The SHiP experiment at the CERN SPS

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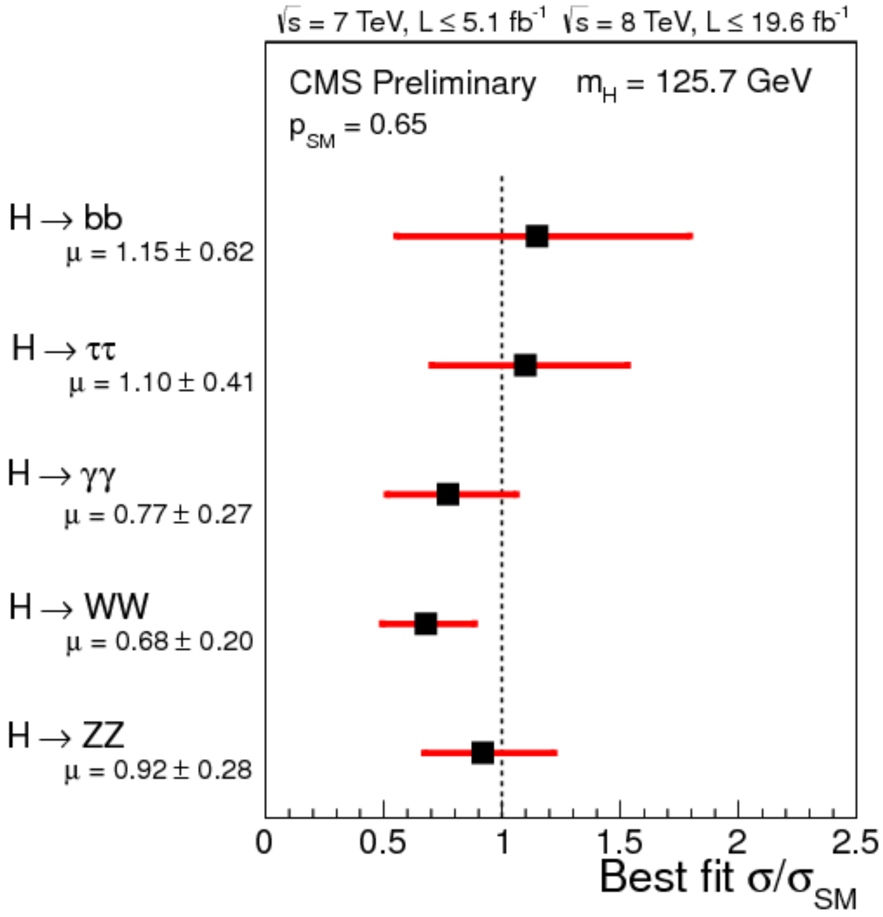
1 Luglio 2014

Why (to) **S**earch for **Hi**dden **P**articles?

(the physics landscape)

1. Higgs boson found and consistent with SM Higgs (so far)



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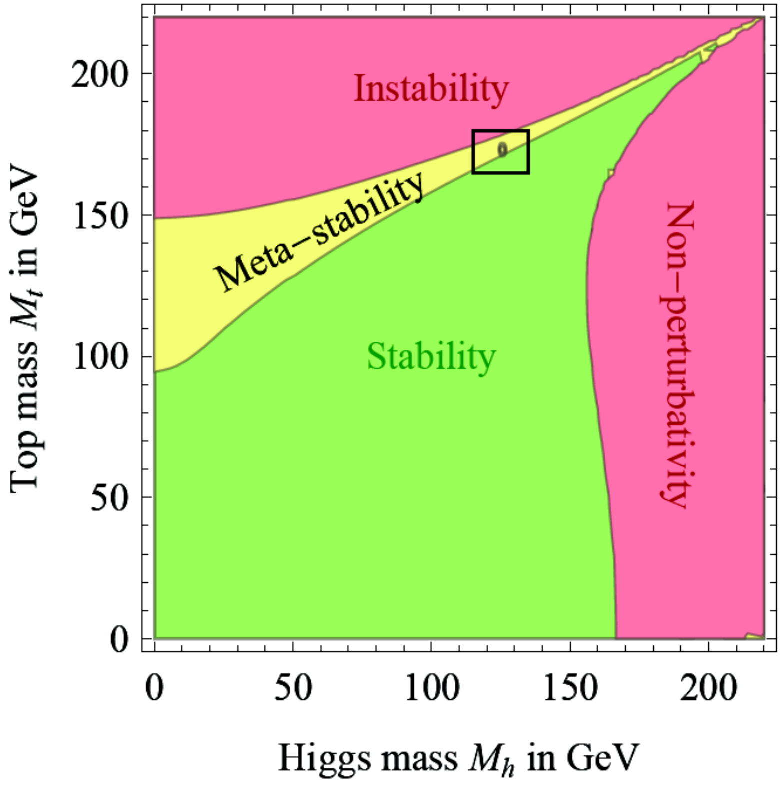
1. Higgs boson found and consistent with SM Higgs (so far)
2. Higgs mass located in a meta-stability wedge:

→Vacuum might be stable or has τ >> τ (universe)

→ SM may work successfully up to the Planck scale i.e. no need for a new mass scale.



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2. Higgs mass located in a meta-stability wedge:

→Vacuum might be stable or has τ >> τ (universe)

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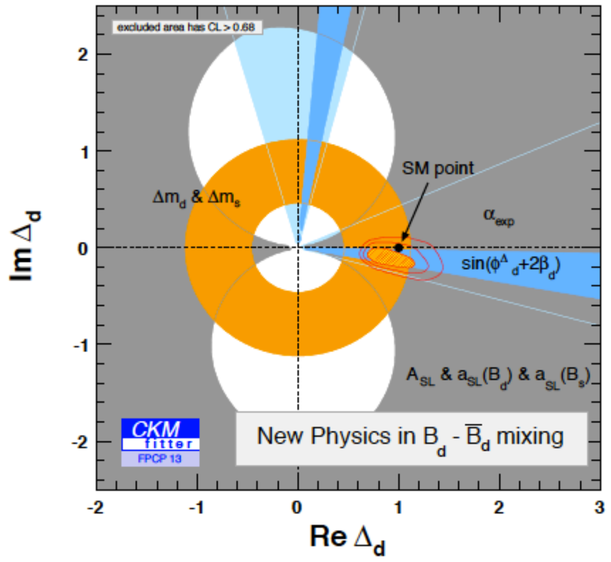
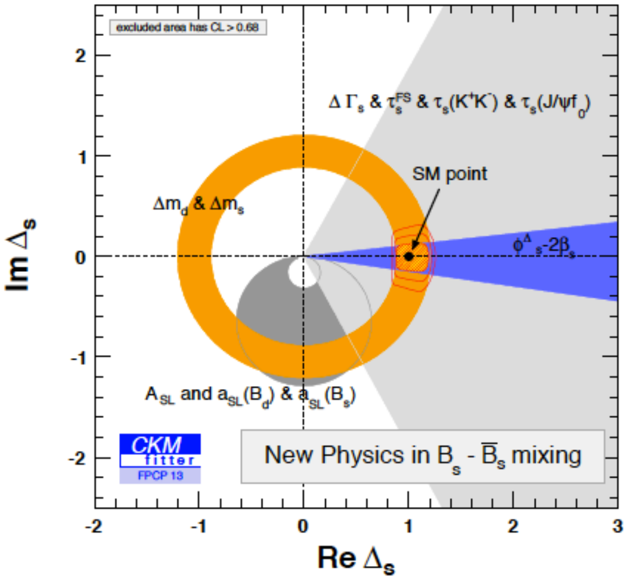
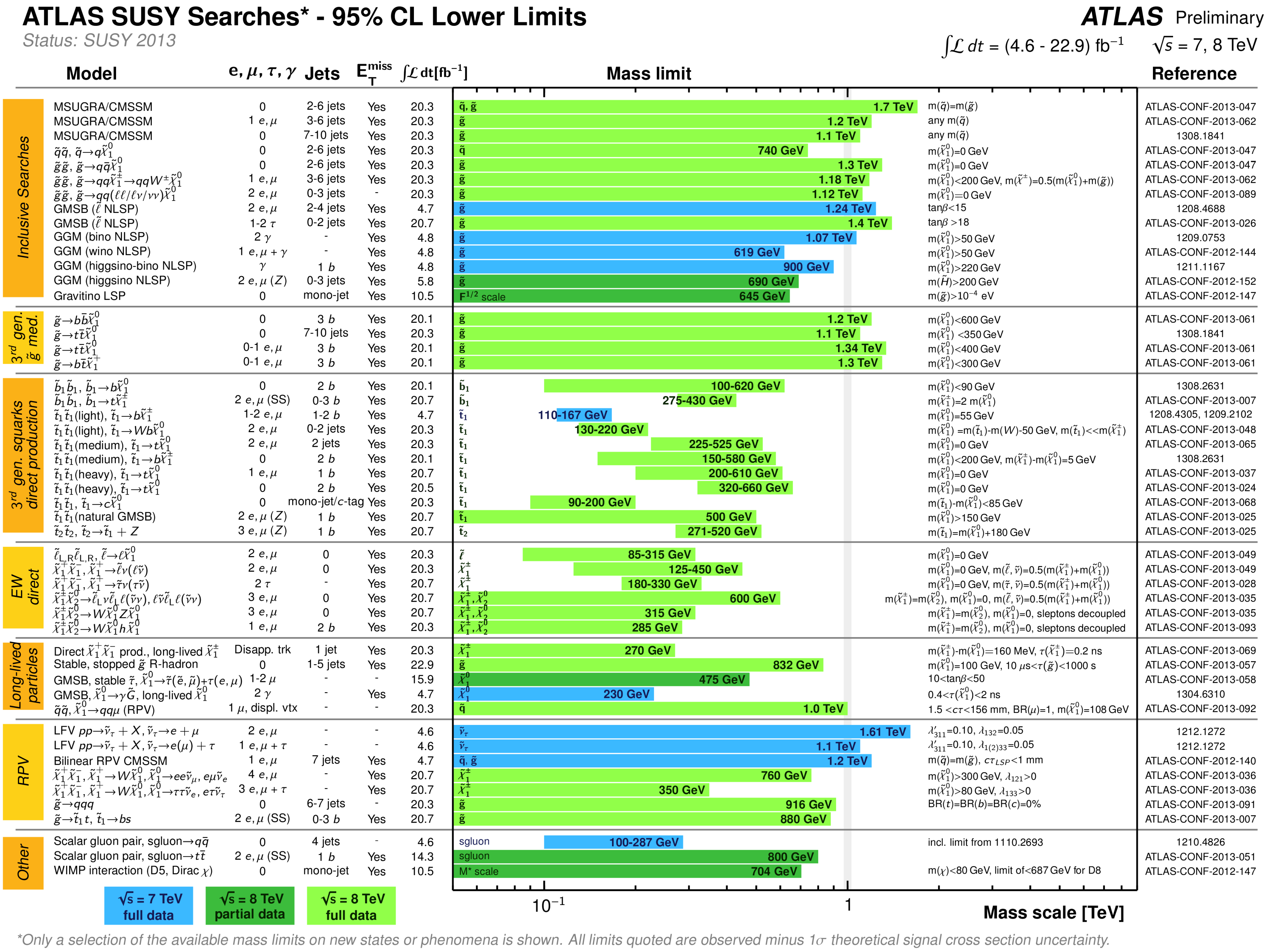
i.e. no need for a new mass scale.

3. Flavor Physics consistent with SM predictions (so far)





What is not found (so far):



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int\mathcal{L}\,dt = (4.6 - 22.9)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 7, 8$ TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^{\pm})$=0.5($m(\tilde{\chi}_1^0)$+$m(\tilde{g})$)	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	$\tan\beta$ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$ 1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 275-430 GeV	$m(\tilde{\chi}_1^{\pm})$=2 $m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-220 GeV	$m(\tilde{\chi}_1^0)$ =$m(\tilde{t}_1)$-$m(W)$-50 GeV, $m(\tilde{t}_1)$<<$m(\tilde{\chi}_1^{\pm})$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$ 225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^{\pm})$-$m(\tilde{\chi}_1^0)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	$\tilde{t}_1$ 200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$ 320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-200 GeV	$m(\tilde{t}_1)$-$m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$ 500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$ 271-520 GeV	$m(\tilde{t}_1)$=$m(\tilde{\chi}_1^0)$+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$ 85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell}, \tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$ 180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau}, \tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 600 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell}, \tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 315 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 285 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 270 GeV	$m(\tilde{\chi}_1^{\pm})$-$m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^{\pm})$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$ 832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$ 475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau + X$, $\tilde{\nu}_\tau\to e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau + X$, $\tilde{\nu}_\tau\to e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$ 1.2 TeV	$m(\tilde{q})$=$m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\tilde{\nu}_\mu$, $e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$ 760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e$, $e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$ 350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t$, $\tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e, μ (SS)	1 b	Yes	14.3	sgluon 800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

$\sqrt{s}$ = 7 TeV full data

$\sqrt{s}$ = 8 TeV partial data

$\sqrt{s}$ = 8 TeV full data

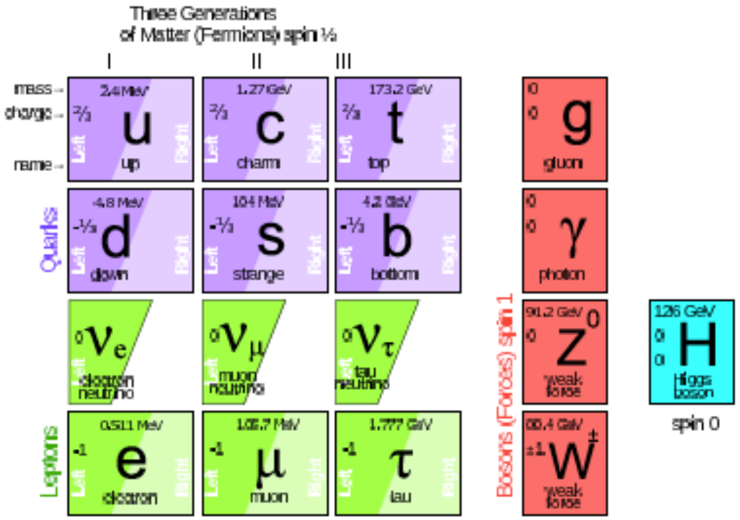
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Is the SM case closed?

NO! SM unable to explain:

1. matter anti-matter asymmetry in universe
2. neutrino mixing → masses
3. Non-baryonic dark matter

How many new particles do we need after the Higgs?



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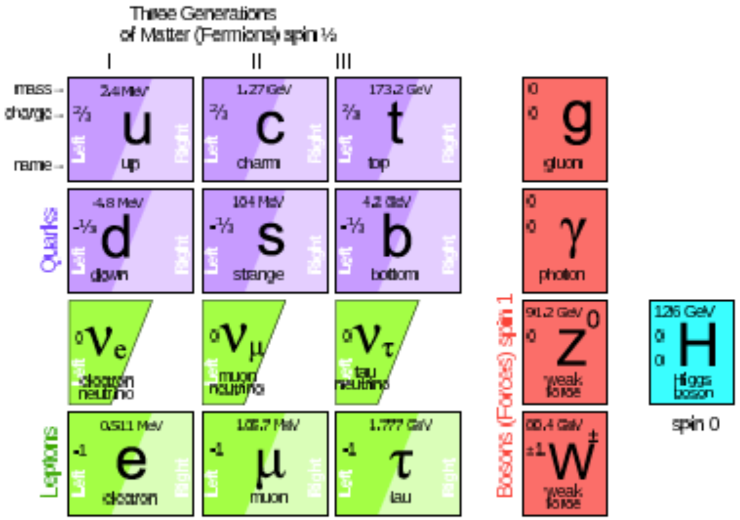
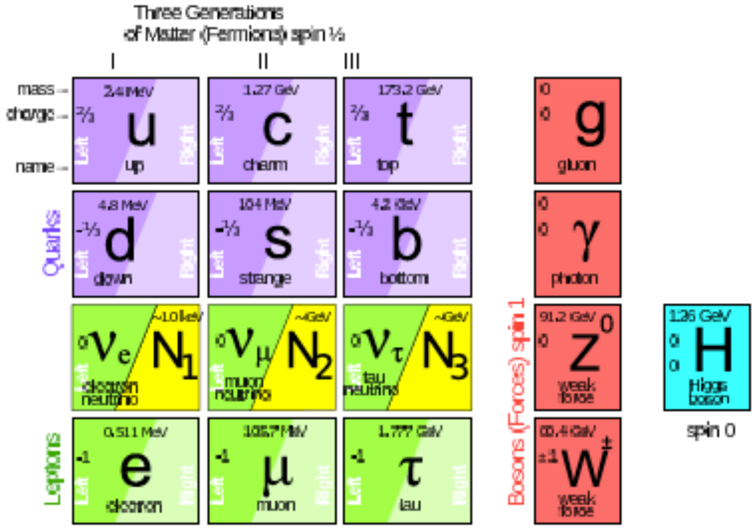
How many new particles do we need after the Higgs? (perhaps) only three.





Adding three right-handed Majorana Heavy Neutral Leptons (HNL): N_1, N_2 and N_3

- N_1 can provide **dark matter candidate**
- $N_{2,3}$ can provide **neutrino masses via Seesaw mechanism**
- $N_{2,3}$ can induce **leptogenesis** → **baryogenesis**

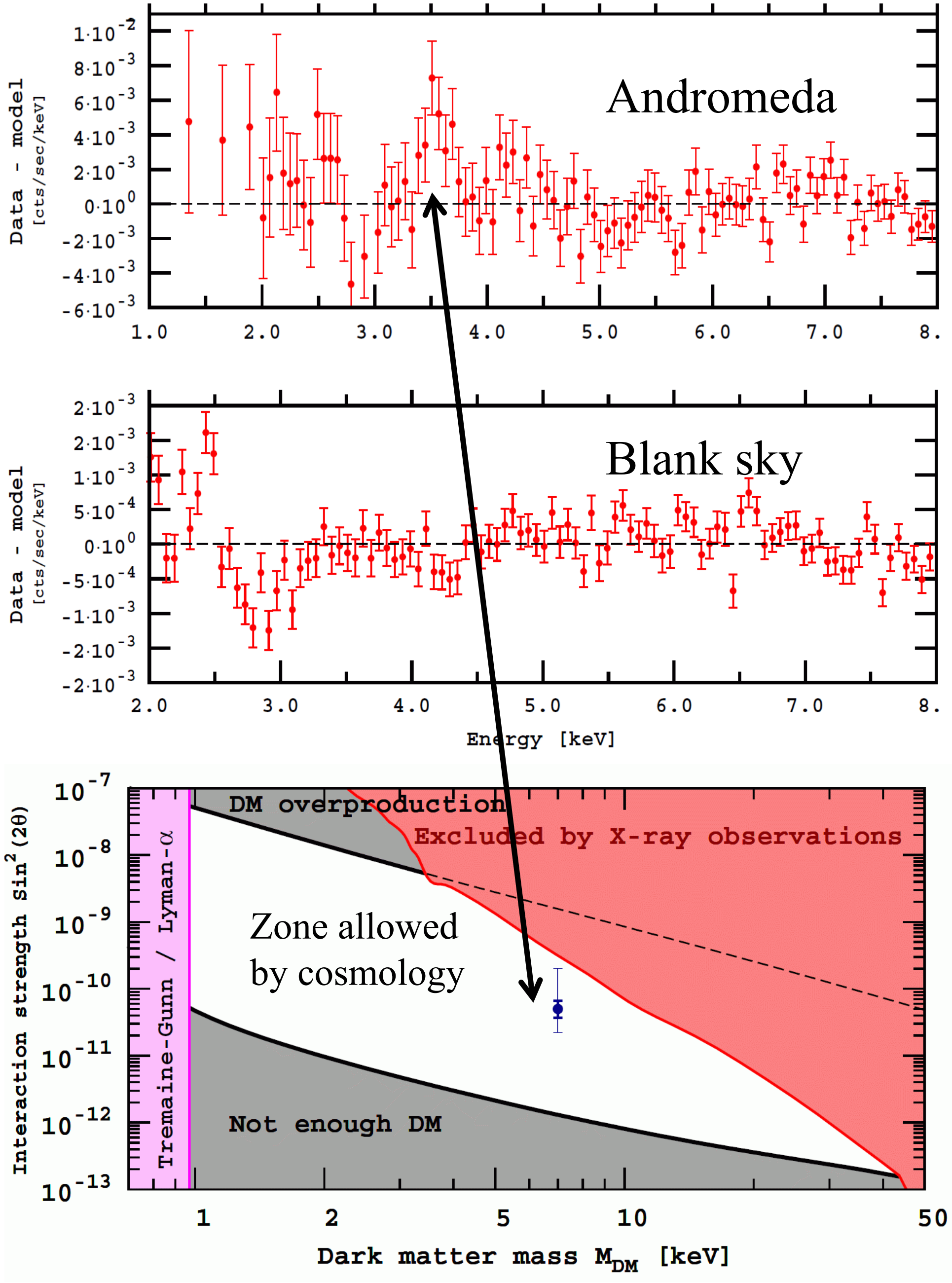
N_1: the Dark Matter candidate

Signature: $N_1 \rightarrow \nu\, \gamma$
Recently two papers on arXiv:

- 10/2/14: arxiv.org/abs/1402.2301:
Detection of an Unidentified Emission Line in the Stacked X-ray spectrum of Galaxy Clusters
E ~ 3.56 keV

- 17/2/14: arxiv.org/abs/1402.4119:
An unidentified line in X-ray spectra of the Andromeda galaxy and Perseus galaxy cluster
E ~ 3.5 keV

Both papers refer to Astro-H
(with Soft X-Ray Spectrometer, 2015 launch)
to confirm/rule-out the DM origin of this signal.



$N_{2,3}$ explain neutrino masses and BAU

1) neutrino masses:

Seesaw constrains Yukawa coupling and $M(N_{2,3})$, i.e. $M\nu \propto U^2/M(N_{2,3})$

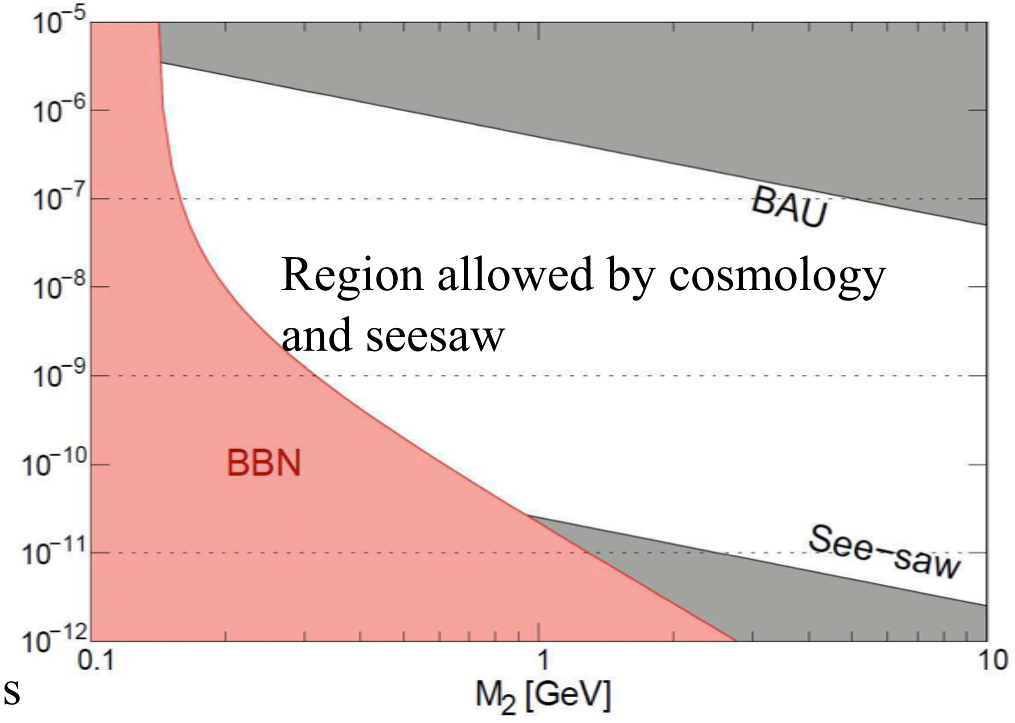
2) Baryo(Lepto)genesis:

N_2 nearly degenerate with N_3, and tune CPV-phases to explain baryon asymmetry of universe (BAU).

3) Big Bang Nucleosynthesis

(BBN, ~ 75/25 % H-1/He-4)

would be affected by $N_{2,3}$ decays if $\tau > 0.1$ s



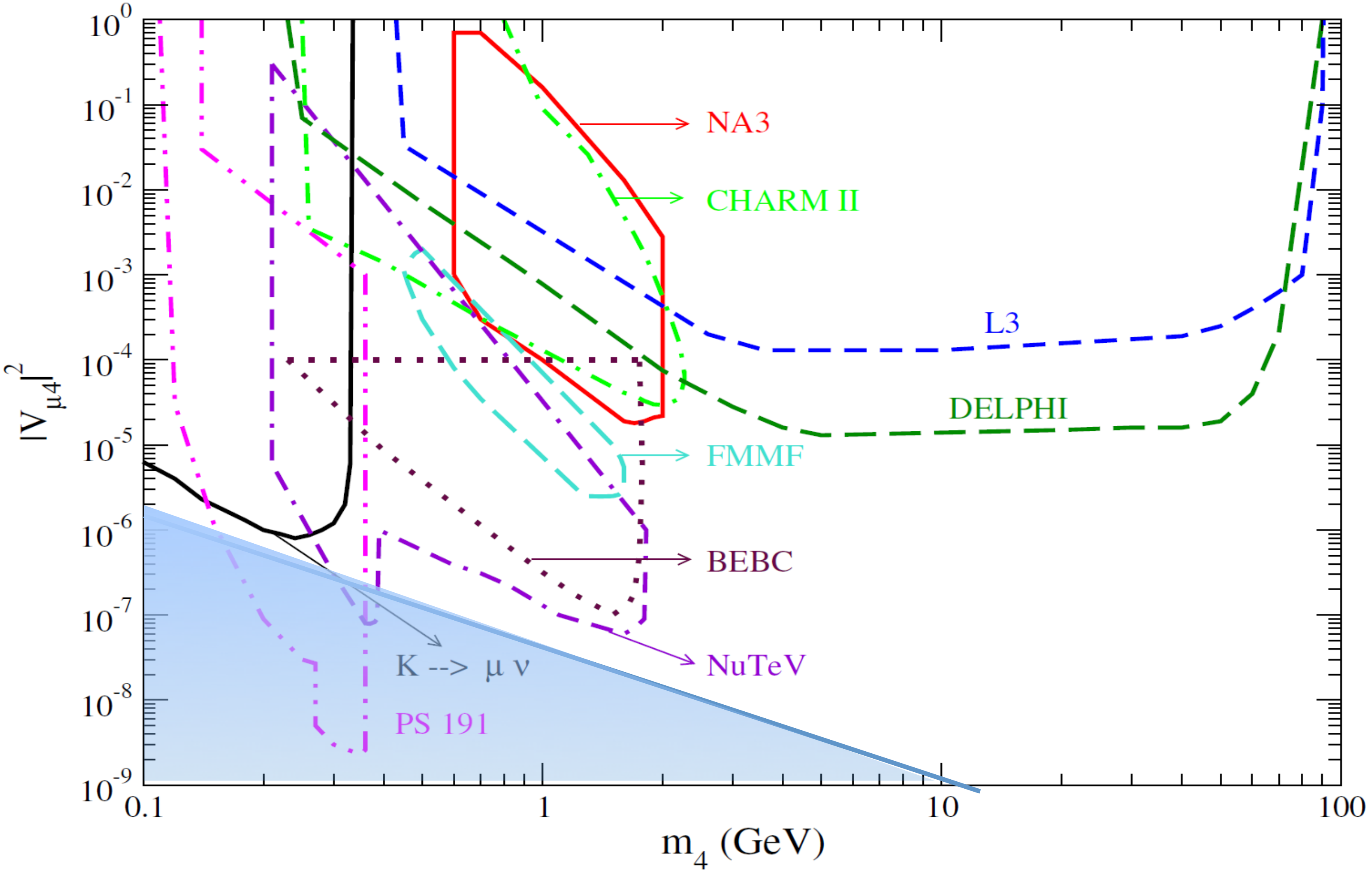
Region allowed by cosmology and seesaw

These are the particles we are searching for!

$N_{2,3}$ explain neutrino masses and BAU

The idea is not new, but previous experiments were far from the interesting cosmological region;

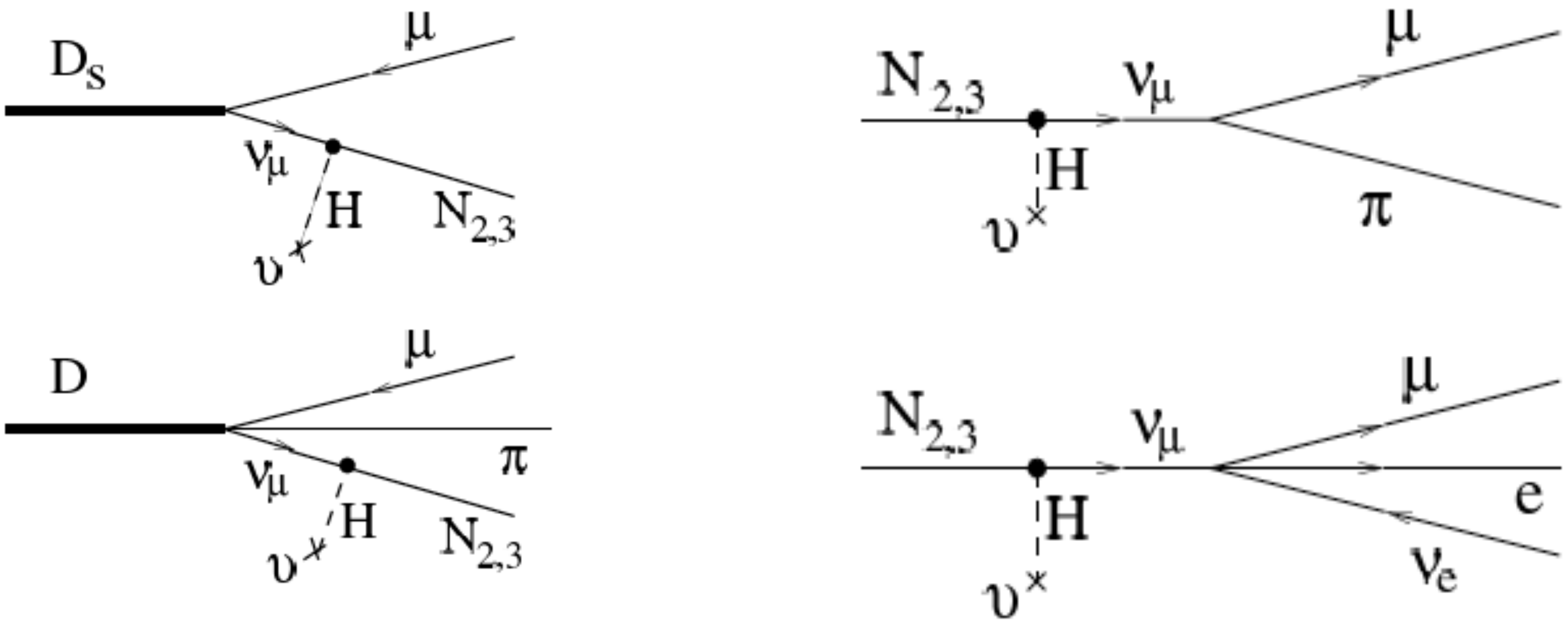
Fixed target experiments better than colliders in the low (< 2 GeV) -mass region



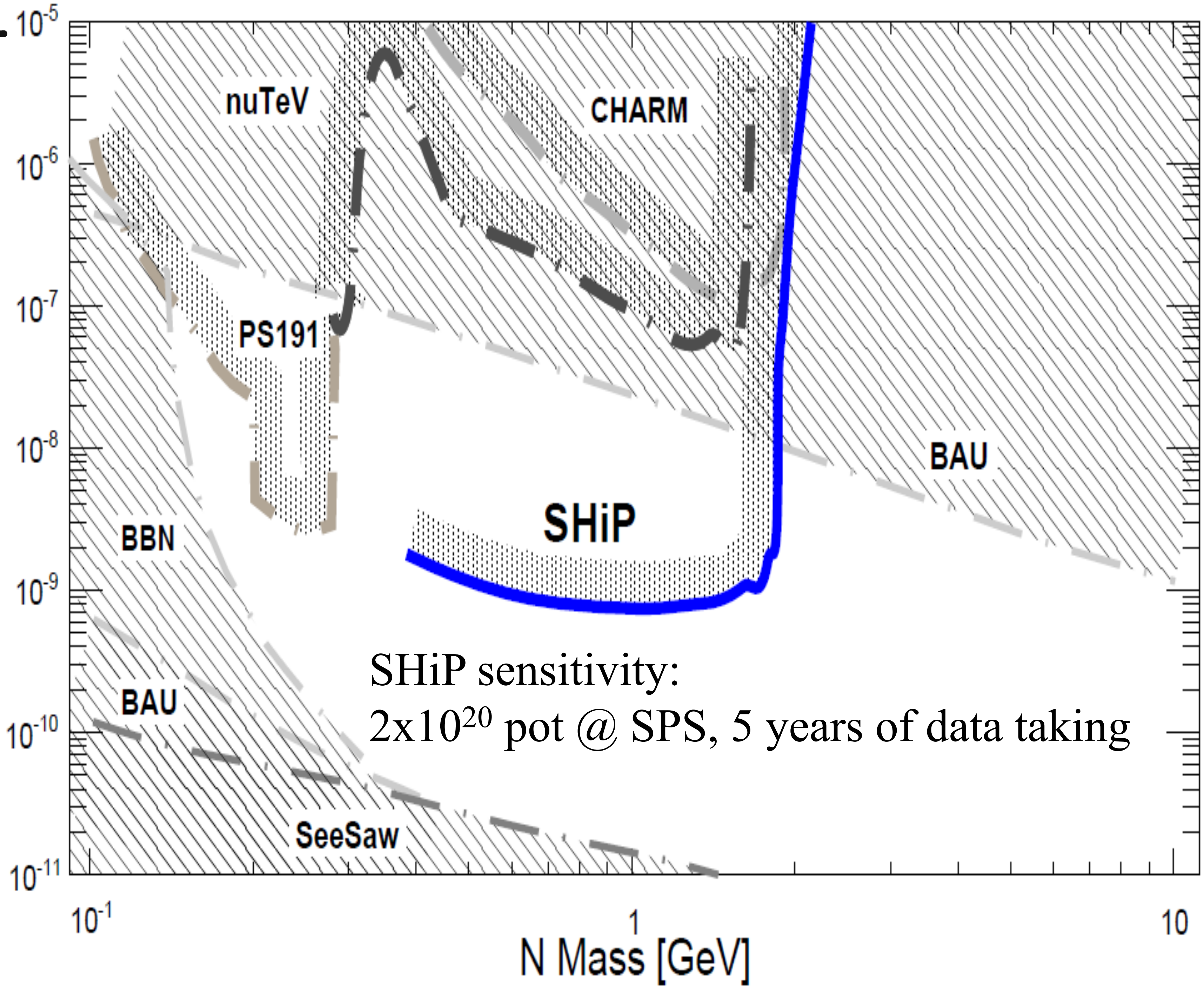
$N_{2,3}$ production and decay

$N_{2,3}$ mix with active neutrinos:

- produced in semileptonic decays of K, D, B (low mass) mesons and from Z decays (high mass)
- Decays in N→**μ**/e π, μ/e rho, ν μ e, etc.)



- Where to produce charm?
  - LHC ($\sqrt{s} = 14$ TeV): with 1 ab^{-1} (i.e. 3-4 years): $\sim 2.10^{16}$ in 4π.
  - SPS (400 GeV p-on-target (pot) $\sqrt{s} = 27$ GeV): with 2.10^{20} pot (i.e. 3-4 years): $\sim 2.10^{17}$
  - Fermilab: 120 GeV pot, $10\times$ smaller $\sigma_{c\bar{c}}$, $10\times$pot by 2025 for LBNE..



SHiP sensitivity:

$2\text{x}10^{20}$ pot @ SPS, 5 years of data taking

SHiP Expression of Interest

Search for Heavy Neutral Leptons @ the SPS

W. Bonivento[1,2], A. Boyarsky[3], H. Dijkstra[2], U. Egede[4], M. Ferro-Luzzi[2], B. Goddard[2],
A. Golutvin[4], D. Gorbunov[5], R. Jacobsson[2], J. Panman[2], M. Patel[4], O. Ruchayskiy[6],
T. Ruf[2], N. Serra[7], M. Shaposhnikov[6], D. Treille[2 (‡)]

[1] *Sezione INFN di Cagliari, Cagliari, Italy*
[2] *European Organization for Nuclear Research (CERN), Geneva, Switzerland*
[3] *Instituut-Lorentz for Theoretical Physics, Universiteit Leiden, Niels Bohrweg 2, Leiden, The Netherlands*
[4] *Imperial College London, London, United Kingdom*
[5] *Institute for Nuclear Research of the Russian Academy of Sciences (INR RAN), Moscow, Russia*
[6] *Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland*
[7] *Physik-Institut, Universität Zürich, Zürich, Switzerland*
(‡) *retired*

arXiv 1310.1762

October 2013: Expression of Interest sent to the CERN SPS Committee.

January 2014: SPSC encourages the proponents to proceed towards a Technical Proposal.

February 2014: The CERN extended directorate setup a Task Force to study the feasibility of the beam line and infrastructure.

May 2014: First SHiP Workshop in Zurich: birth of the SHiP Collaboration
41 groups of 16 countries expressed interest to participate.

June 2014: the INFN "giunta" puts SHiP in CSN1 as part of "what's next" projects.

July 2014 (today): presentation at LNF….

CERN Task force

- Initiated by CERN Management after SPSC encouragement in January

Detailed investigation, feasibility, resources

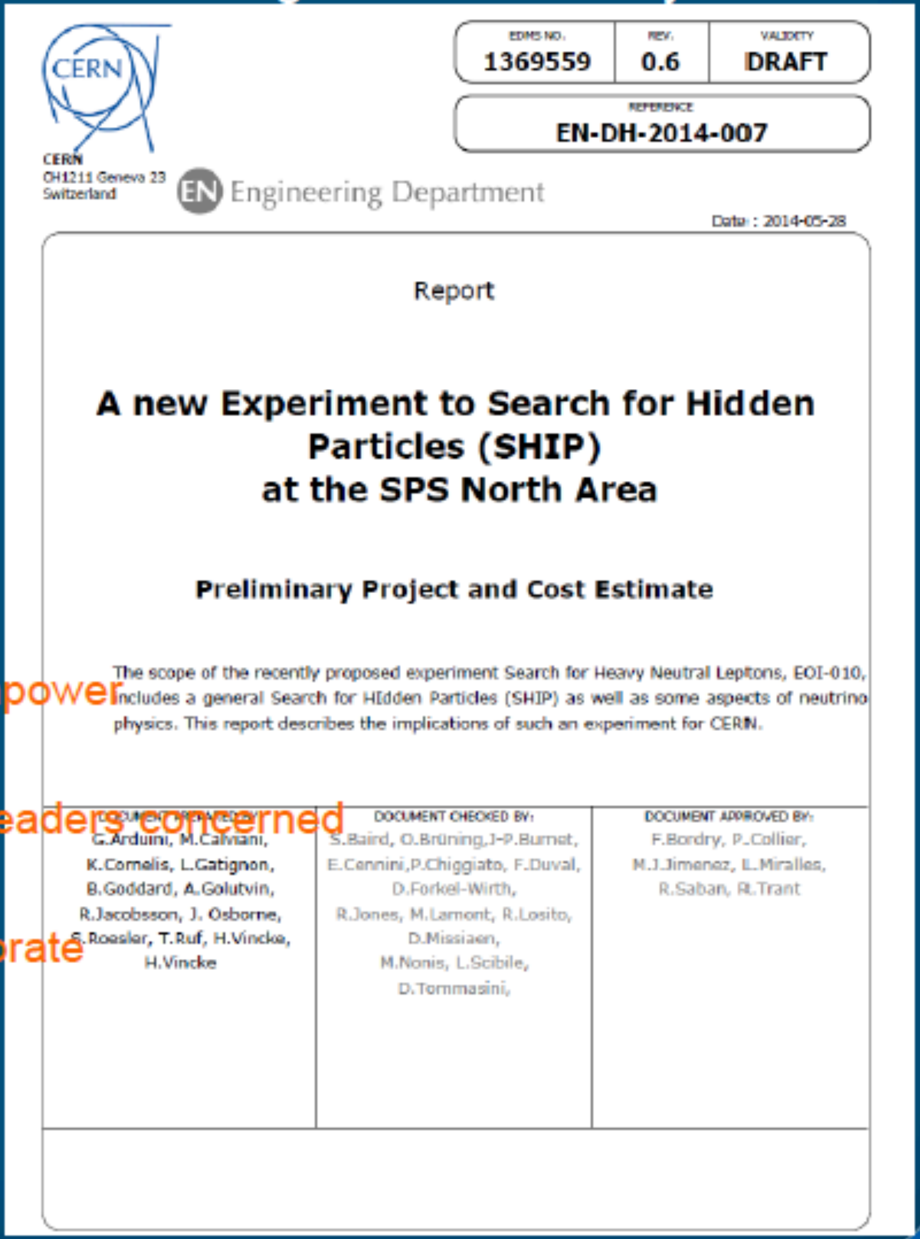
- Physics motivation and requirements
- Experimental Area
- SPS configuration and beam time
- SPS beam extraction and delivery
- Target station
- Civil engineering
- Radioprotection

- Full detailed cost estimate including manpower

- Currently being circulated with all group leaders concerned

- To be presented at next Extended Directorate

→ Not public yet!



EDMS NO.	REV.	VALIDITY
1369559	0.6	DRAFT

REFERENCE
EN-DH-2014-007

CERN
CH1211 Geneva 23
Switzerland

EN Engineering Department

Date : 2014-05-28

Report

A new Experiment to Search for Hidden Particles (SHIP)
at the SPS North Area

Preliminary Project and Cost Estimate

The scope of the recently proposed experiment Search for Heavy Neutral Leptons, EOI-010, includes a general Search for HIdden Particles (SHIP) as well as some aspects of neutrino physics. This report describes the implications of such an experiment for CERN.

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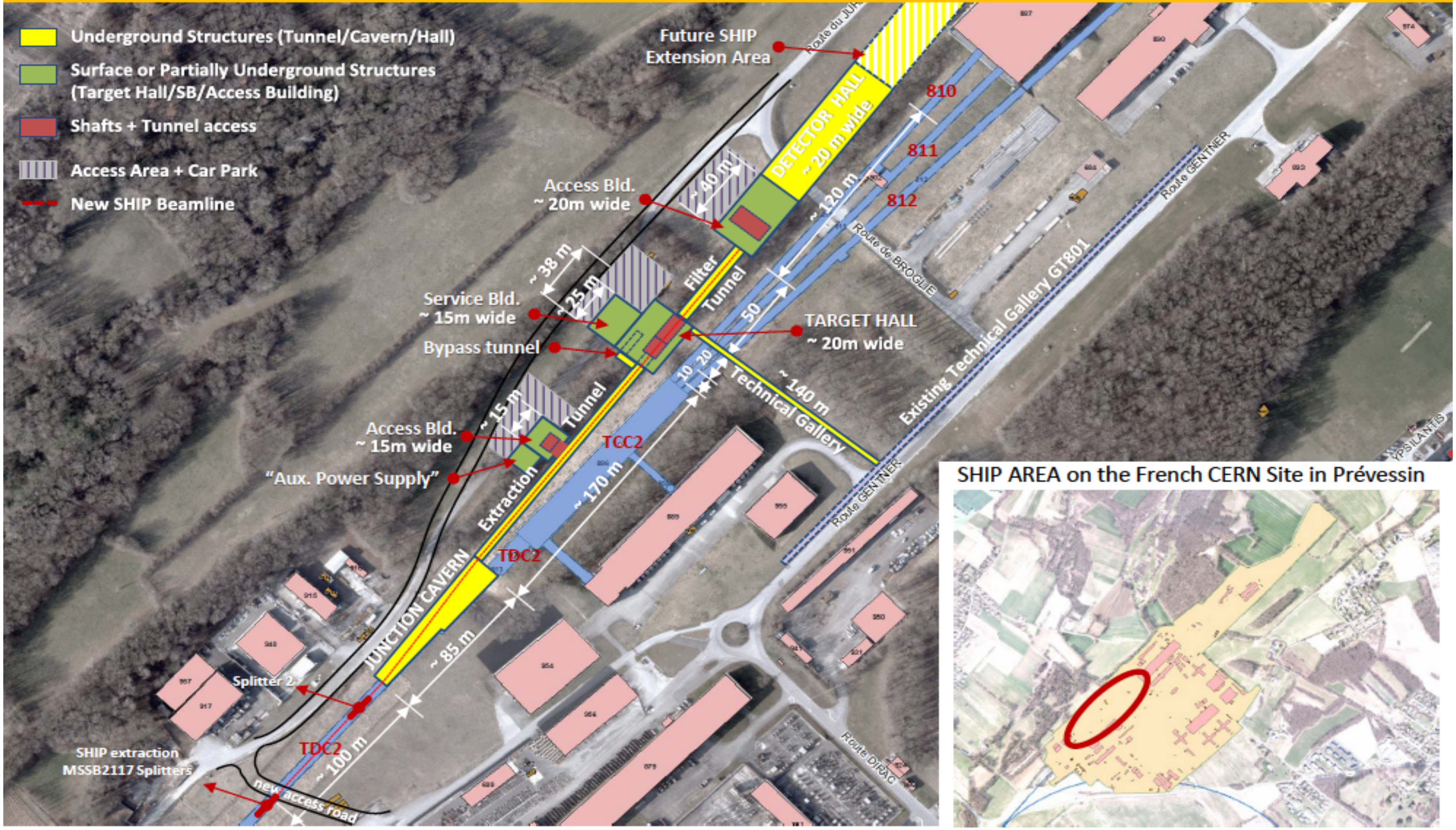
Beam and infrastructure

SHiP

General Infrastructures Services Department

General Layout



- 🟨 Underground Structures (Tunnel/Cavern/Hall)
- 🟩 Surface or Partially Underground Structures (Target Hall/SB/Access Building)
- 🟥 Shafts + Tunnel access
- ▥ Access Area + Car Park
- --- New SHIP Beamline

SHIP AREA on the French CERN Site in Prévessin

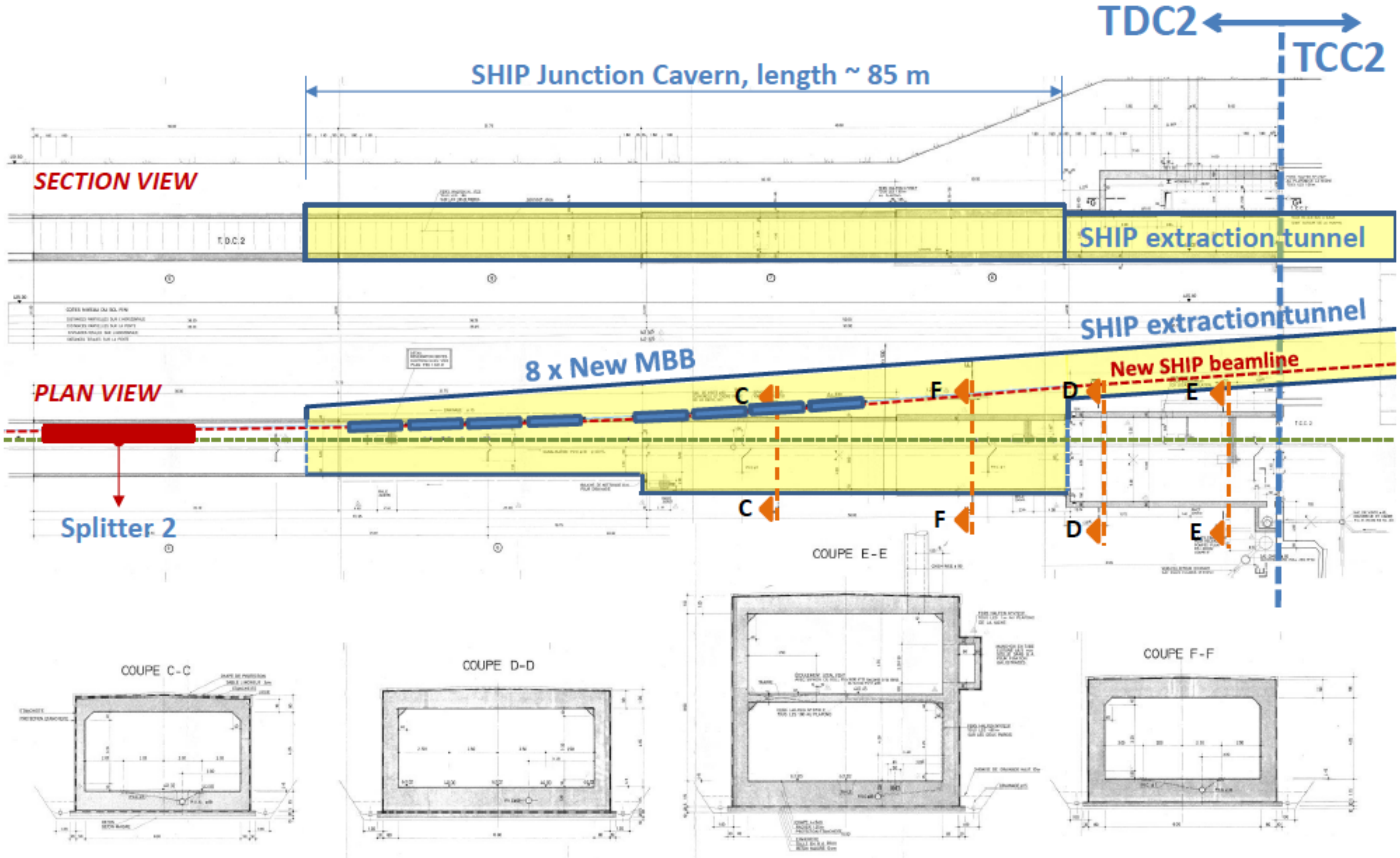
2/6/2014

J. Osborne, M. Manfredi, GS-SE-FAS

Beam and infrastructure

GS General Infrastructures Services Department

Existing drawing tunnel TDC2 (part 2/2)

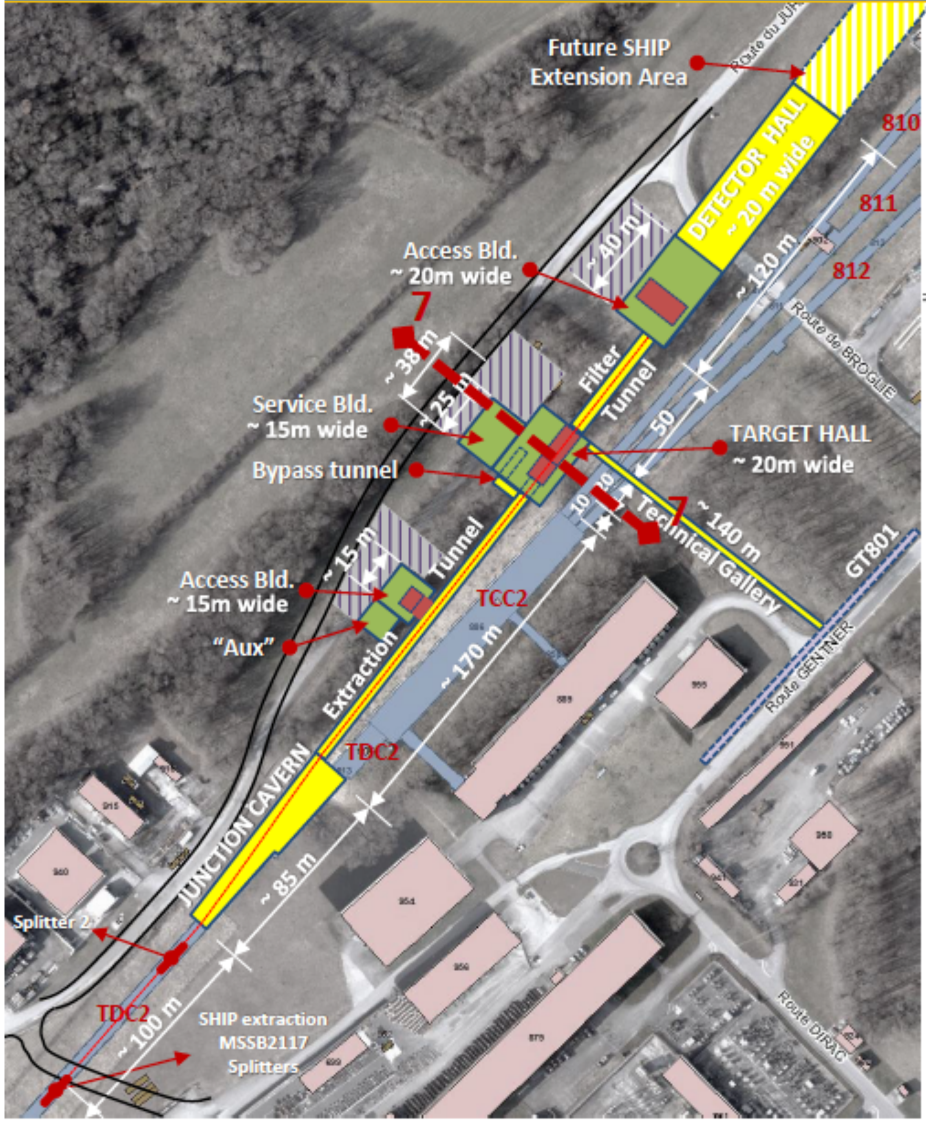


J. Osborne, M. Manfredi, GS-SE-FAS

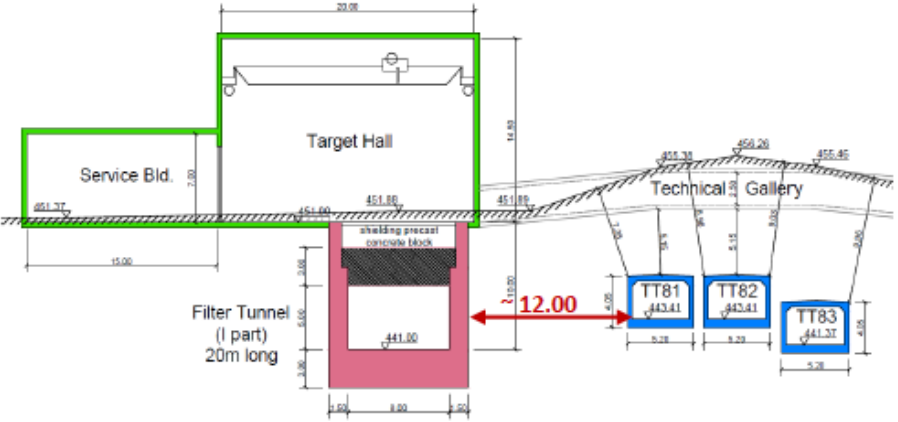
Beam and infrastructure: target zone

General Infrastructures Services Department

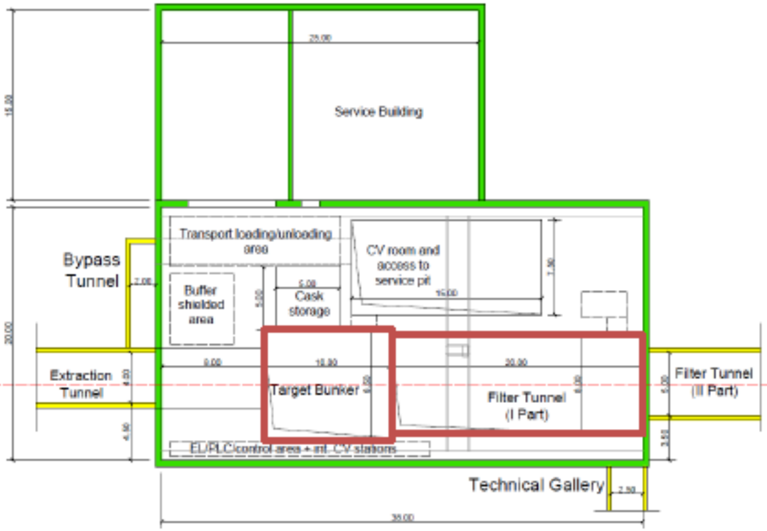
Cross Sections Existing Tunnel/Hall and Facilities foreseen



SECTION 7-7



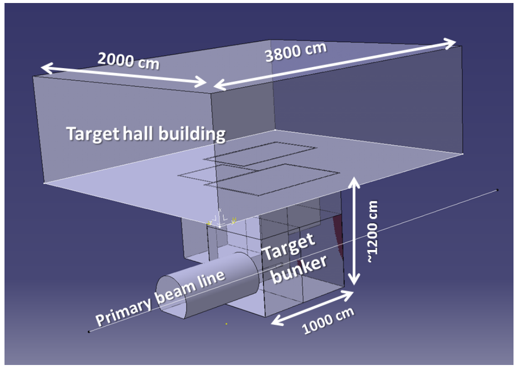
SHIP_Target Hall: Plan view

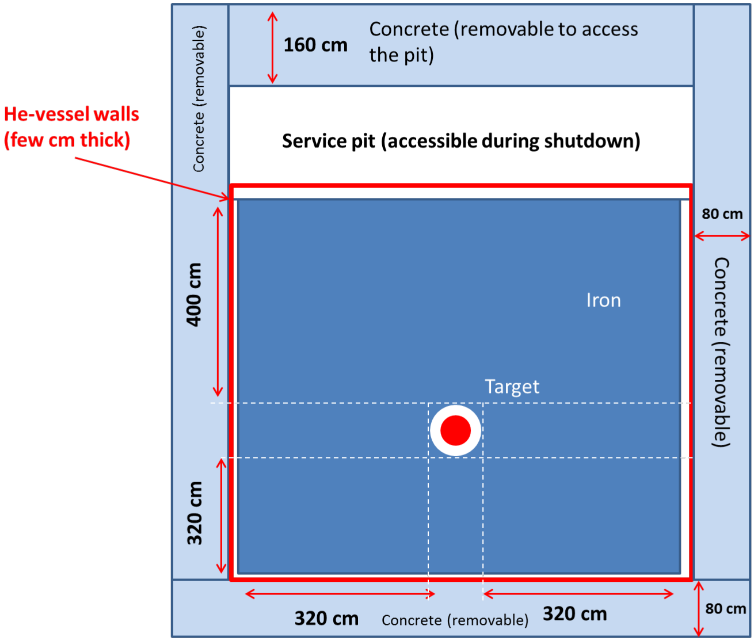


Beam and infrastructure: target zone

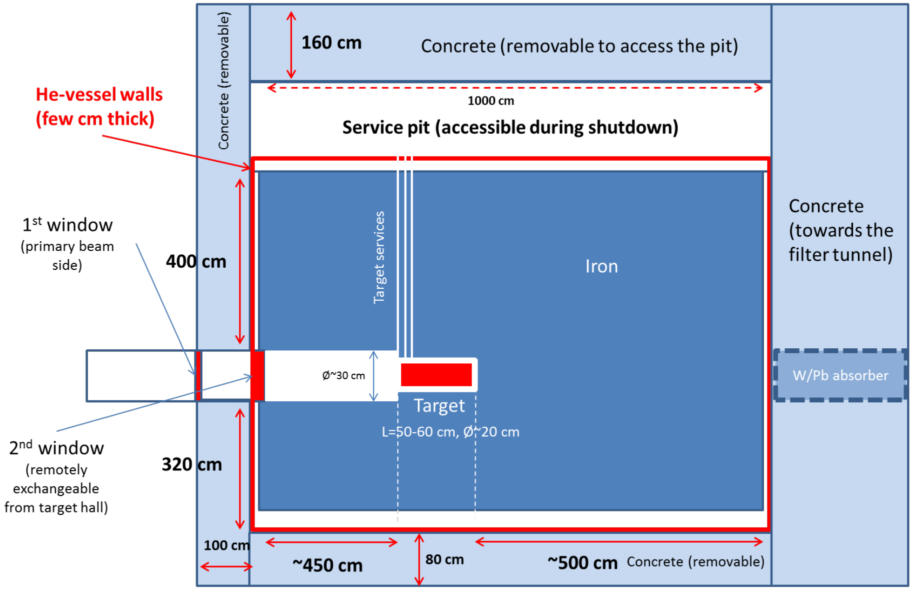
Production target installed inside an **underground Fe shielded bunker** accessible from the top:

- Fully remote handling/manipulation of the target and shielding from the target hall: ***High residual dose rate (~tens of Sv/h!);***
- Target station shall be designed for a MW-class spallation target
- Specific attention to radioprotection & environmental releases





front view

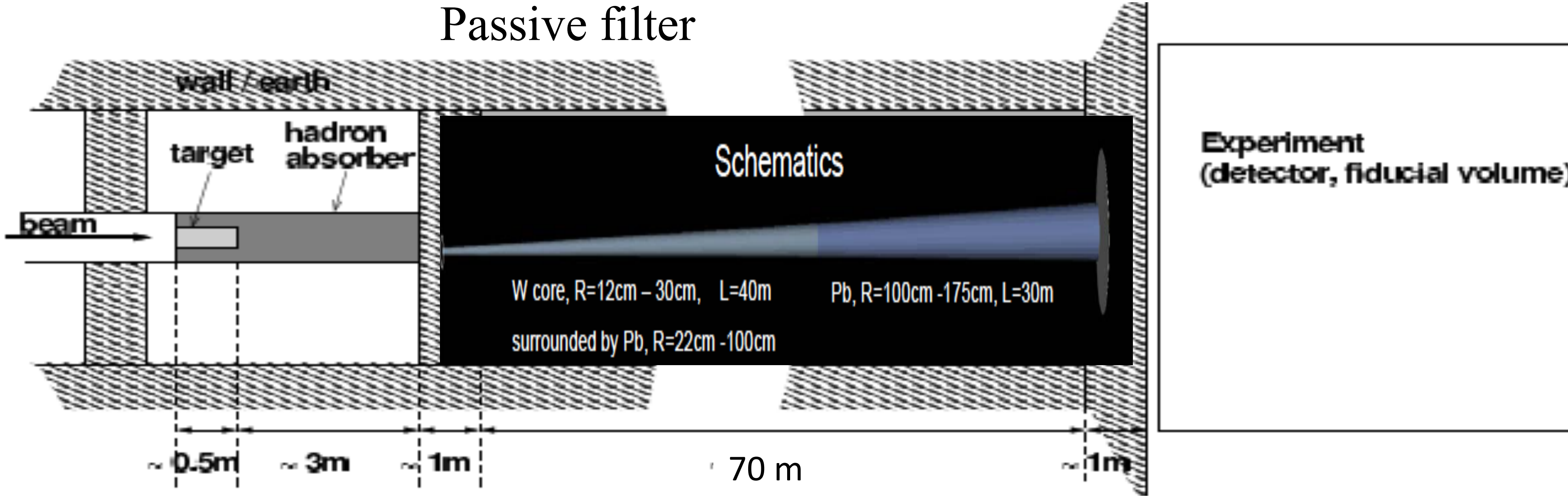


Side view

Beam and infrastructure: the beam dump

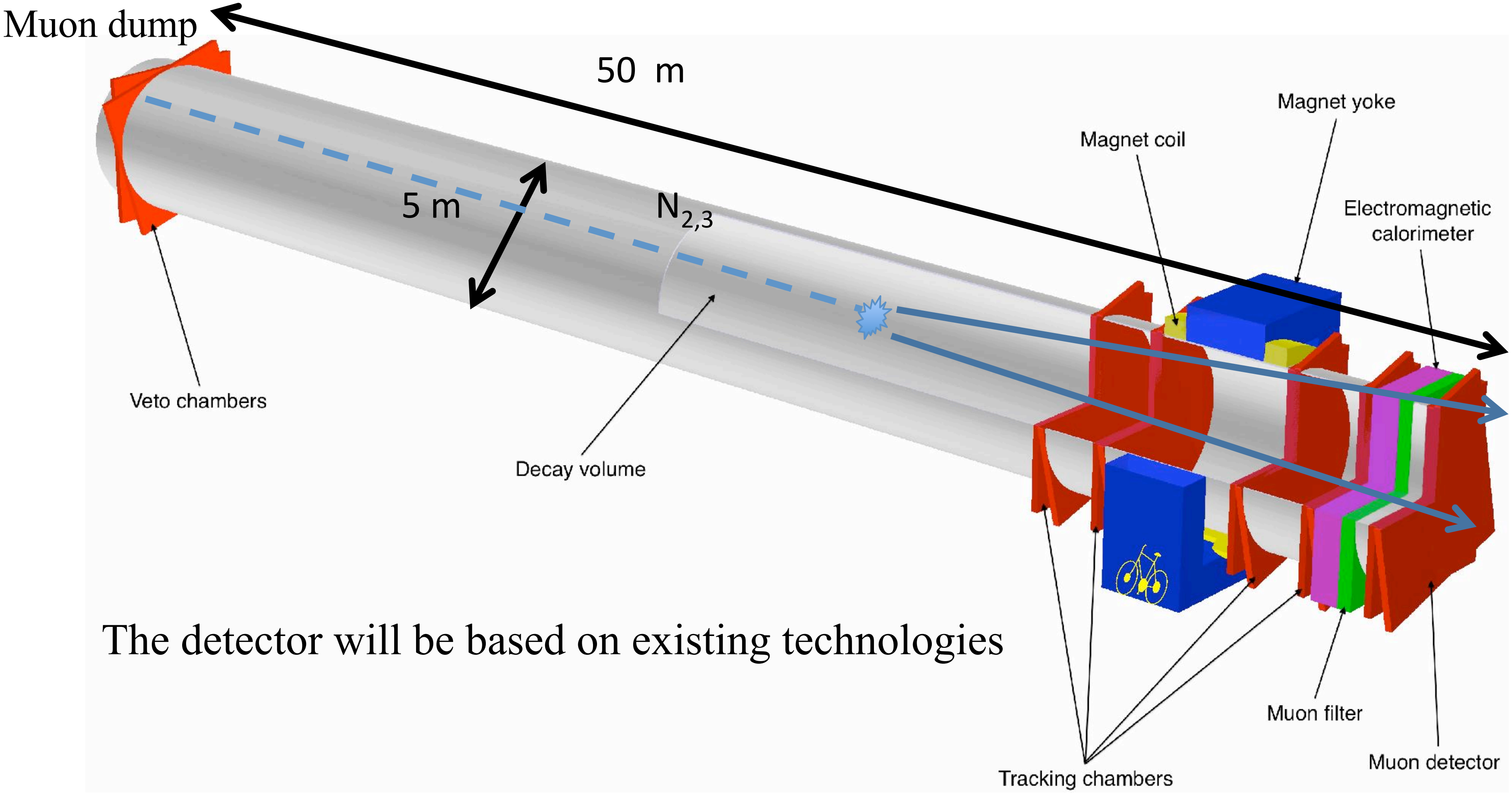
15 GHz of muons up to 400 GeV on 5x5 m^2 surface without dump
Muon dump: 40 m of (W+Pb) + 30 m Pb

Passive filter



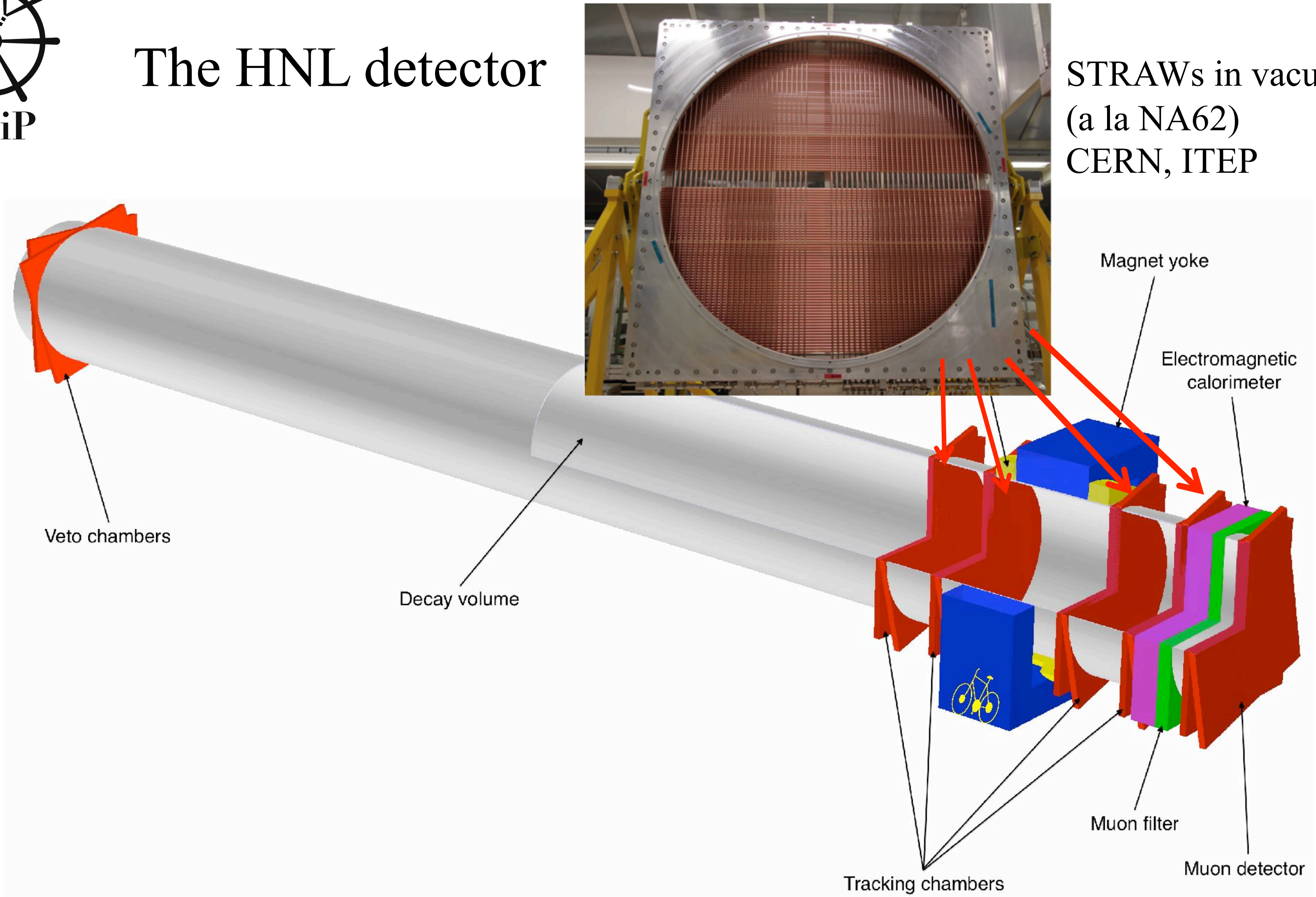
Active filter under study

The HNL detector



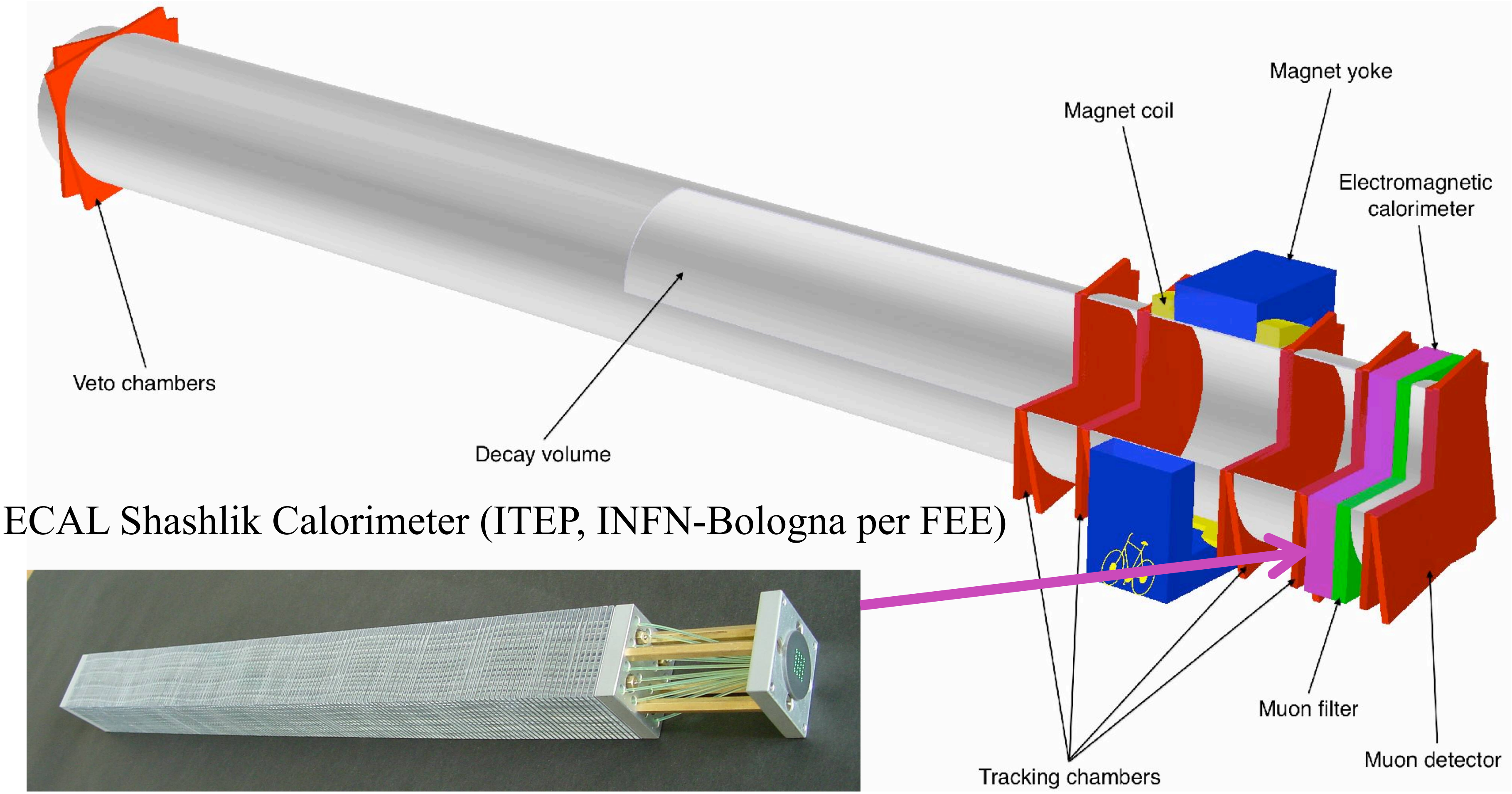
The detector will be based on existing technologies

The HNL detector



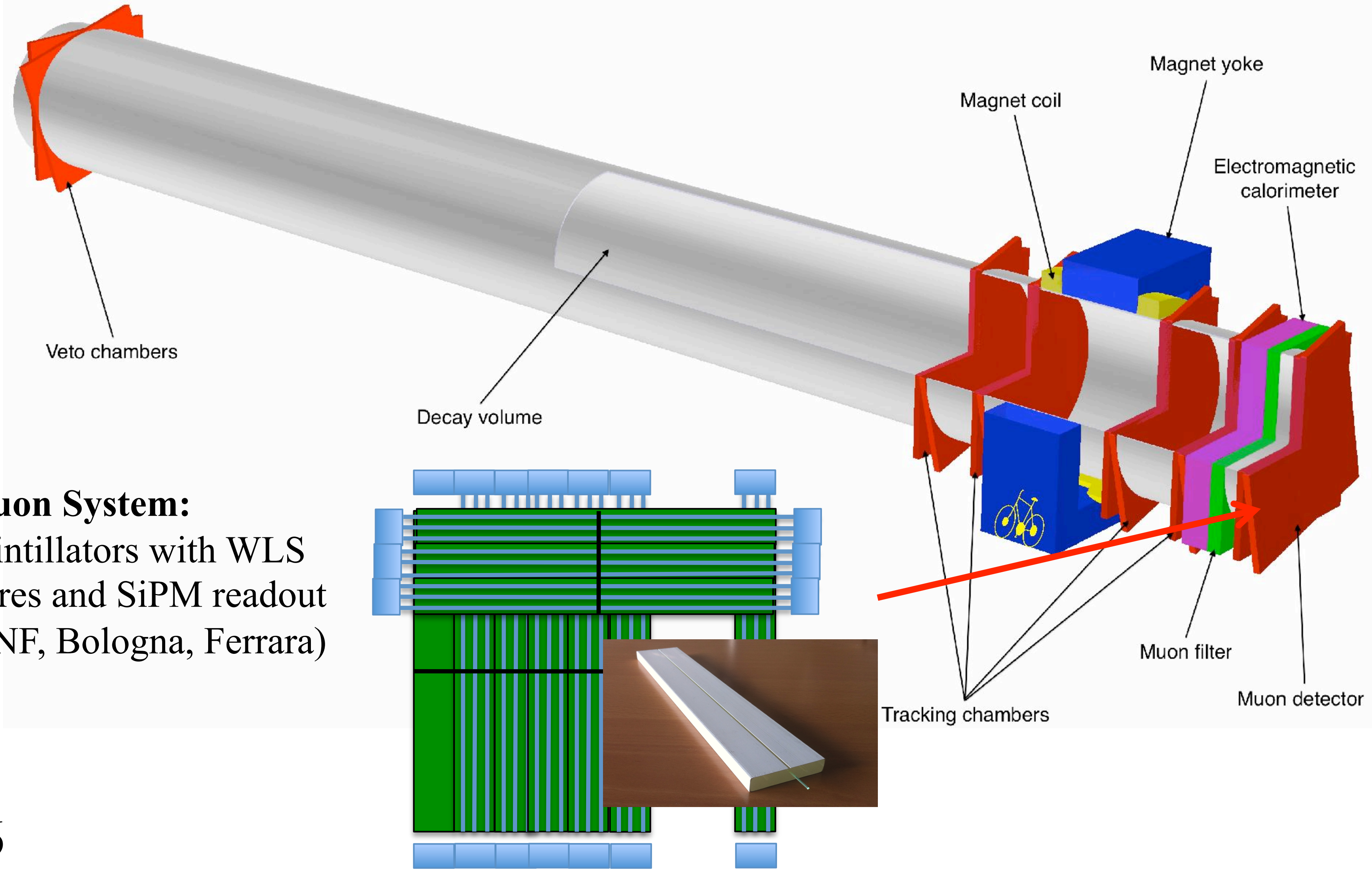
STRAWs in vacuum
(a la NA62)
CERN, ITEP

The HNL detector



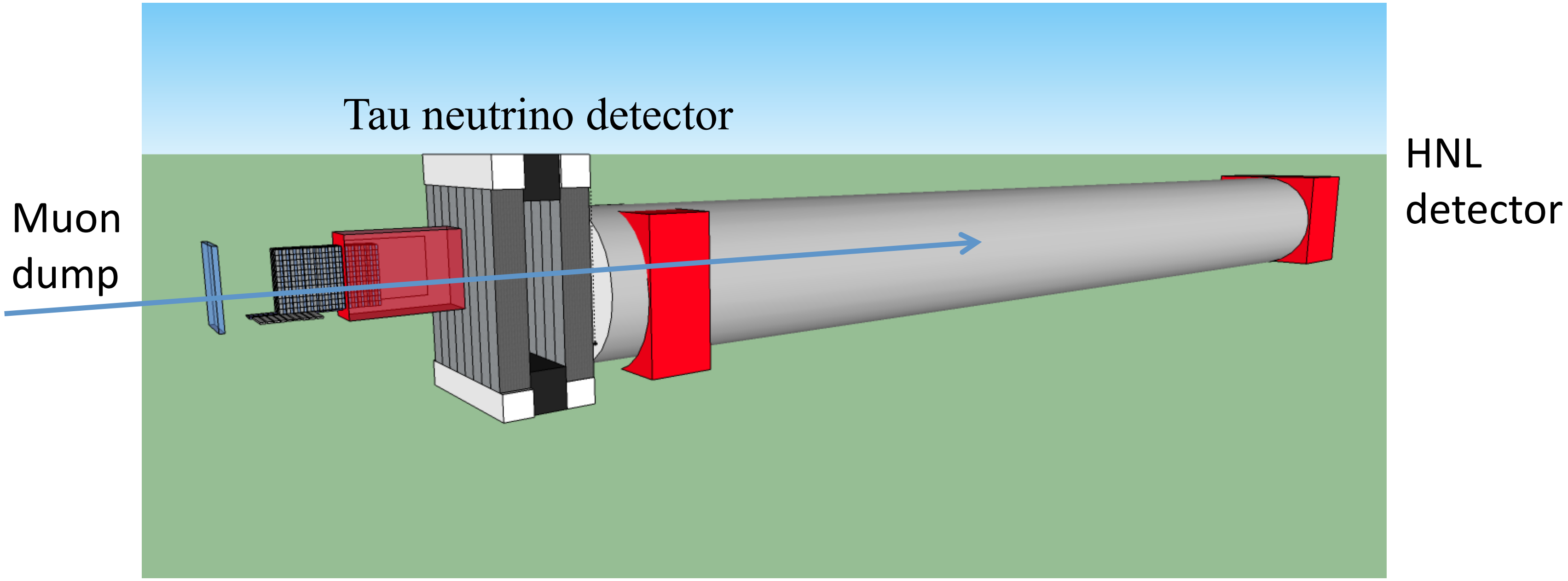
ECAL Shashlik Calorimeter (ITEP, INFN-Bologna per FEE)

The HNL detector



Muon System:
Scintillators with WLS fibres and SiPM readout (LNF, Bologna, Ferrara)

Not only hidden particles… SHiP beam dump is the most intense source of tau neutrinos of the world!

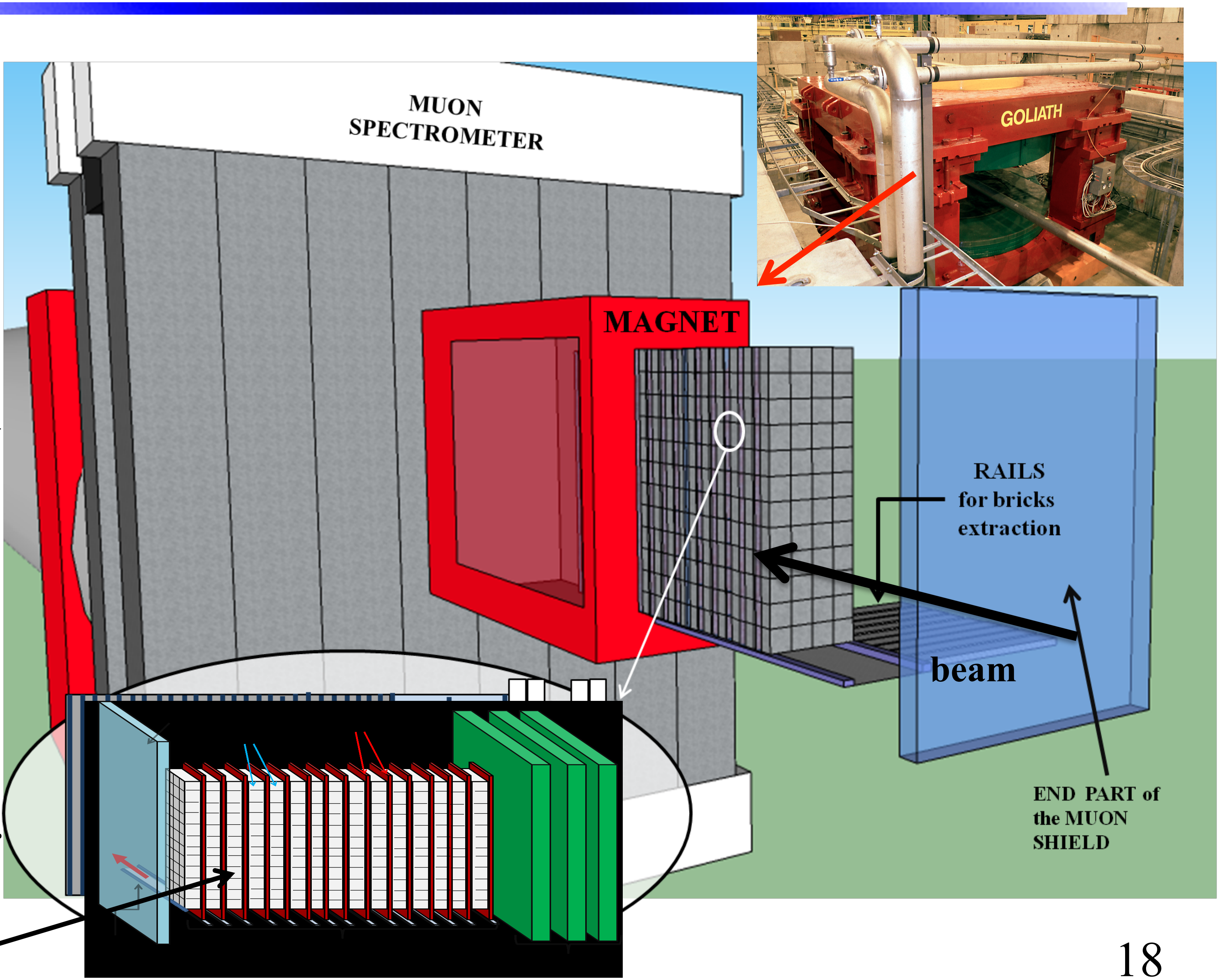


A powerful source of tau neutrinos originated by charm decays (Ds→ τ ν(τ))

1. **Tau neutrinos** observed so far: 4 events observed by OPERA (oscillations) and 9 by DONUT (first observation); SHiP will have 4000 ντ…
2. **Tau anti-neutrino**: never observed so far: SHiP: first observation and cross section
3. **Charm physics** with neutrinos and anti-neutrinos: nucleon structure functions, associated charm production, decay constant of D mesons

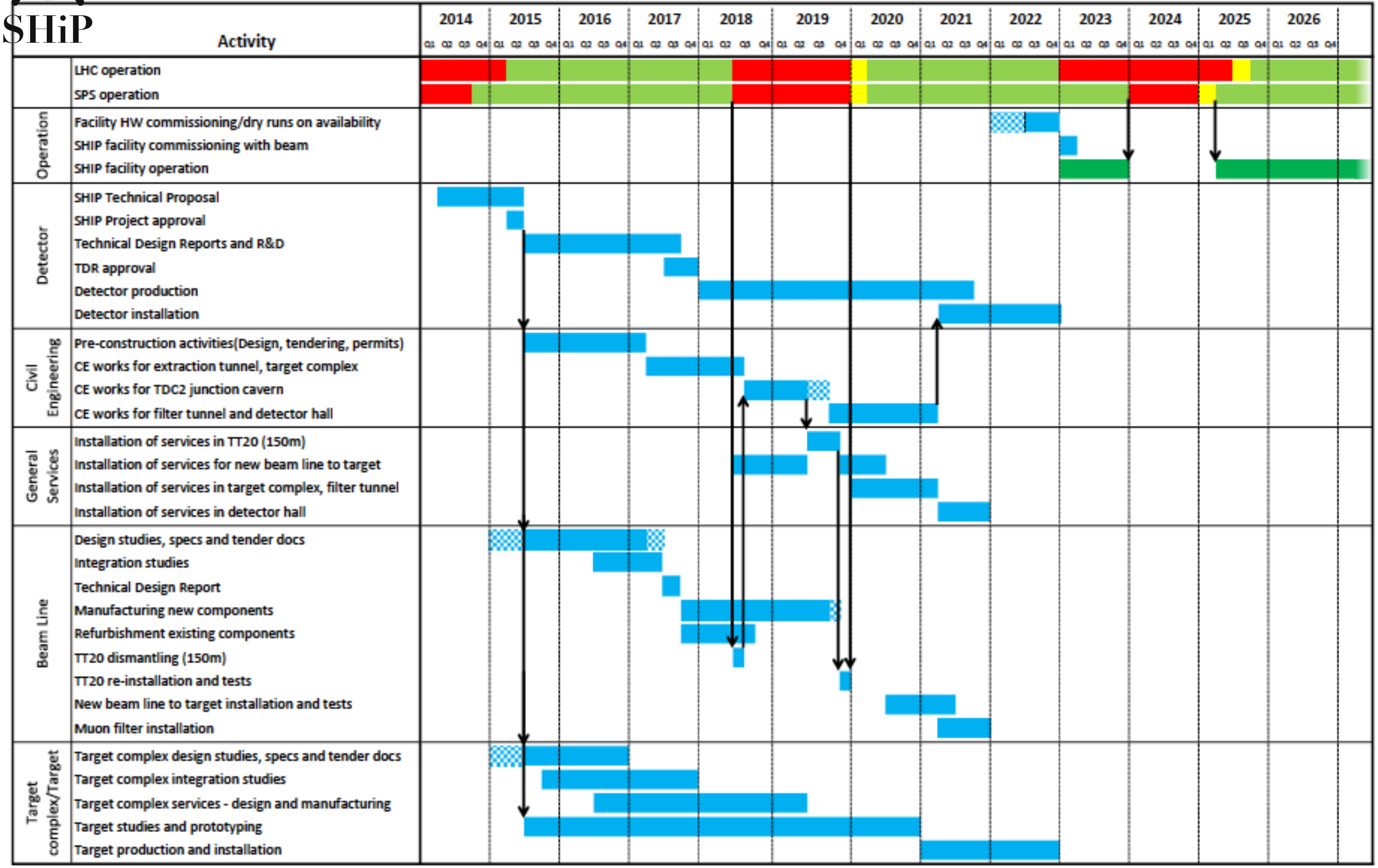
The tau neutrino detector

Decay tunnel



High resolution (100 µm) tracker (GEM or Fibres) + emulsions

Preliminary planning from the CERN Task Force



Preliminary planning from the CERN Task Force

Relevant dates for the Collaboration:

2014: form the **SHiP Collaboration**

→ done in Zurich 2 weeks ago.

2015: **Technical Proposal**

→ next ~ 10 months

2015-2017: R&D and **Technical Design Reports**

2018-2020: Construction of the detectors

→ well fits with the end of many activities @ LNF

2020-2022: Installation & commissioning

2023-2028: data taking

Il planning e' ottimistico, molto probabile shift di un anno

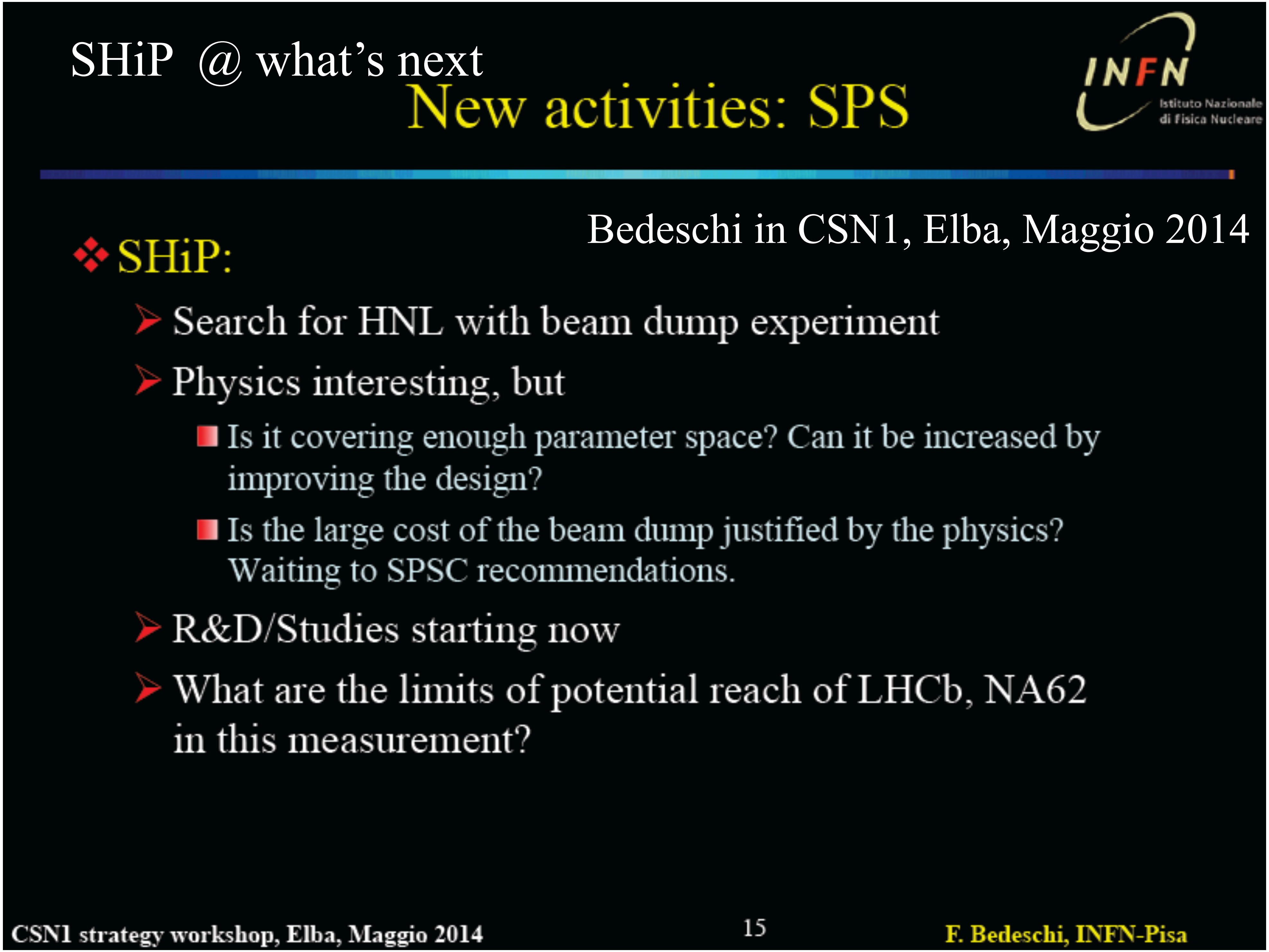
SHiP in the world

40-41 institutes of 16 different countries have expressed interest:
perhaps not all will stay, details will be worked out in the coming months

Brazil	**1**
Bulgaria	**1**
Chile	**1**
Denmark	**1**
France	**2**
Germany	**1**
Italy	**7**
Japan	**5**
Netherlands	**2**
Russia	**6**
Sweden	**2**
CERN	**1 (> 7 physicists)**
Switzerland	**3**
Turkey	**1**
UK	**5-6**
USA	**1**

SHiP @ what's next

Bedeschi in CSN1, Elba, Maggio 2014



New activities: SPS

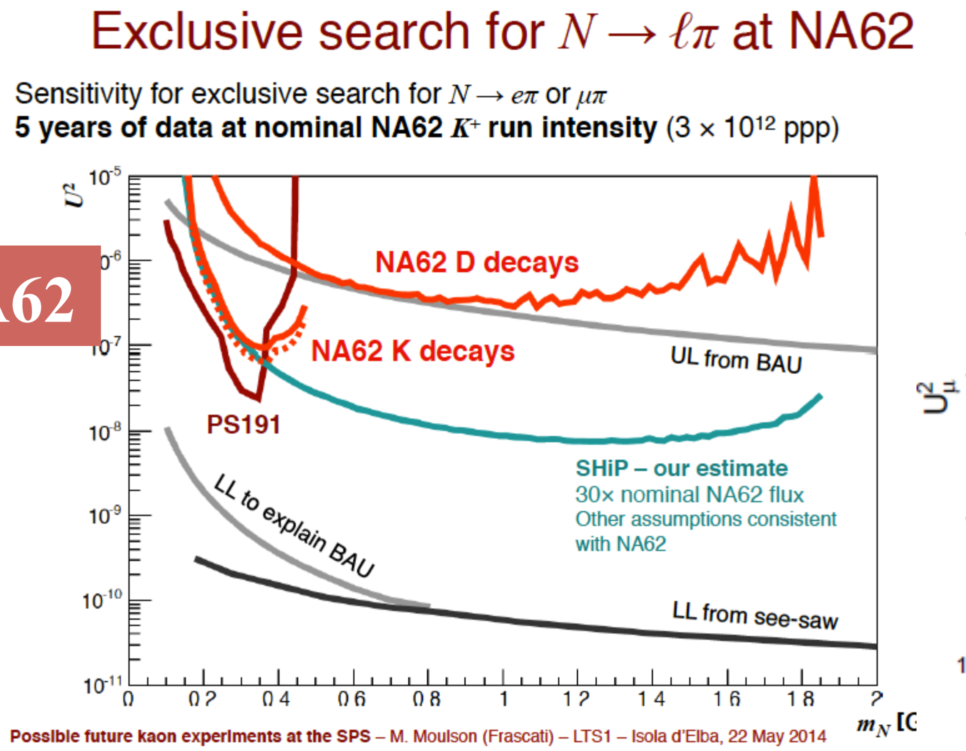
- SHiP:
  - Search for HNL with beam dump experiment
  - Physics interesting, but
    - Is it covering enough parameter space? Can it be increased by improving the design?
    - Is the large cost of the beam dump justified by the physics? Waiting to SPSC recommendations.
  - R&D/Studies starting now
  - What are the limits of potential reach of LHCb, NA62 in this measurement?

CSN1 strategy workshop, Elba, Maggio 2014 15 **F. Bedeschi, INFN-Pisa**

Prospects for HNL search

LHCb has poor sensitivity for HNL
NA62 has sensitivity below the K mass (M<0.5 GeV)
SHiP has sensitivity below the D mass (M<2 GeV)
TLEP will cover masses between 20 and 80 GeV

NA62


Exclusive search for $N \rightarrow \ell\pi$ at NA62

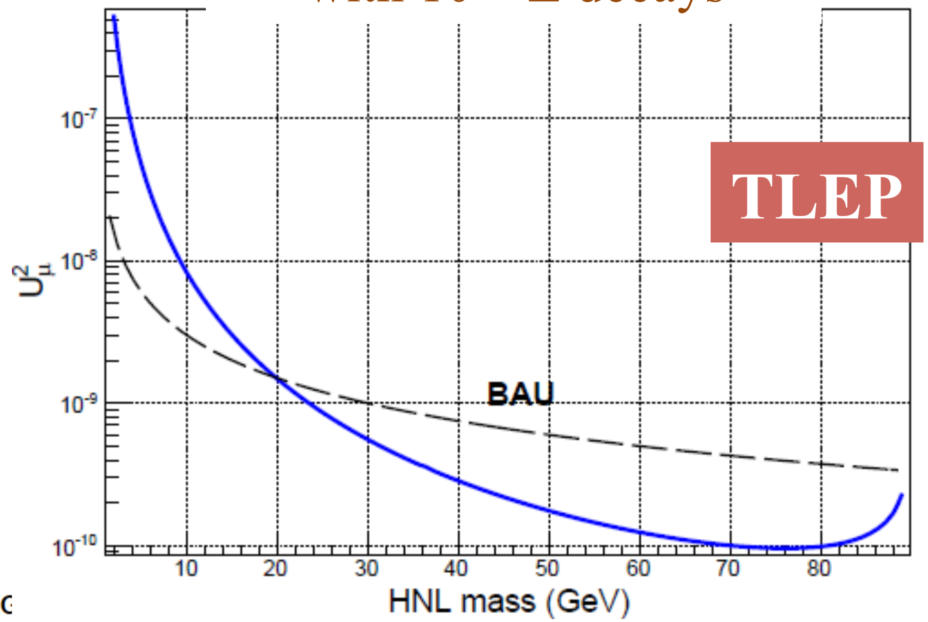
Sensitivity for exclusive search for $N \rightarrow e\pi$ or $\mu\pi$
5 years of data at nominal NA62 K^+ run intensity (3×10^{12} ppp)

Possible future kaon experiments at the SPS – M. Moulson (Frascati) – LTS1 – Isola d'Elba, 22 May 2014

M. Moulson, LTS1, Elba, May 2014

TLEP sensitivity to HNL with 10^{12} Z decays

TLEP



A. Blondel, TLEP Workshop, CERN, June 2014

Interesting synergy NA62-SHiP-TLEP

SHiP - Italia

SHiP nasce nell'INFN come sigla di GR1 con referees di GR1 & GR2.
Parteciperanno a SHiP inizialmente ~ **40 fisici/tecnologi di 7 istituti** INFN per un totale di **8.7 FTE:**

→ **LNF, LNGS, Bologna, Ferrara, Bari, Napoli e Cagliari**

→ **percentuali basse (10-20%) visto lo stato (molto) iniziale del progetto**
(situazione comune a tutte le nazioni che partecipano, la collaborazione e' nata solo 2 settimane fa!)

→ **attivita' 2014-2015 – relativamente piccola (ma importante!):**

- inserirsi nella collaborazione, dividersi i compiti,
- scrivere il Technical Proposal (contributo intellettuale, simulazione, no R&D)
- fare qualche test-beam nel 2015 in vista dei TDR da preparare per il 2017.

Importante inserirsi subito per avere ruoli rilevanti
sfruttiamo al massimo le sinergie tra le varie sezioni per
ottimizzare costi & manpower

SHiP – LNF

7. LNF: 8 persone, 1 FTE in total :

- Gianni Bencivenni (primo ricercatore)	10%
- Monica Bertani (ricercatore)	10%
- Alessandro Calcaterra (primo ricercatore):	10%
- Paolo Ciambrone (primo tecnologo)	10%
- Danilo Domenici (ricercatore, art.23)	10%
- Giulietto Felici (dirigente tecnologo):	10%
- Gaia Lanfranchi (primo ricercatore)	30%,
- Alessandro Paoloni (ricercatore)	10%

SHiP – LNF

LNF ben posizionato per avere un ruolo di rilievo sui seguenti items

1) Muon system detector HNL (scint.+WLS+SiPMs): (LNF, Bologna, Ferrara)

→ **sfruttiamo i 4 anni di R&D fatti per l'IFR di SuperB**, grande esperienza a Bologna e Ferrara, poco R&D da fare, solo un test beam nel 2015 in vista del TDR

→ **Produzione moduli (LNF, Ferrara) & elettronica (LNF, Bologna) non prima del 2018**;

2) GEM- tracker per il rivelatore a neutrini: (LNF, Napoli?)

→ **Grossa sinergia con rivelatore a GEM di BES-III**

→ Test beam congiunto SHiP+BES-III nel 2015 per studiare la risoluzione spaziale di GEM in campo magnetico;

→ R&D (rivelatore & elettronica) tra il 2015 e 2017;

→ **produzione detector & elettronica non prima del 2018**

3) Spettrometro a muoni per il rivelatore a neutrini (LNF, LNGS, Bari, Napoli)

→ **Opera verra' decommissionato l'anno prossimo, riutilizziamo il riutilizzabile** (RPC):

→ Allestimento test stand per RPC ai LNF;

→ Test beam nel 2015 (o 2016?) per studiare la rate capability delle RPCs di Opera.

→ **Nessuna produzione prevista, solo test stands.**

LNF: Attivita' 2014 – preparazione Proposal

Nel 2014 ci serve solo spazio per stoccaggio e missioni per collaboration meetings e meetings in Italia, il resto e' lavoro di software (e di testa!)

- **Spazio:** 4x4 m^2 per stoccaggio RPCs di OPERA che arrivano dal Gran Sasso

-missioni:

- **2 collaboration meetings** x 2 gg x 3 persone
  - 120 euro/giorno x 12 gg …………………………………..……… 1.440 k€
  - 6 viaggi x 300 euro/viaggio …………………………………..…1.8 k€
- **1 tutorial di software per 1 persona:**
  - 3 gg x 120 euro/giorno ……………………………………… 360 €
  - 1 viaggio x 300 euro/viaggio ……………………………… 300 €
- **Gruppo 1 di Settembre** a Catania x 2 persone: ………………….… 1.4 k€

----

totale ……………………………………………………………5.3 k€

LNF: Attivita’ 2015 - preparazione TDR

1) Test beam GEM in campo magnetico (con BESIII) & scintillatori

(contatti con RD51 per TB ad H4 dell’ SPS)

- consumi (GEM):

- costruzione di 2 rivelatori GEM 10x10 cm2 (6 rivelatori da BESIII + KLOE)... 2.0 k€
- realizzazione di meccanica di precisione con tubi BOSCH …………………….. 2.0 k€
- n. 8 APV25 con cavi .... 2.0 k€

- richieste ai servizi (GEM):

- 0.5 MU DI SEA (ELETTRONICO) –
- 0.5 MU DI SPAS (PROGETTAZIONE MECCANICA) –
- 0.5 MU DI OFFICINA MECCANICA (MONTAGGIO DEL SUPPORTO RIVELATORI)

- **consumi & servizi (scintillatori)**: niente at LNF (hanno tutto Bologna e Ferrara)

- **Trasporto per test beam:** camioncino INFN:
- 2 viaggi A/R ………………………………………………………. 500 € x 2
- 4 gg di missione x 120 €/giorno …………………………………….…. 480 €

-**Missioni:** 4 persone x 10 gg (altre 3 persone pagate da BESIII) x 120 € ….4.8 k€
4 viaggi x 300 €/viaggio ………………………………………….. 1.2 k€

LNF: Attivita' 2015 - preparazione TDR

2) **Istallazione test-stand RPC al laboratorio di OPERA @ LNF**

- **consumi:**
  - bombole di gas…………………………………..….2 k€

3) Missioni 2015 per meetings:

- 4 meetings di Collaborazione al CERN:

3 persone x 2 gg x 4 = 24 gg
120 euro/giorno x 24 gg = 2.880 kEuro
12 viaggi @ 300 Euro/viaggio = 3.6 kEuro

Probabilmente **meetings in Italia**, ne stiamo discutendo in questi giorni.

Conclusions

- SHiP will search for NP in the largely unexplored domain of new, very weakly interacting neutral particles.

- Encouragement of the SPSC to proceed towards a Proposal
- CERN directorate has set-up task force to study accelerator part.
- The Collaboration is being setup in these months:

(41 Institutes expressed interest, 7 from INFN)

- The impact of HNL discovery on particle physics is difficult to overestimate!

Discovery would shed light on BSM physics:

– The origin of the baryon asymmetry of the Universe
– The origin of neutrino mass
– The nature of Dark Matter, did we get already a hint?

- SHiP timescale fits very well with the LNF activities:

- **SHiP will take off only in late 2017 –2018** when most of the current LNF activities will be over.

- **Unique opportunity to join the Collaboration at the very beginning!**