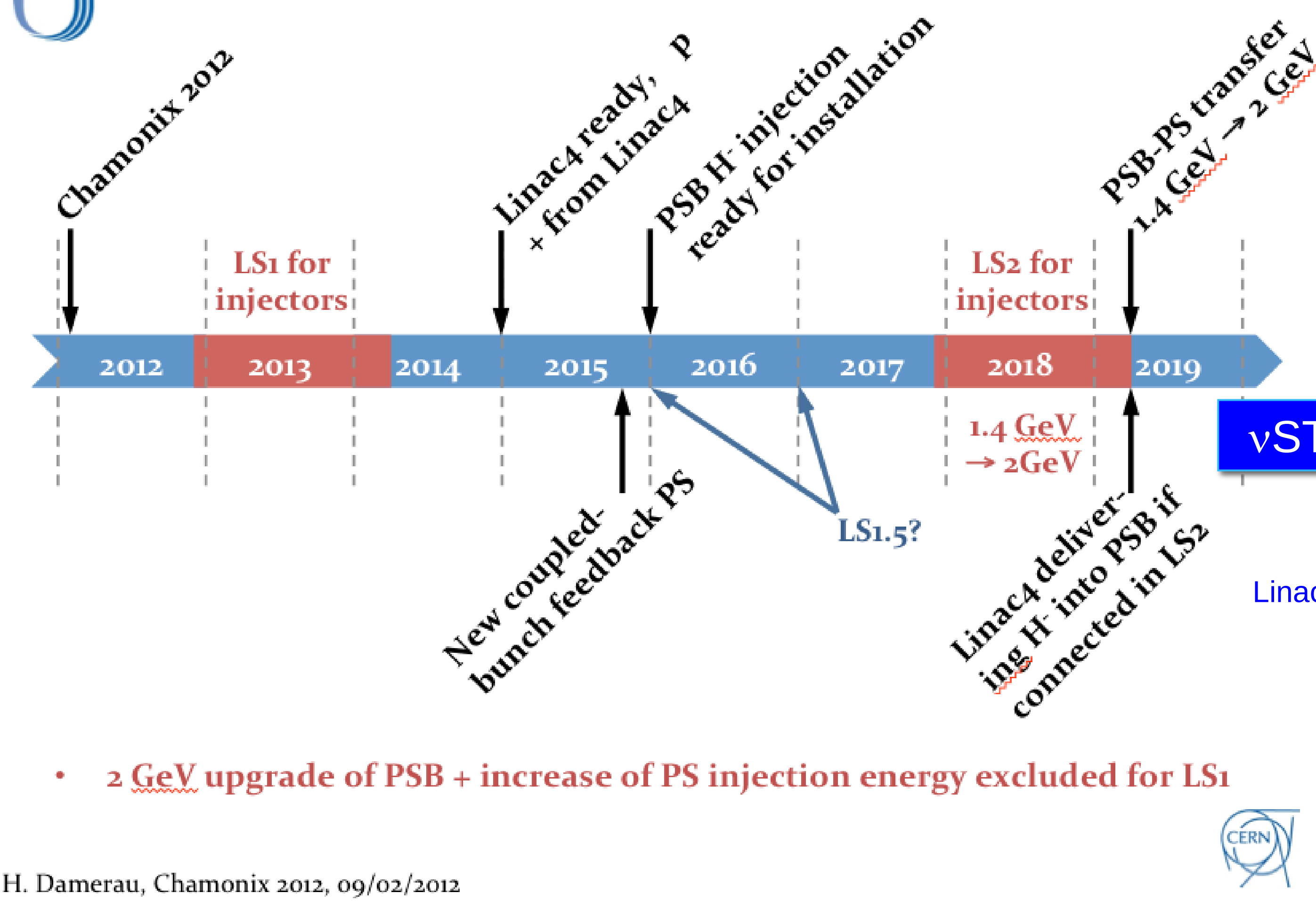
Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector. *CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading neutrino projects in the US and Japan.*

How? See next slide…

νSTORM

- Preparation for future powerful facilities
  - ν_e and $\bar{\nu}_e$ cross-sections to fully evaluate the physics reach
  - Technology test-bed
    - Best Ring design, Collection, Injection, extraction
    - Cooling
    - Beam Diagnostics
    - Detectors
    - Etc.
- Discovery potential, e.g. sterile neutrinos
- Worldwide collaborative efforts to pave the way to a high precision neutrino/muon program
- CERN can offer the infrastructure for νSTORM (CENF)
- EOI for νSTORM @ CERN:
  - Existing proposals for the North Area Neutrino production has been used as far as possible

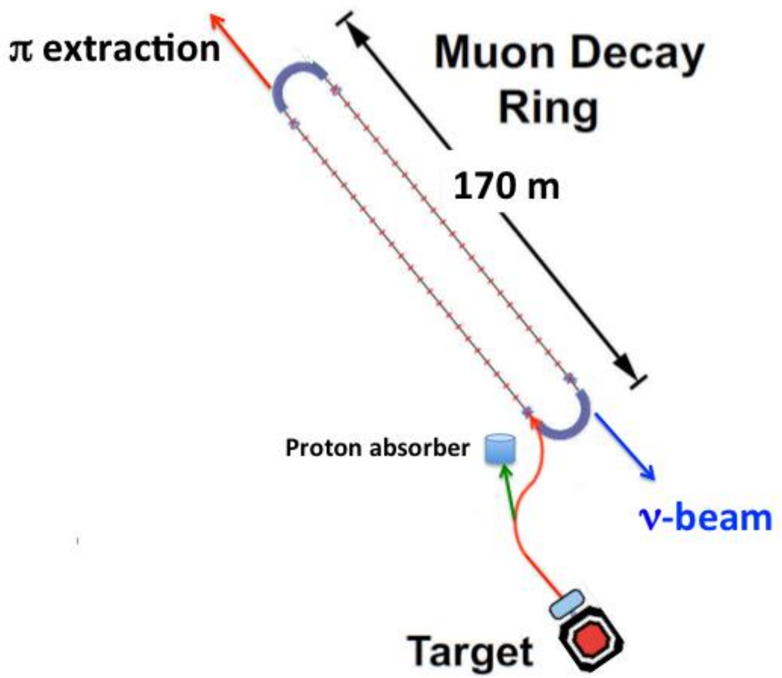
Timeline (present baseline)

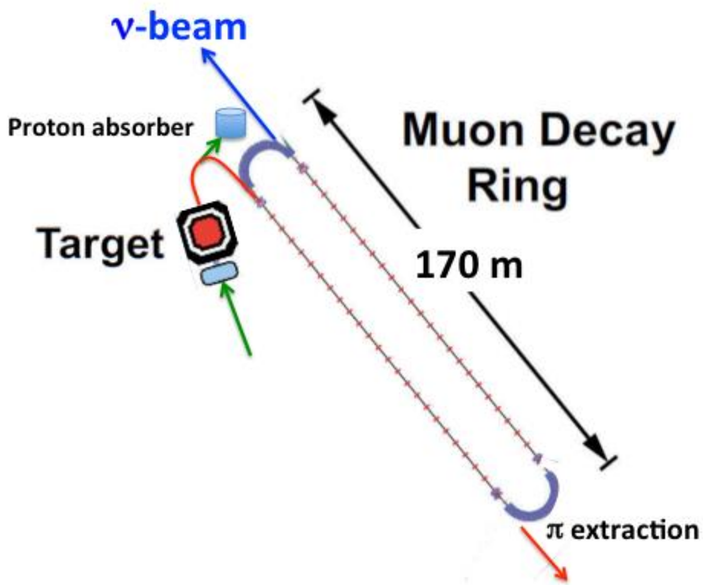


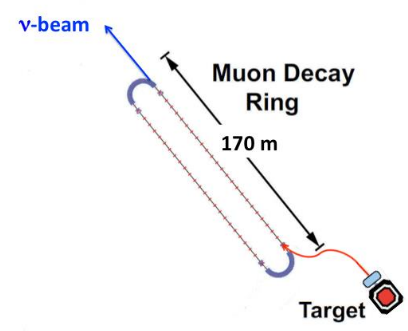
νSTORM ?

Linac4 needed for proton yield

CERN Configurations







FNAL configuration

CERN SPS beam pulse10 μsec.
FNAL MI beam pulse 2 μsec.

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)

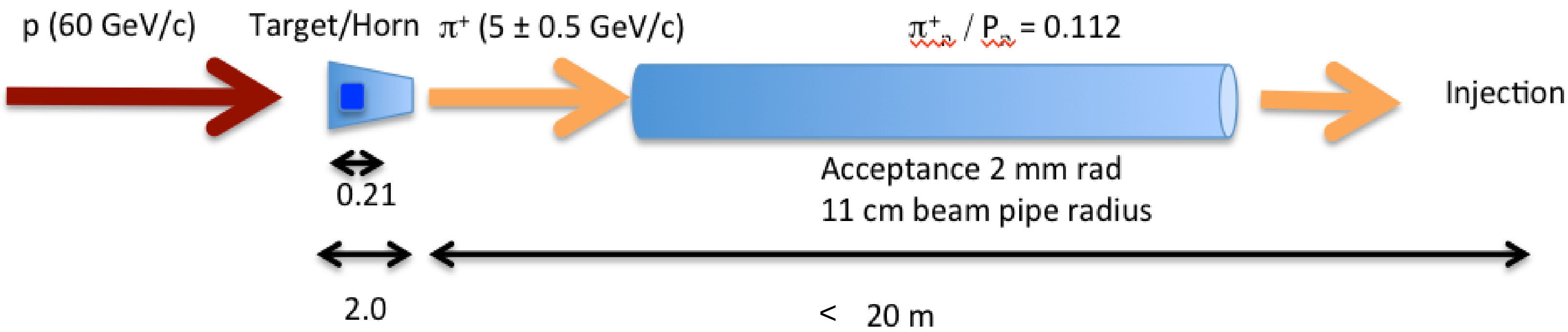
Table 3: Summary of the SPS beam characteristics at present and after the LS2 upgrade.

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

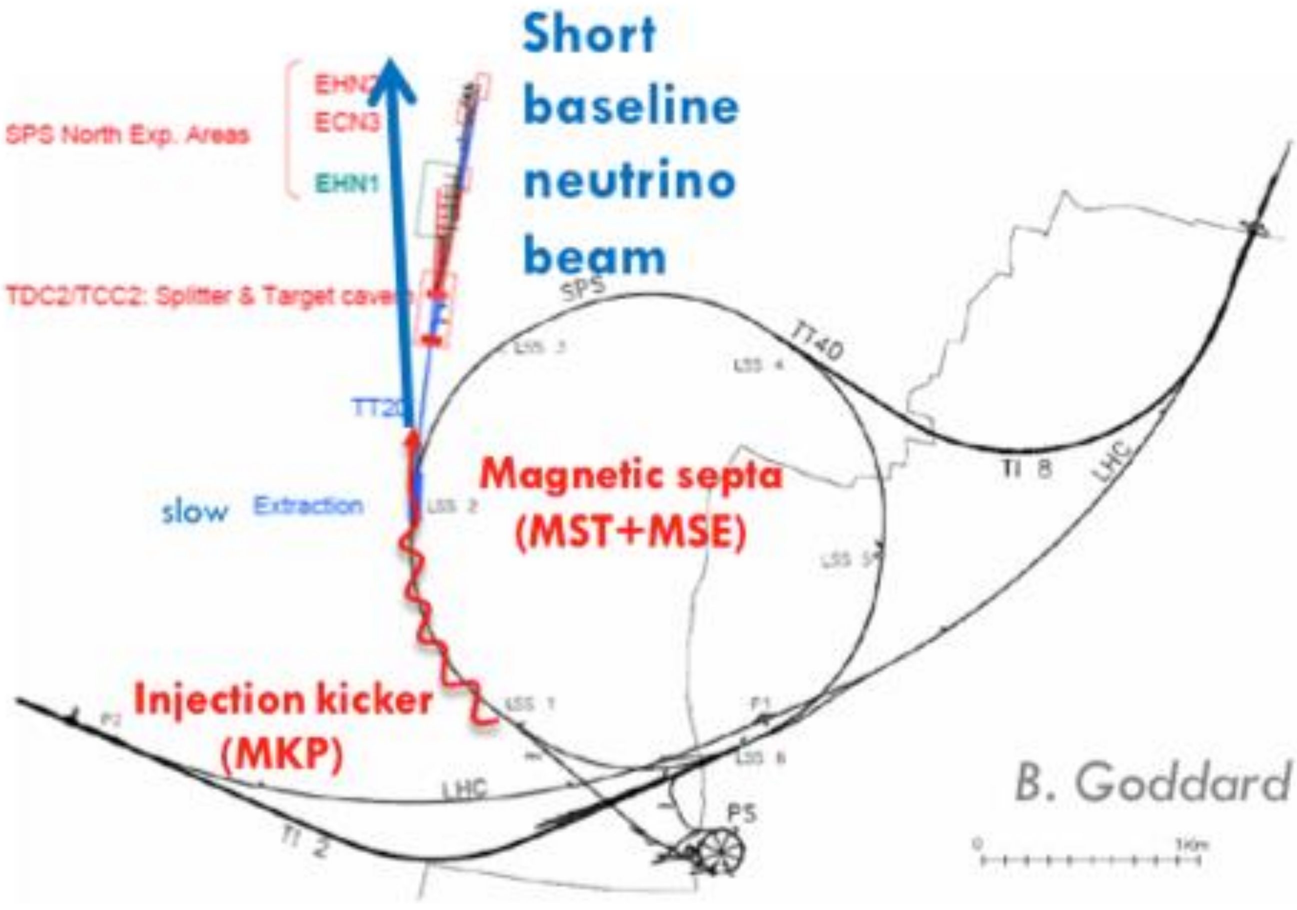
Production, Capture, Injection



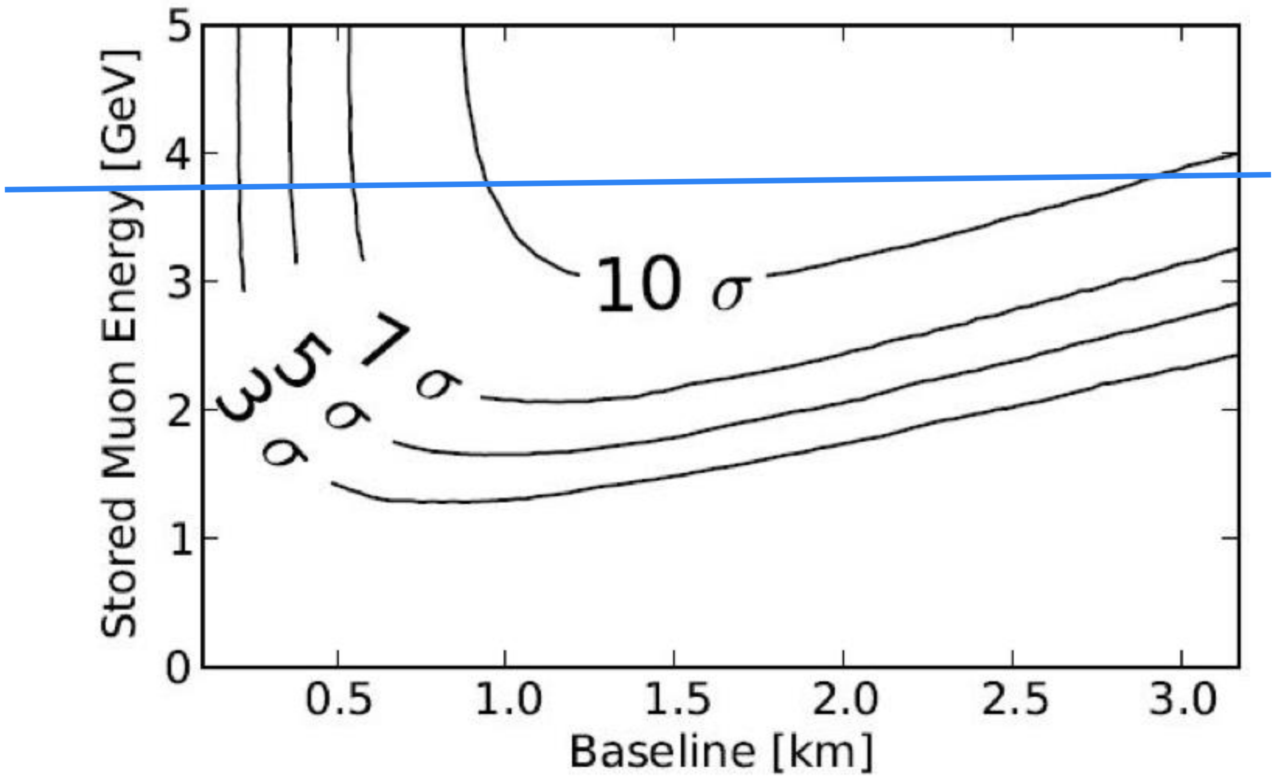
arXiv:1206.0294

nuSTORM: Neutrinos from STORed Muons

Use of the SPS Beam

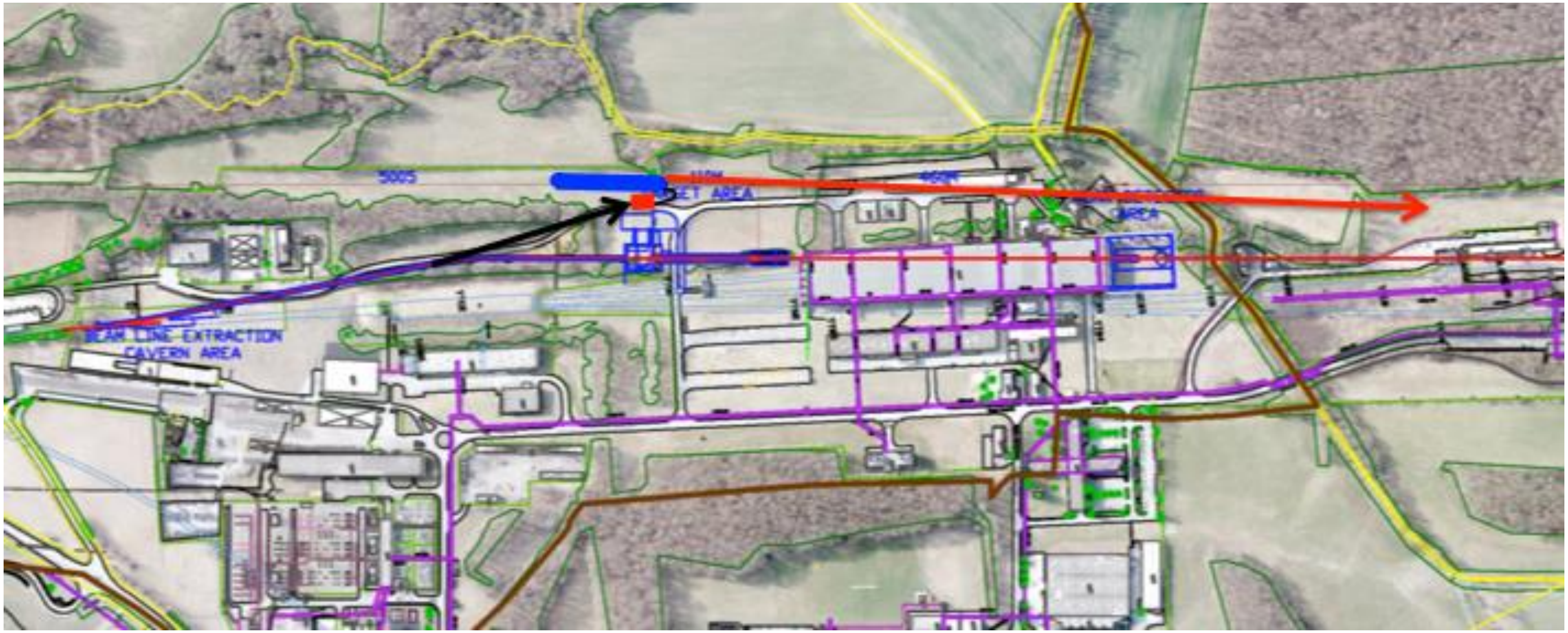


We need a good baseline



The detector position for 10 sigma exclusion of the CPT conjugate LSND signal

Example 1



Re-used

1. Extraction from SPS
2. Parts of beam line
3. Target station
4. One detector hall

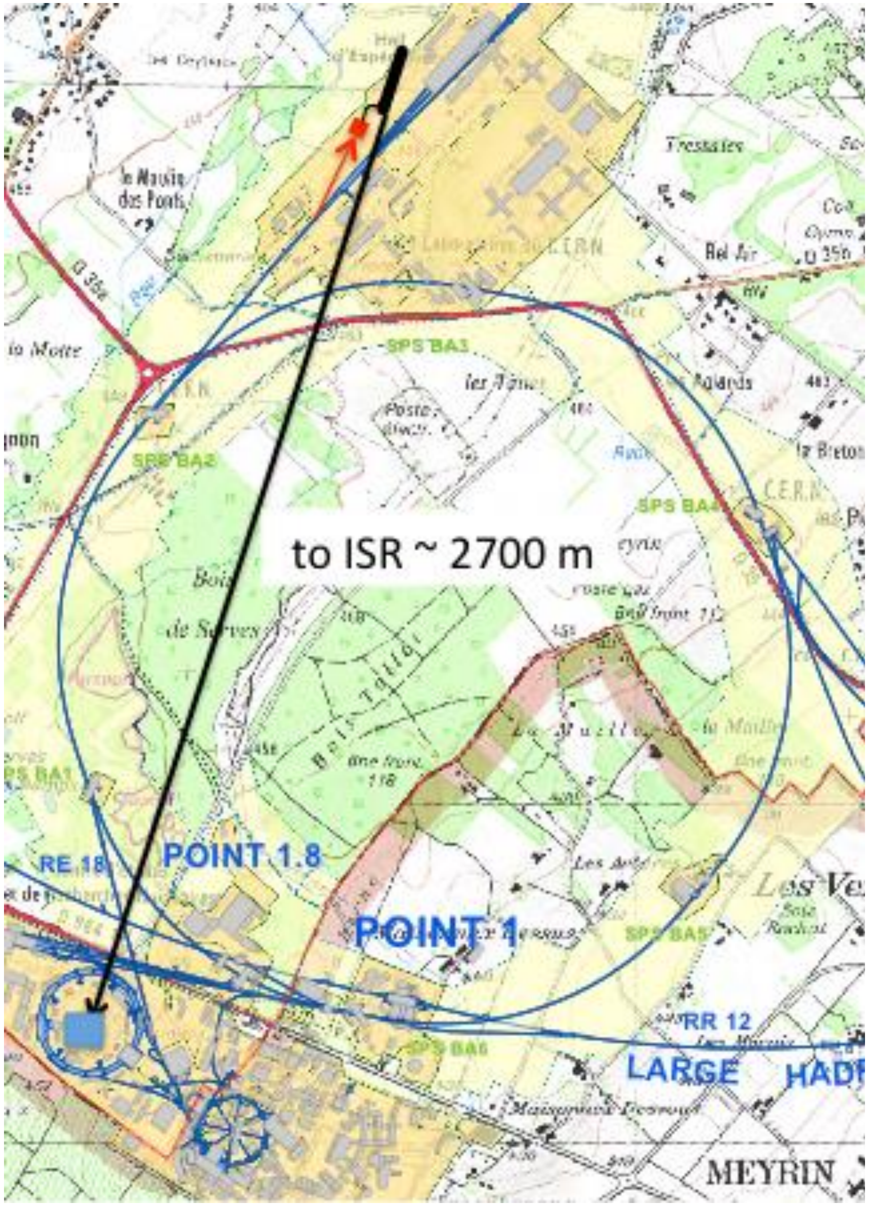
Problems and doubts

1. Target Stations difficult to re-use
2. Prepare TS in advance ?
3. Benefits?
4. Pion channel difficult design

Example 2

Re-used
1. Extraction from SPS
2. Parts of beam line
3. FNAL Pion injection ok

Problems and doubts
1. New Target Station
2. Space for the Ring
3. Somewhat long baseline
   Detector hall can be moved



Example 3,
Ring at SPS level (60m)

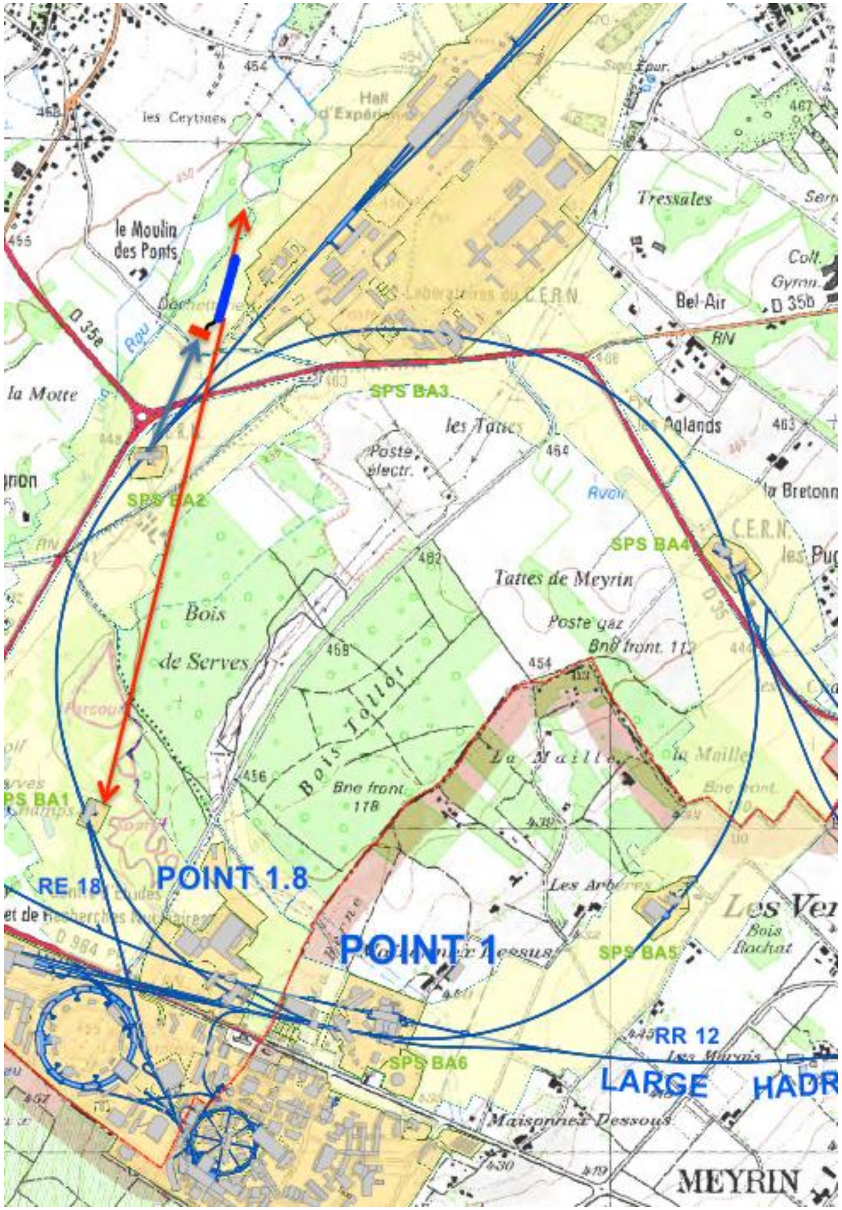
Re-used

1. Extraction from SPS
2. FNAL Pion injection ok
3. SPS caverns

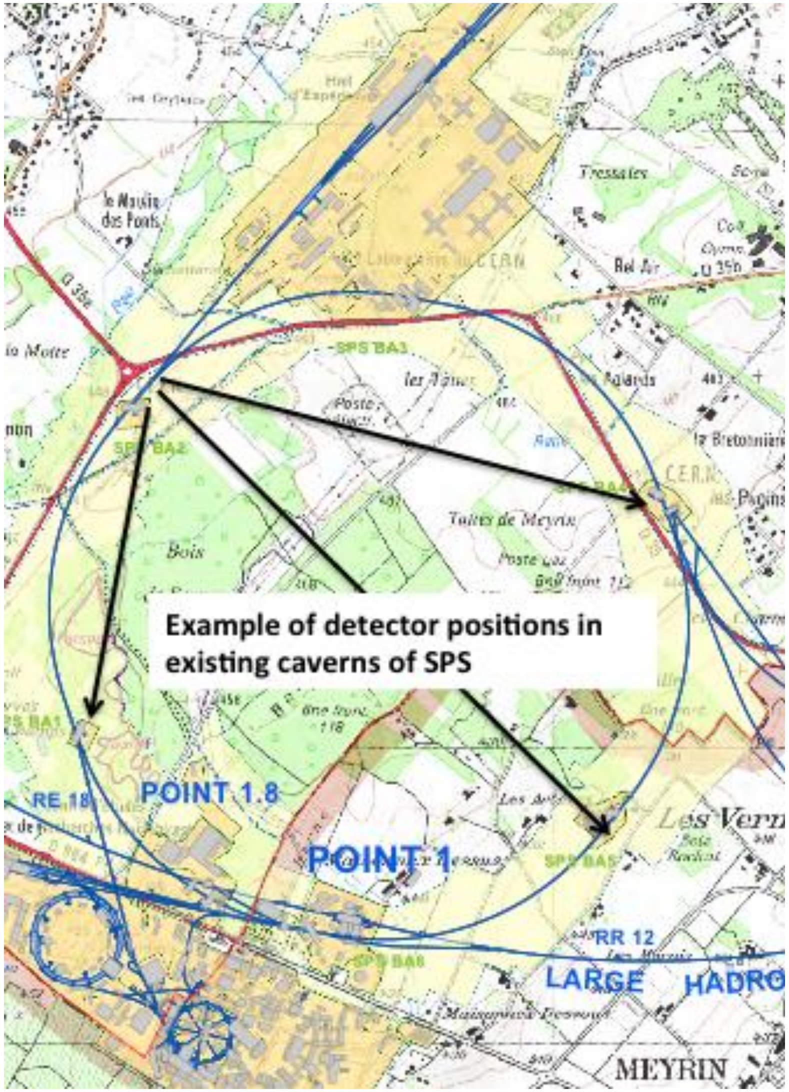
The underground facility

1. More space for ring
2. Space in caverns?
3. Background from SPS beam?
4. Muon cooling exp
5. Lower energy experiment

   Where can we put detector?



Other existing caverns?



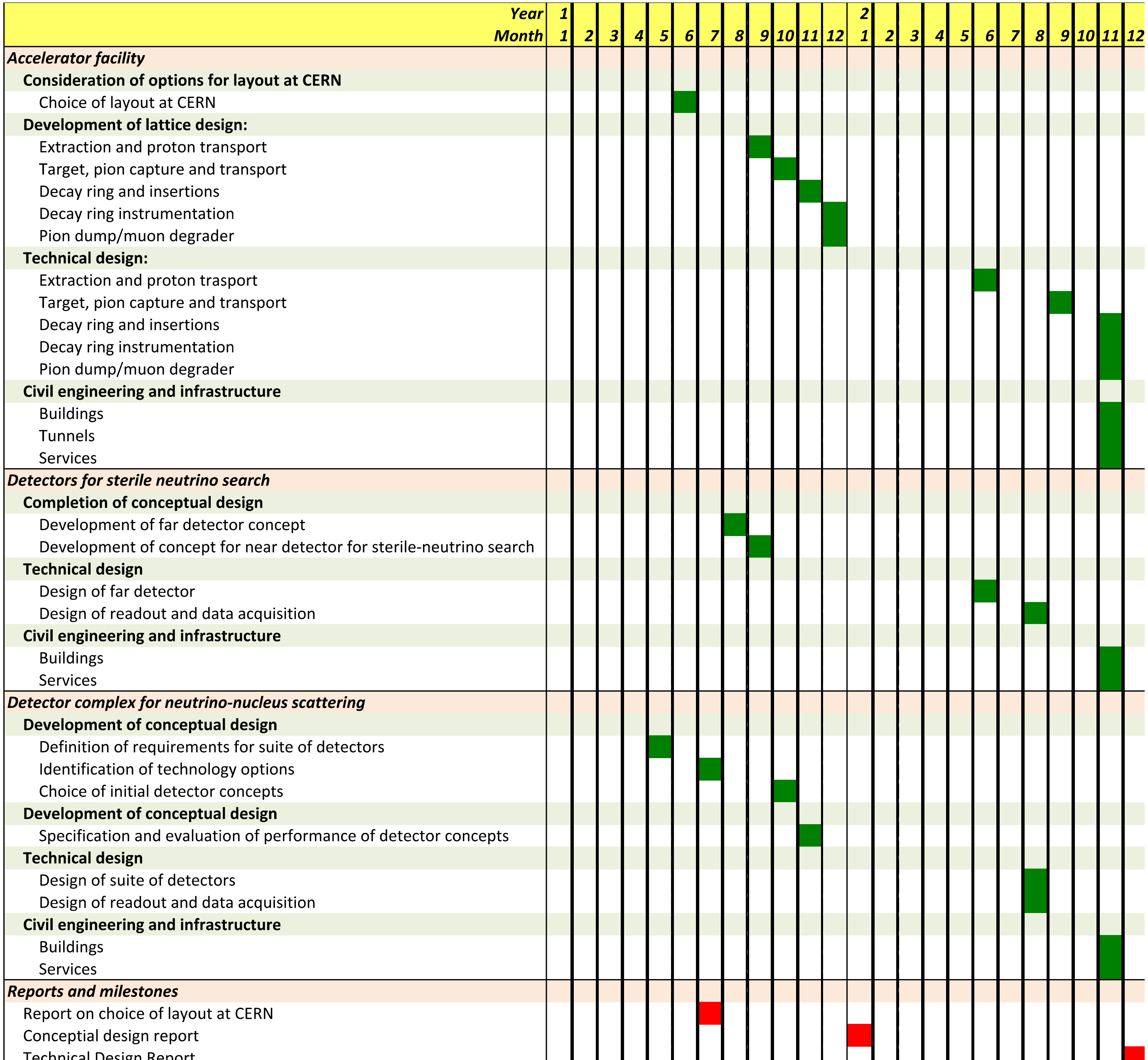
Id	System,*subsystem*or*component	Site*specific item
1	**nuSTORM**	
1.1	**The,accelerator,facility**	
1.1.2	*Proton)beam*	
1.1.2.1	Extraction	Yes
1.1.2.2	Septum	Yes
1.1.2.3	Trasnport6ine	Yes
1.1.2.4	Tunnels,6surface6buildings6and6nfrastructure	Yes
1.1.3	*Target)and)pion)capture*	
1.1.3.1	Target6assembly	No
1.1.3.2	Horn	No
1.1.3.3	Transport6chanel	Yes
1.1.2.4	Tunnels,6surface6buildings6and6nfrastructure	Yes
1.1.3	*Decay)ring*	
1.1.3.1	Injection6and6extraction	No
1.1.3.2	Injection6straight	No
1.1.3.3	Return6straight	No
1.1.3.4	Arcs	No
1.1.3.5	Pion6dump/muon6degrader	No
1.1.2.4	Tunnels,6surface6buildings6and6nfrastructure	Yes
1.2	Neutrino6detectors6for6sterile6neutrino6search	
1.2.1	*Far)detector*	
1.2.1.1	Iron/scintillaror6tracking6calorimeter	No
1.2.1.2	Superconducting6transmission6ine	No
1.2.1.3	Readout6and6data6acquisition	No
1.2.1.4	Tunnels,6surface6buildings6and6nfrastructure	Yes
1.2.2	*Near)detector*	
1.2.2.1	Iron/scintillaror6tracking6calorimeter	No
1.2.2.2	Excitation6current6oop	No
1.2.2.3	Readout6and6data6acquisition	No
1.2.2.4	Tunnels,6surface6buildings6and6nfrastructure	Yes
1.2.3	*Neutrino)detectors)for)neutrino-nucleus)scattering)studies*	
1.2.3.1	Detector6specification,6design6and6fabriaction	
1.2.3.2	Magnet	
1.2.3.3	Readout6and6data6acquisition	No
1.2.3.4	Tunnels,6surface6buildings6and6nfrastructure	Yes

Site specificity

Joint project/Collaborations:

Work-packages to be defined and distributed

Timeline TDR



Preliminary list of work units from EOI draft

- Pion transport: The pion transport may be different from the already designed transport channel done for the FNAL implementation due to the chosen vSTORM topology at CERN. Important parts of the work that is already done at FNAL can be reused;

- Engineering study of pion-capture magnets: The large aperture magnets have to be fully studied, including radiation. Super conduction magnets in the arcs including cryogenic evaluations and radiation studies;

- Contributions to the design of muon storage ring: The work on a storage ring is ongoing within the vSTORM collaboration (FNAL);

- Contributions to design of storage ring diagnostics: Specification of needed instrumentation. Studies concerning the possibility to use the beam structure from SPS for beam instrumentation. Influence of electron production from the decay;

- Participation in the evaluation of a possible muon cooling experiment: A muon cooling experiment could be set up after the straight section that is not used for for neutrino production. A muon cooling ring is a second option; a study is envisaged;

- Contributions to the design of the neutrino-scattering programme: The European Strategy for Particle Physics [] has emphasized the importance of studying the physics of the neutrino. The next generation of long- and short-baseline require that the systematic error related to the neutrino- scattering cross sections and modeling of the hadronic final states be mimimised. We request support from PH Division to provide supervision for a CERN Fellow and a research student. The latter would be jointly supervised by one of the institutes within the European collaboration;

- Site specific infrastructure

What to do for a TDR, CERN

- Define the CERN specific Work units
- Evaluate resources for each of them
- Get resources and funds
- Find suitable people who can do the necessary research
- … and go ahead

    - All steps needs time!!

Thank you

Apart from nuSTORM collaborators:

- Rende Steerenberg
- Brennan Goddard
- Luigi Scibile
- Marzio Nessi
- Luca Bruno
- and others