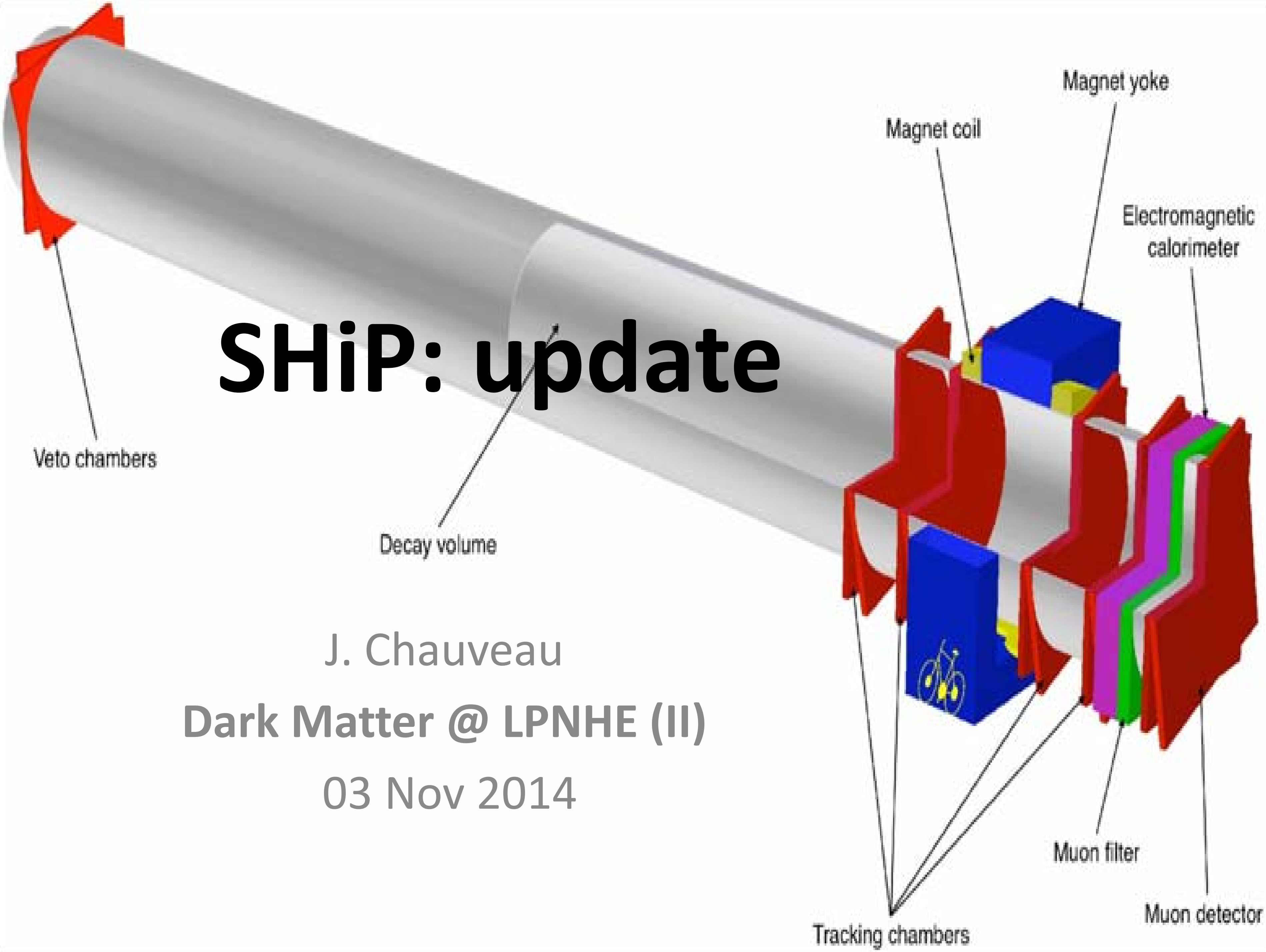
SHiP: update



J. Chauveau

Dark Matter @ LPNHE (II)

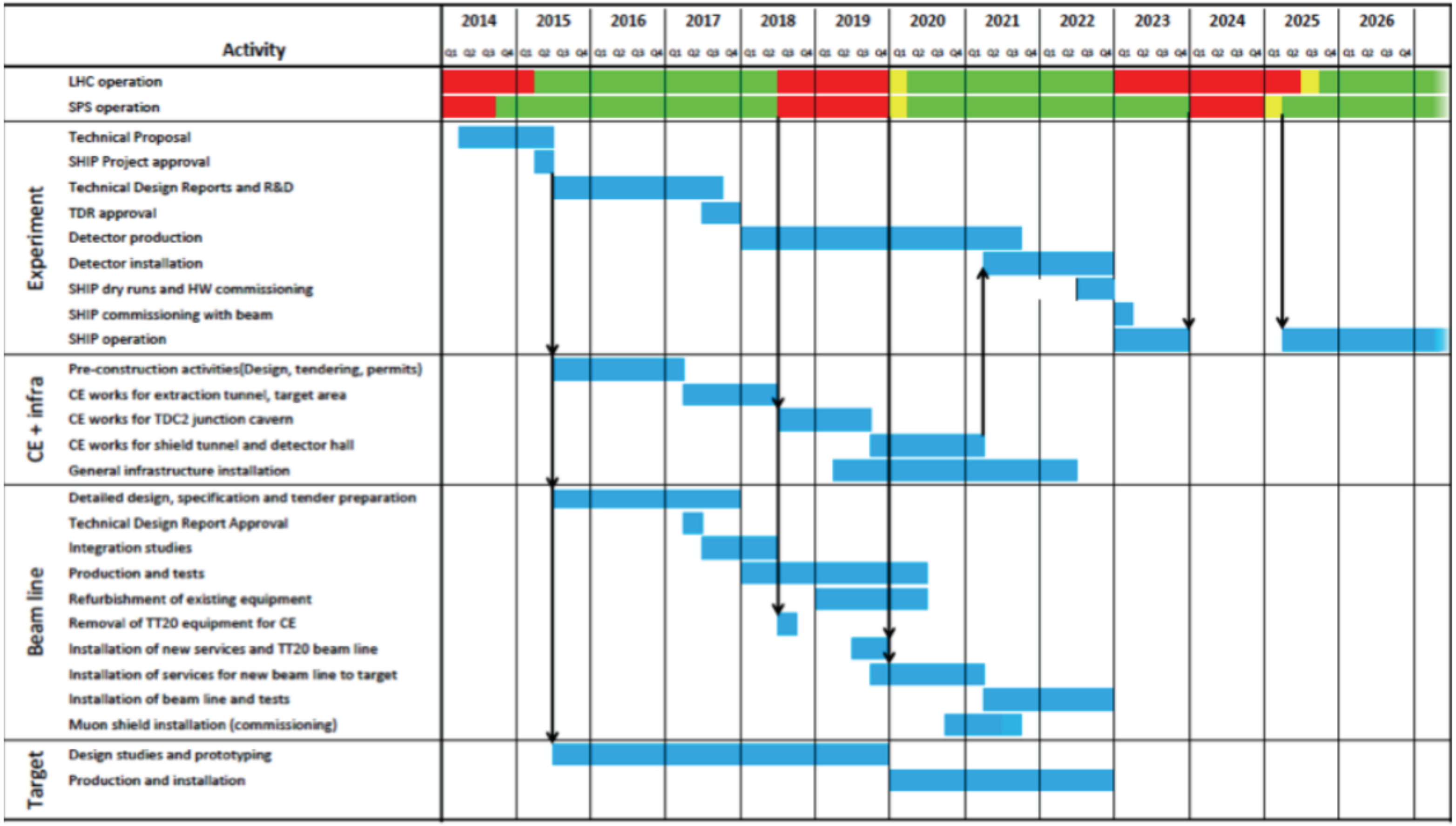
03 Nov 2014

SHiP in a nutshell

http://ship.web.cern.ch/ship/

- general-purpose fixed target facility at the SPS proton (400 GeV) beam dump
- to search for hidden particles as predicted by models of Hidden Sectors addressing
  - **dark matter,**
  - **neutrino oscillations,**
  - **origin of the full baryon asymmetry in the Universe**.
- By looking for very weakly interacting long lived particles,
  - **Heavy Neutral Leptons** - right-handed partners of the active neutrinos;
  - light supersymmetric particles - sgoldstinos, etc;
  - Axion like particles (scalar portal to the hidden sector),
  - **Dark photons** (vector portal)
- Also, **tau neutrinos**.

Schedule



- Technical proposal (2015)
- Technical Design Report (2018)
- Construction and installation (2018-2022)
- Commissioning (2022-2023)
- Data taking and analysis of 2×10^{20} pot (2023-2027)

28

Outline

1. The SHiP experiment brief summary
2. Physics
3. Events since DM@LPNHE(I)
4. Subsystems
5. Pro and Cons for the LPNHE and next steps

2. Physics

- Emerging theories of **Hidden Sectors** into which there are *portals* from the SM.
- *Neutrino portal*: **νMSM is the baseline physics case for SHiP: very strong case for DM + BAU**
- *Vector portal*: dark photon physics case
- *Higgs and axion portals*: ALP physics case
- SUSY
- Also Tau neutrino

- Questions asked at and after DM@LPNHE (I)
- Sensitivity to more general HNLs

See-saw generation of neutrino masses

Most general renormalisable Lagrangian of all SM particles (+3 singlets wrt the SM gauge group):

$$L_{\text{singlet}} = i\bar{N}_I\partial_\mu\gamma^\mu N_I - Y_{I\alpha}\bar{N}_I^c\tilde{H}L_\alpha^c - M_I\bar{N}_I{}^c N_I + \text{h.c.},$$

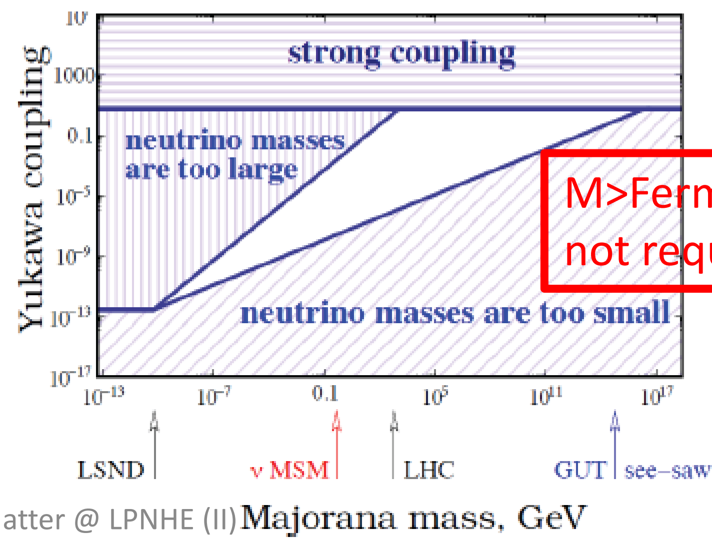
Yukawa term: mixing of N_I with active neutrinos to explain oscillations

Majorana term which carries no gauge charge

The scale of the active neutrino mass is given by the see-saw formula: $m_\nu \sim \frac{m_D^2}{M}$
where $m_D \sim Y_{I\alpha}v$ *- typical value of the Dirac mass term*

Example:

For M ~ 1 GeV and m_ν ~ 0.05 eV it results in m_D ~ 10 keV and Yukawa coupling ~ 10^{-7}

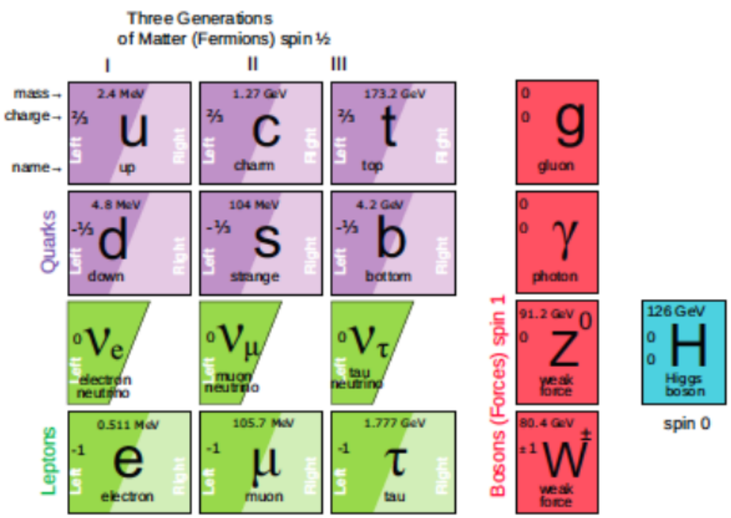


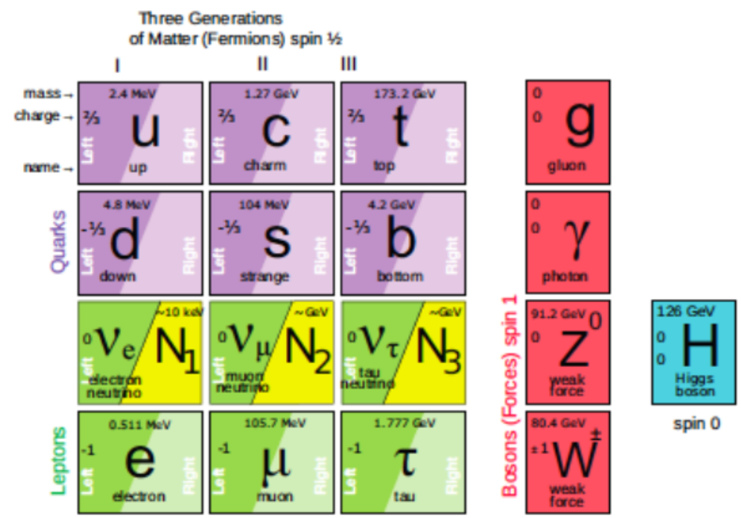
M>Fermi scale, not required!

Golutvin seminar

Neutrino portal observables: (Heavy Neutral Leptons)

νMSM (*T.Asaka, M.Shaposhnikov PL **B620** (2005) 17*) ***explains all short comings of the SM at once by adding 3 HNL: N_1, N_2 and N_3***





N = Heavy Neutral Lepton - HNL

$N_1 \to \nu\gamma$, seen ?

Role of N_1 with mass in keV region: dark matter

Role of N_2, N_3 with mass in 100 MeV – GeV region: "give" masses to neutrinos and produce baryon asymmetry of the Universe

Role of the Higgs: give masses to quarks, leptons, Z and W and inflate the Universe.

SHiP
Search for Hidden Particles

Golutvin seminar

N_2 N_3

Masses and couplings of HNLs

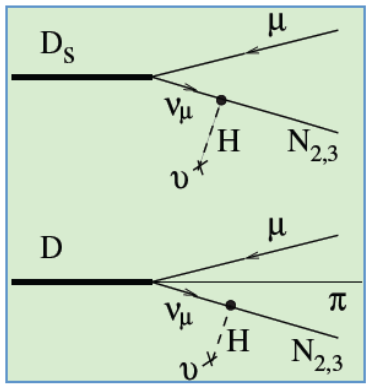
Mitesh Patel

- **$M(N_2) \approx M(N_3)$ ~ a few GeV→ CPV can be increased dramatically to explain Baryon Asymmetry of the Universe (BAU)**

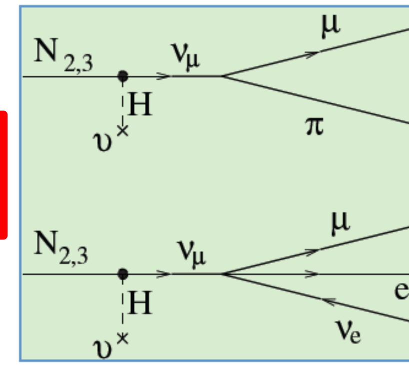
Very weak $N_{2,3}$-to-ν mixing (~ U^2) → $N_{2,3}$ are much longer-lived than the SM particles

Example:

$N_{2,3}$ production in charm



and subsequent decays



- *Typical lifetimes > 10 μs for $M(N_{2,3})$ ~ 1 GeV*

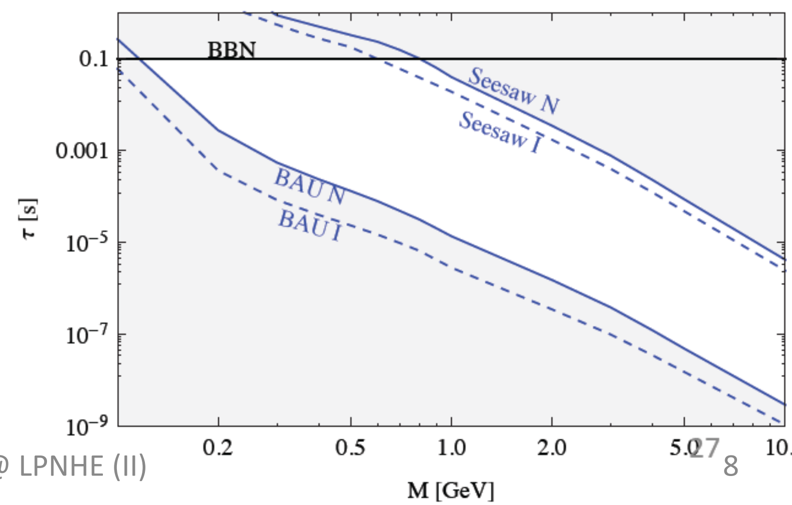
Decay distance O(km)

- *Typical BRs (depending on the flavour mixing):*

Br(N → μ/e π) ~ 0.1 – 50%

Br(N → μ^-/e^- ρ^+) ~ 0.5 – 20%

Br(N → νμe) ~ 1 – 10%



Experimental Design

- p+W → D or D_s +X
- $D_{(s)}$ → N μ (+h) [also e]
- N → $\mu\pi$, $\mu\rho$, $\nu e\mu$, …

- Target
- Dump
- Muon shield
- [decay vol. + detector]*2

- 2×10^{20} pot. 400 GeV. Slow.
- BF $\approx 10^{-8} - 10^{-12}$
- BF $\approx$ 0.1 – 50 %

- 50 cm (W) – 750 kW
- 3 m heavy stuff (W + ?? + concrete)
- 52 or 54 m (U or W or ??)
- 10 m each

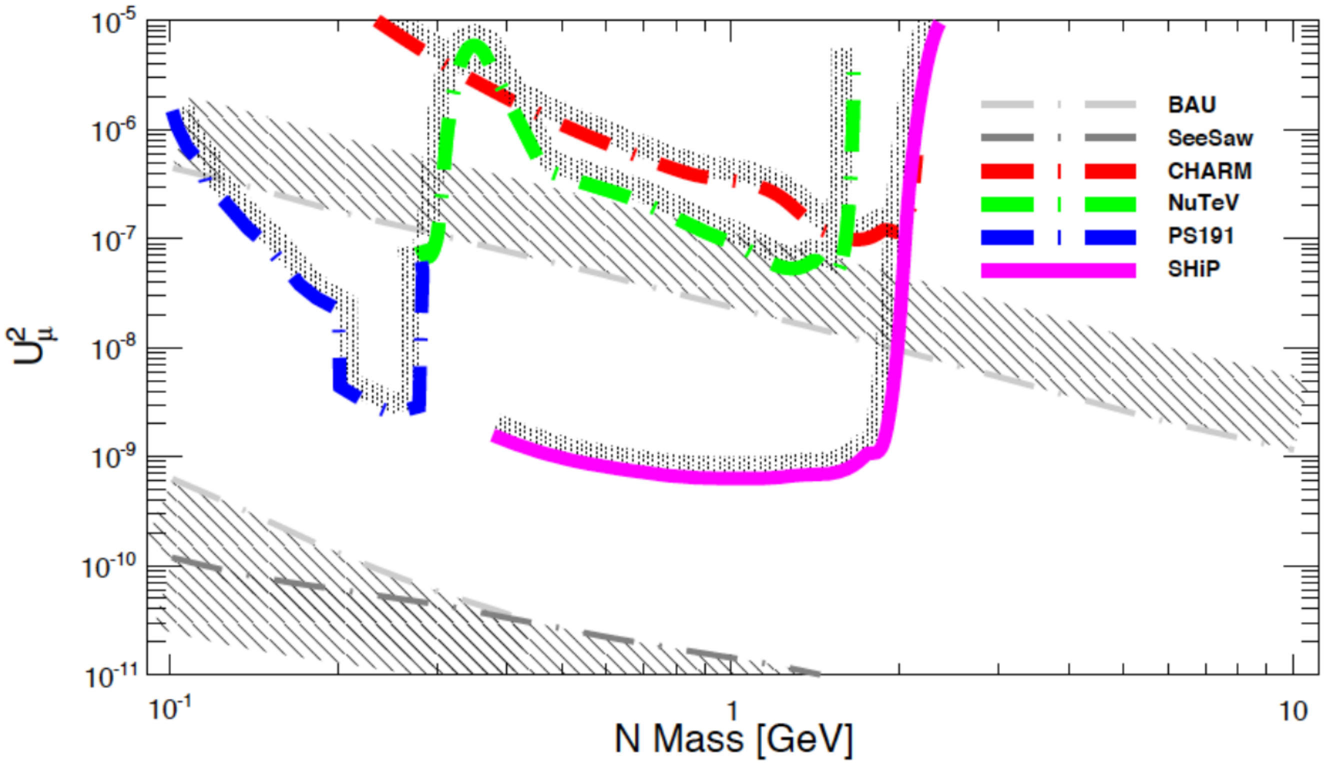
- signal: $\theta_N \approx 50$ mrad, $\theta_{l,p} \approx 100$ mrad
  - short decay distance,
  - wide detector
- dominant background from ν in the last λ of shield

Expected Physics reach

Mitesh Patel

Expected event yield (cont.)

Assuming $U_{\mu}^2 = 10^{-7}$ (corresponding to the strongest experimental limit currently for $M_N \sim 1$ GeV) and $\tau_N = 1.8\times10^{-5}$ s
~12k fully reconstructed $N \to \mu^-\pi^+$ events are expected for $M_N = 1$ GeV



120 events for cosmologically favoured region: $U_{\mu}^2 = 10^{-8}$ & $\tau_N = 1.8\times10^{-4}$s

35

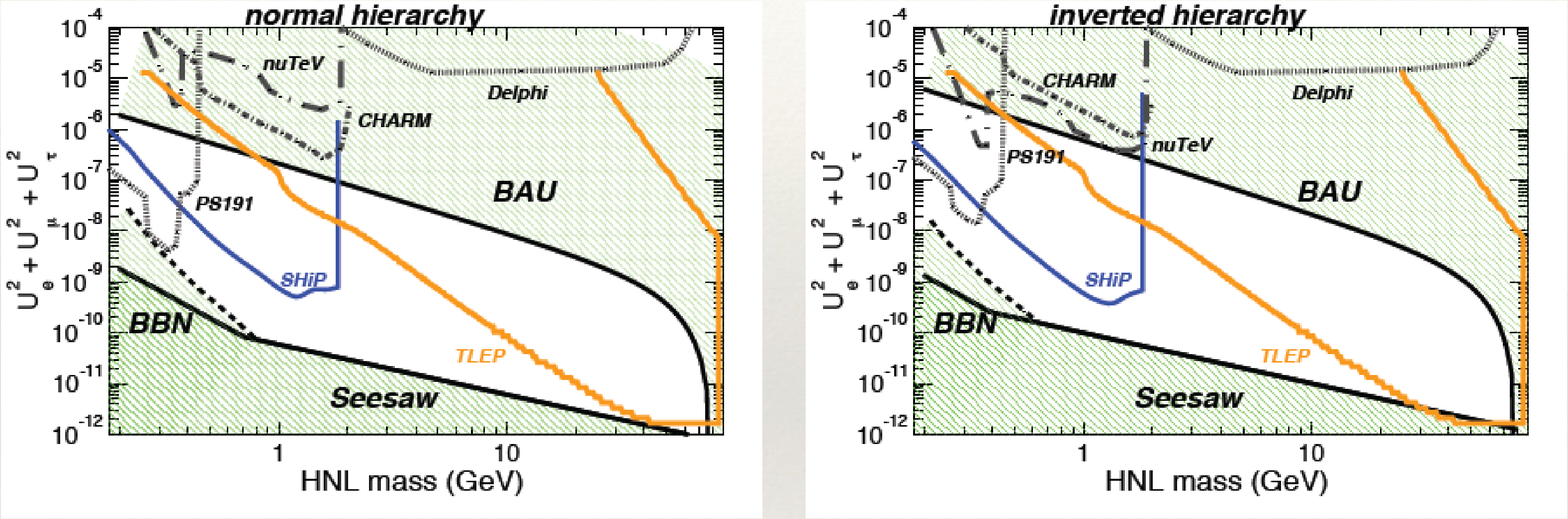
HNL reach

- In νMSM there is a region in parameter space consistent with the constraints from
  - Cosmology BAU (BBN)
  - Dark matter
  - ν oscillations
- N_1 with keV mass are favored in (thanks JML, FV)
  - **H. J. de Vega, N. G. Sanchez, 'Model independent analysis of dark matter points to a particle mass at the keV scale', arXiv:0901.0922, Mon. Not. R. Astron. Soc. 404, 885 (2010).**
- Synergy with Belle 2, FCCee,
  - all needed to cover parameter space
- If above constraints are relaxed a wider region in U^2 vs M can be reached. Extreme example: 'just so' HNLs.

N. Serra at FCCee workshop 29/10/2014

Sensitivity assuming zero background

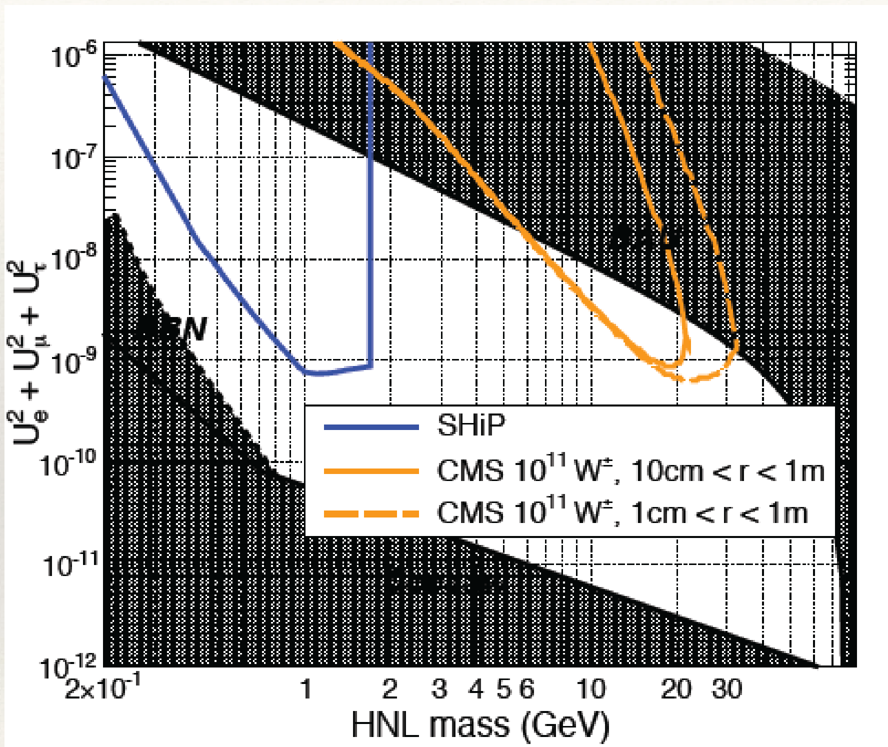
Let's start with the most optimistic scenario, i.e. the maximum region we can probe



This should be considered the maximum sensitivity managing to go to zero background in the region 100um and 5m with 10^{13} Z^0

N. Serra at FCCee workshop 29/10/2014

CMS/ATLAS sensitivity estimation



‘just so’ HNL

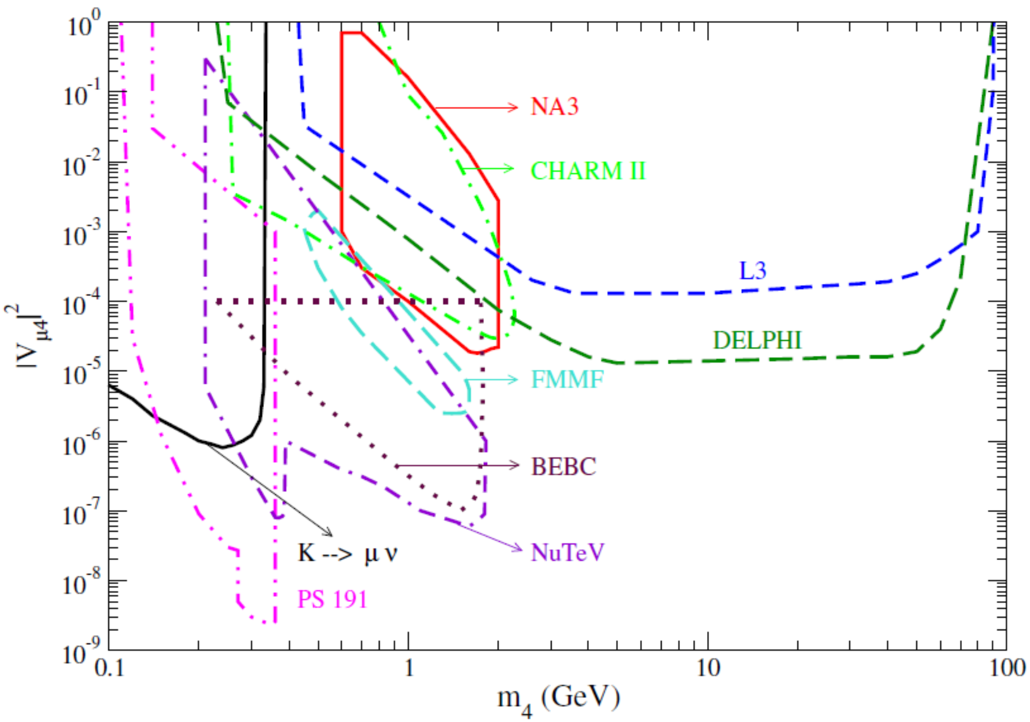


Figure 5: Current experimental upper bounds on the mixing of the HNLs with the muon neutrino. The area with the solid black contour labeled $K \to \mu\nu$ [87] is excluded by peak searches. The other bounds indicated by contours labeled by PS191 [92], NA3 [101], BEBC [102], FMMF [103], NuTeV [93] and CHARMII [104] correspond to the beam-dump experiments with limits at 90% C.L., while DELPHI [105] and L3 [106] correspond to collider experiments at LEP with limits at 95% C.L. The figure is taken from Ref. [100].

‘just so’ HNL, Belle

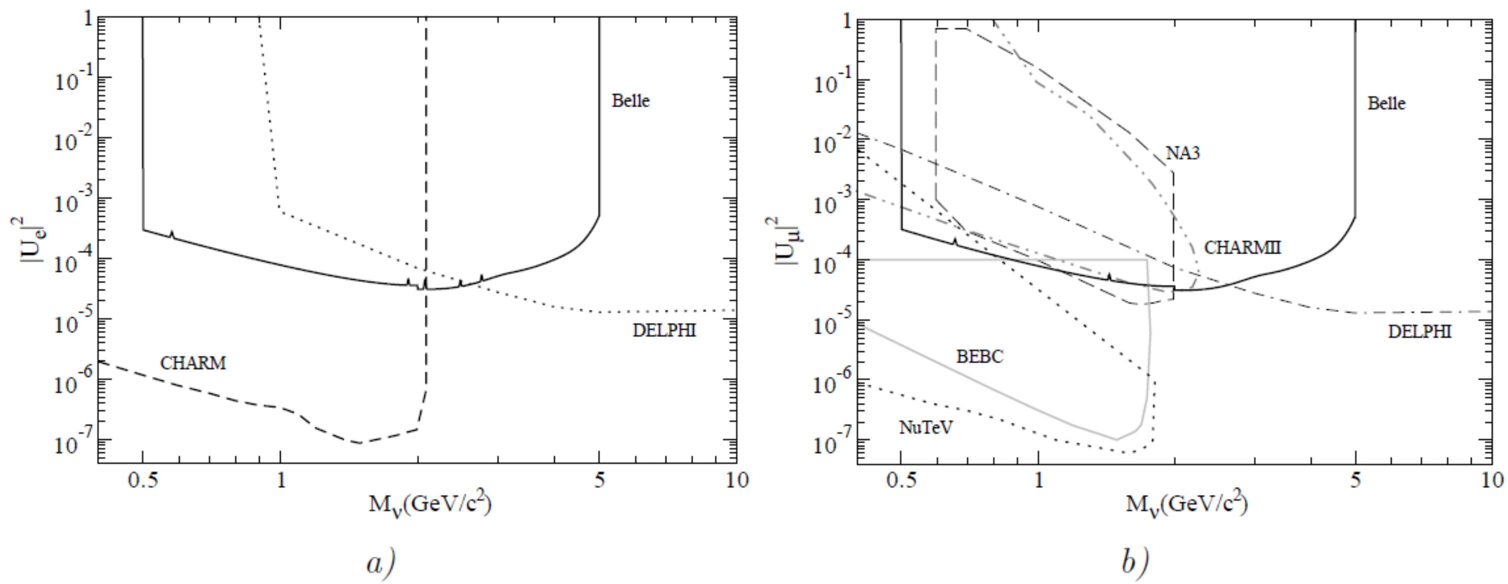
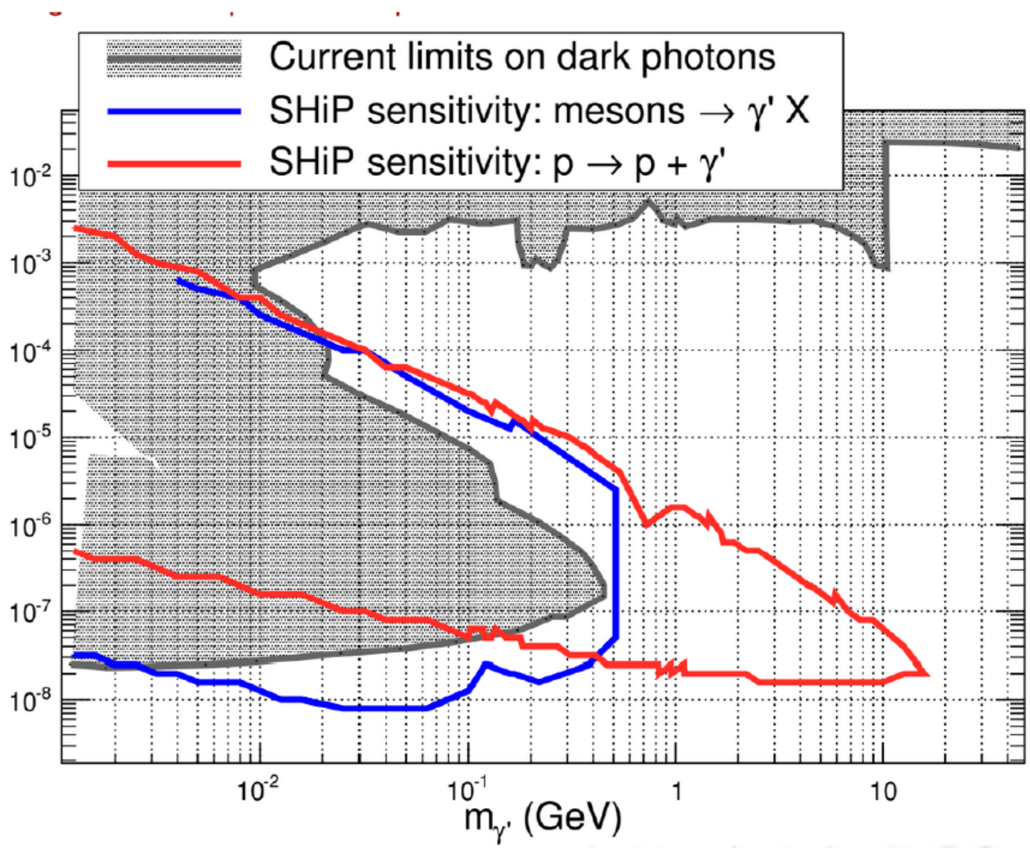


FIG. 5. Comparison of the obtained upper limits for $|U_e|^2$ *(a)* and $|U_\mu|^2$ *(b)* with existing experimental results from CHARM [15], CHARMII [16], DELPHI [17], NuTeV [18], BEBC [19] and NA3 [20].

Expected Physics reach

Mitesh Patel

Sensitivity – vector portal



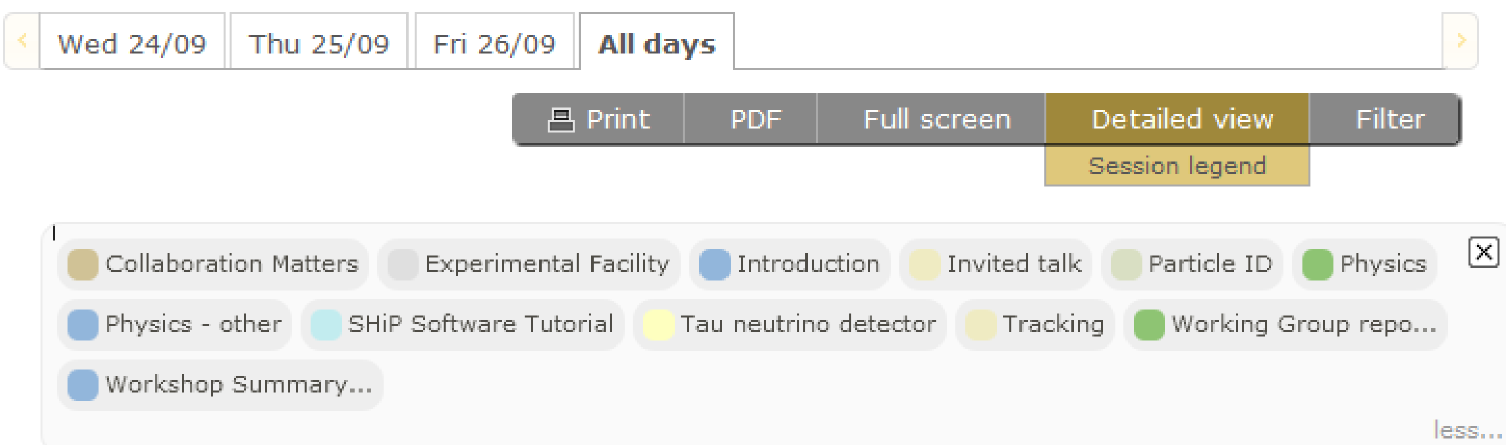
- Comparable studies for axion, higgs portals, R-parity violating neutralinos, light-goldstinos… in progress

3. Since last meeting

- 2^{nd} SHiP workshop
- Collaboration forming
- TP being written
  - Working groups
- Biweekly meeting, …

2nd SHiP workshop and Collaboration Meeting CERN 24-26/9

- 66 participants
  - IT (19), CH (18)/CERN(10), RUS(11), F(5), D(4), UK(4), NL(1), S(1), TR(1), USA(1)
- 71 contributions
- 3 days 1) Working groups 2) Plenaries 3) Soft tutorials



Collaboration forming

SHiP Search for Hidden Particles

SHiP **24 September 2014**

Minutes of the 2nd SHiP Collaboration Matters Meeting (CERN, Geneva, 24th September 2014)

1. Introduction. J. Panman, Chairman of the SHiP membership panel.
J. Panman welcomed the delegates.

2. Status of the SHiP. A. Golutvin showed his slides:
https://indico.cern.ch/event/336469/session/9/material/0/0.pdf. In summary:

- SHiP will submit two papers to the SPSC by spring 2015. One will cover the physics programme and the other will be the actual Technical Proposal.
- SHiP will become a Collaboration before the submission of the Technical Proposal. This will be formalized during the one day SHiP meeting on December 15th.
- The next SHiP collaboration meeting will take place on Feb. 9-11 in Naples.
- Furrther meetings in 2015: 1-3 July and 7-9 October, both at CERN

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J. Panman said that to be able to form the Collaboration a list of groups and individuals is required. This list will become the author list of the TP. The signature of the TP will imply a promise to do the experiment when approved and if they would get the support from their funding agencies. This bootstrapping process can only start once CERN has given its clear approval for committing infrastructure and money. Furthermore the groups are asked to come with a single contact person per country and per funding agency.

M. Titov mentioned that in France, they can say what they can commit to technically but it might take up to 2 years before funding is available. Putting in a request too early may also backfire.

3. 3rd SHiP Collaboration meeting in Naples, 9-11 February 2015

What I've been up to

- Meeting with
  - In SHiP
    - Spokesperson
    - Former colleagues involved
    - M. Titov and other interested French people
    - During TLEP workshop
  - In LPNHE
    - Physicists
    - Engineers
- Attending the biweekly collab wide meetings

Technical Proposal mid-2015

Scope of the Technical Proposal

- ✓ ***Widen physics case both for the BSM and SM physics***
- ✓ *Provide Conceptual Design Report (few options per sub-detector is ok at this stage)*
- ✓ *Detailed analysis of the sub-detector technologies complemented, if really needed, with some RD studies of prototypes.*
  No large scale detector modules is expected at this stage. It is however important to identify critical RD milestones for the TDR
- ✓ *Full simulation based sensitivity reach and background evaluation for representative channels*
- ✓ *Provide cost evaluation of the detector*
- ✓ *Reach internal understanding who will do what for the TDR*

A. G.

Biweekly meetings (1)

✓ ***General SHIP meetings are scheduled on Thursday at 13:30***

Will take place bi-weekly or weekly depending on the needs

- *Every meeting will start with short news from the management and with a short summary on the highest priority items as currently seen by the management*
- *Very short introduction will be followed by the reports from various working groups. If you have ideas on possible discussion topics (obviously including physics) please let us know !*
    - *In addition to the general Thursday meeting we will have weekly meetings of the conveners of the working groups*

Biweekly meetings (2)

23 October 2014

Update on the SHIP geometry

Reminder *We must have a realistic evaluation of the particle fluxes in the SHIP detector → implementation of the realistic set-up in FairShip is very Urgent !*

Many ongoing activities

- ✓ *New design of the muon filter*
  "Active" filter is the baseline option
- ✓ *Geometrical envelope for the tau neutrino detector is fixed*
  10m longitudinal, 4.5×8 m^2 transversal
- ✓ *Optimization of the vacuum vessel geometry:*
  - *2 detector elements (EoI) with 5 m diameter vs 1 detector with appreciably larger cross-section 5×10 m^2*
  - *Elliptical vs rectangular cross-section*
- ✓ *Optimization of the vacuum vessel design*
  - *Reduce the shell thickness to minimize backgrounds*
- ✓ *Optimization of the tracking system and spectrometer magnet*
  - *Momentum reconstruction in vertical plane, horizontal orientation of the straw tubes allows to keep their maximal length < 5m*

SHIP meeting 23 October 2014

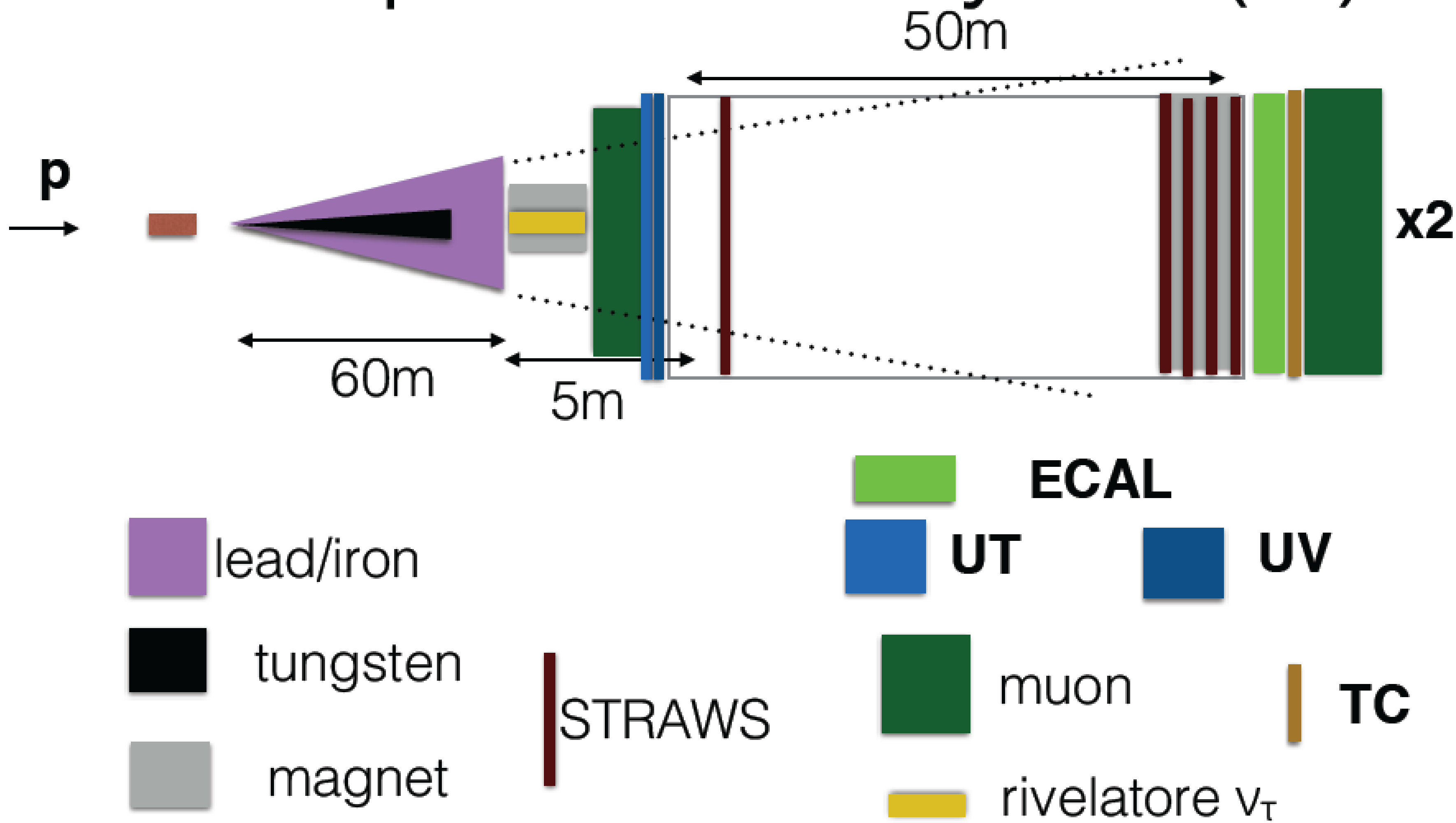
- ✓ *Optimization of the PID. New ideas on the HCAL (see presentation of Ivan)*

4. Subsystems

- Main thrust
  - Define the experiment geometry
  - muon filter options
  - 1 or 2 decay volume + spectrometer
- Design a zero background setup
- Subsystems
  - Brief descriptions
  - Possible opportunities

- Veto(s), Tagger, Timing ctr
- Tracking
- EM calorimeter
- Muon filter/detector

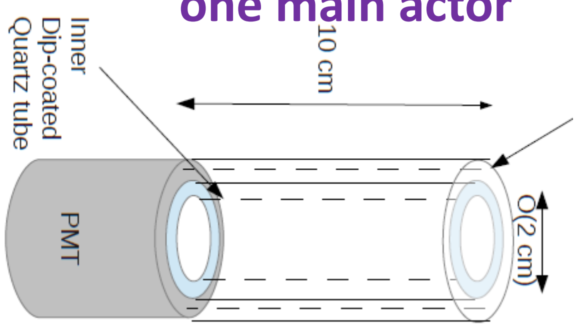
New possible layout (iii)



Muon Veto

- Purpose: Tag wide angle muons + neutrons from hall/filter shine
- Specs: wide area, timing
- Options (Cherenkov), Liquid scintillator with wide area photodetectors
- **Opportunities**
  - **photodetectors**
  - **easy to contact**

  one main actor

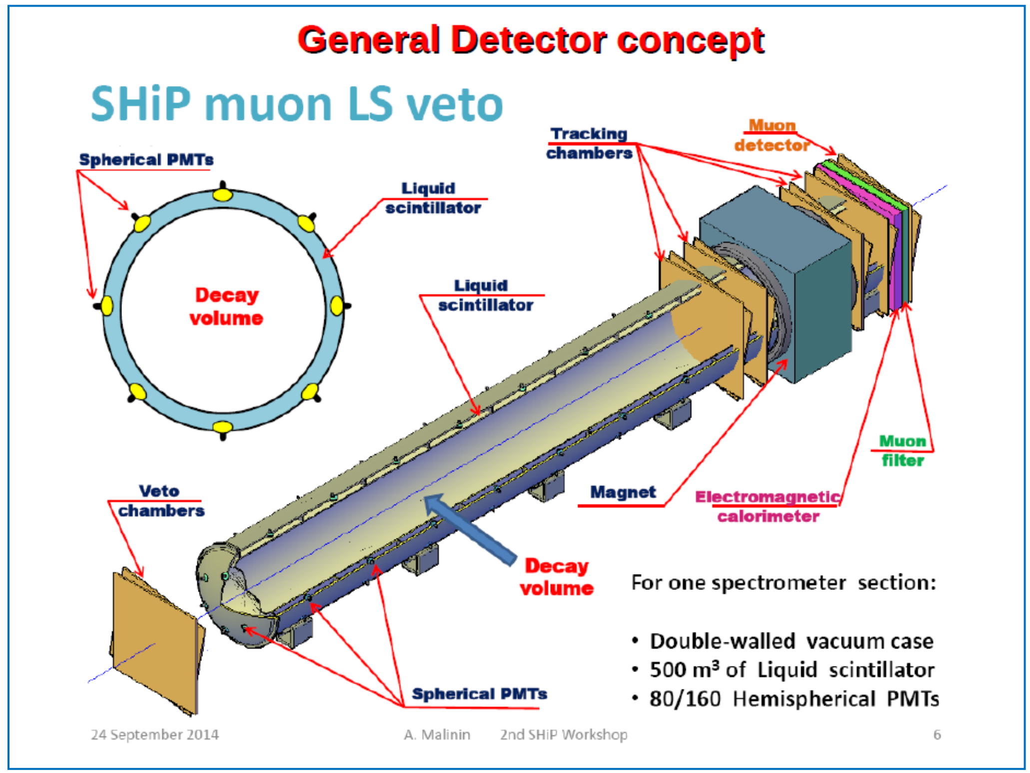


33rd International Cosmic Ray Conference, Rio de Janeiro 2013
The Astroparticle Physics Conference

ICRC 2013

A large-area single photon sensor employing wavelength-shifting and light-guiding technology

Lukas Schulte[1], Markus Voge[1], Akos Hoffmann[1], Sebastian Böser[1], Lutz Köpke[2], Marek Kowalski[1]
[1]*Physikalisches Institut, Universität Bonn, Nußallee 12, D-53115 Bonn, Germany*
[2]*Institut für Physik, Universität Mainz, D-55099 Mainz, Germany*



Upstream veto

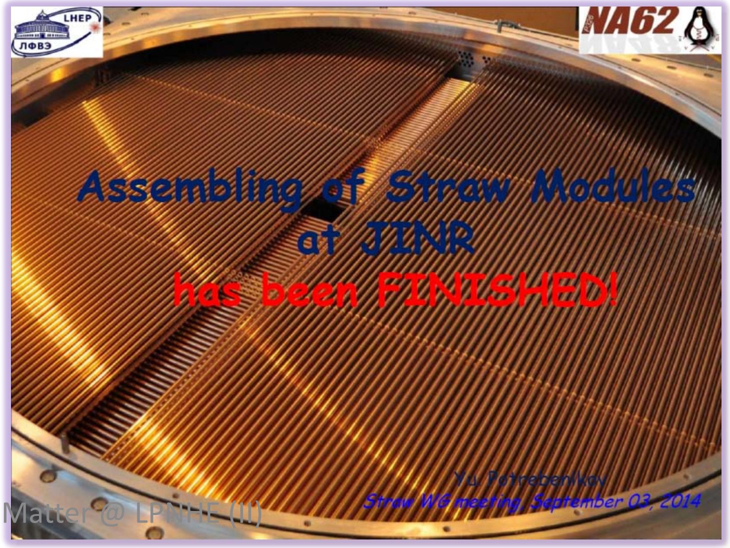
- Scintillators upstream the evacuated decay volume
- Also in the last i.l. of the muon filter
- **Not much studied, so there are opportunities**

Timing counter

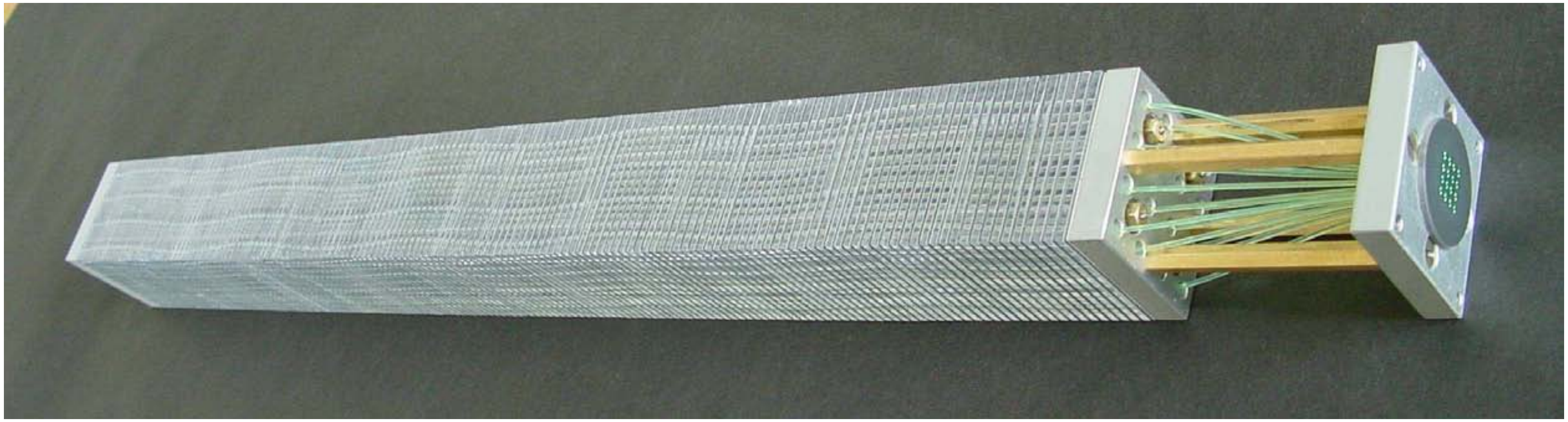
- If E/HCAL, muon detetectors not fast enough, a TC can be added
  - Multiple RPC multigap, or stacked
  - Cherenkov + MCP (LAL SuperB)
- **Not much studied, so there are opportunities**

Tracking

- Adapt from NA62 (straw chambers)
- Main actors CERN, EPFL, Dubna
- Specs
  - 5 m diameter
  - 18k straws /spectro * 2 spectrometers
- **Opportunities**
  - **Electronics**
  - **No contact yet**



Shashlik EM calorimeter



Specs

- σ_E < 10%/sqrt E
- σ_t = O(1 ns)
- π^0 id
- dyn. range 25 MeV – 50 GeV

Opportunities:
Electronics, DAQ

SAMchip

Developed in Saclay

M. Bruschi, M. Villa

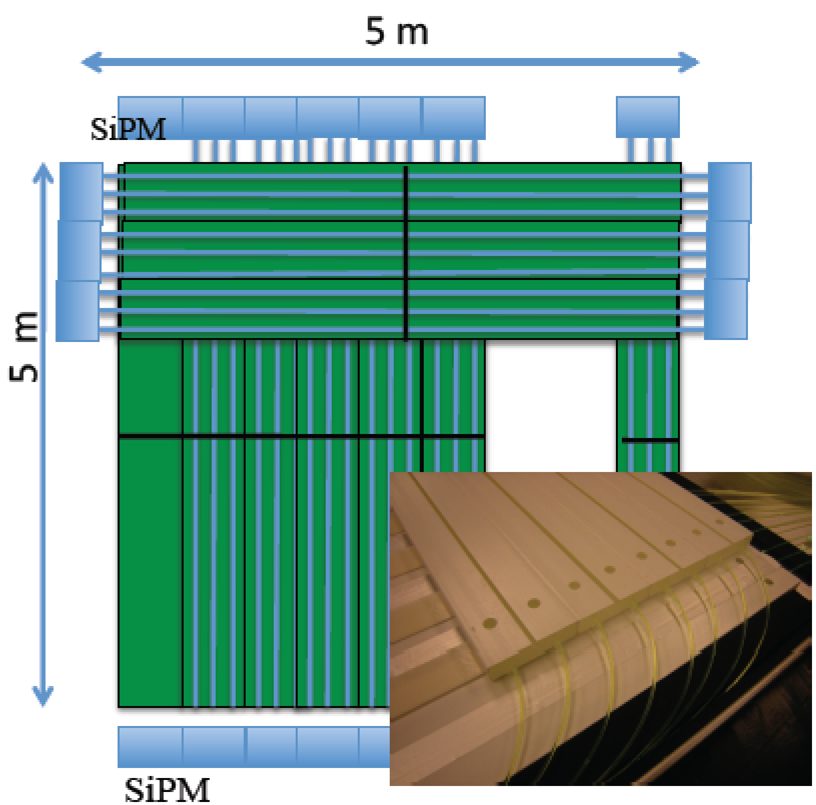
Muon filter/detector -- PID

- Specs:

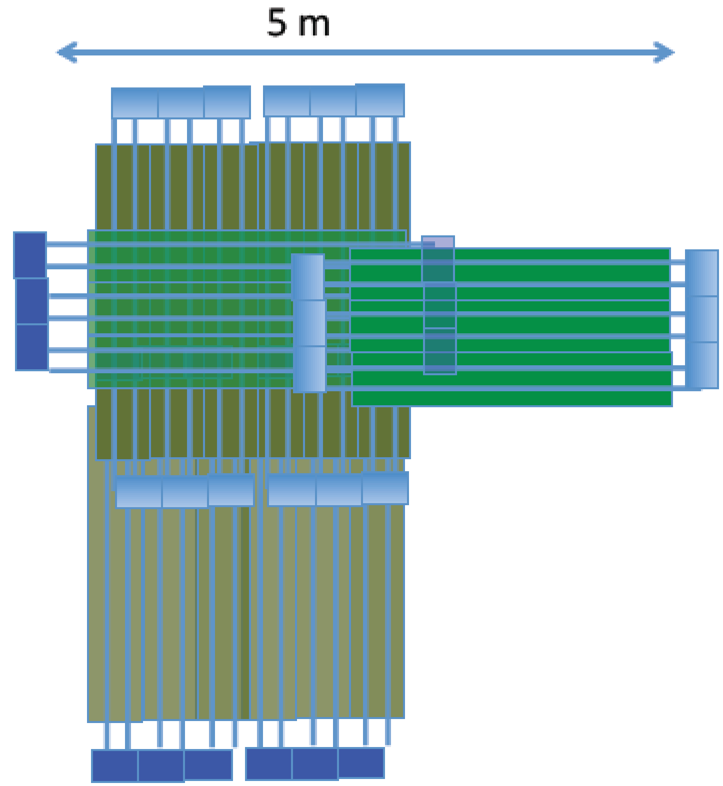
  10(or less?) -20 (50?) GeV/c, modest granularity, size
- Options
  - Layout w or w/o HCAL, 1 or 2 filters, #stations
  - Scintill + WLS + SiPM (base)
  - extra timing plane ?
- Main actors Frascati, Bologna, Ferrara (already many)
- **Opportunities**
  - **SiPM in LHCb SciFi ?**
  - **Electronics (FE, or BE)**

A possible layout for the SHiP Muon System: rectangular scintillator bars with WLS fibres and SiPM readout

A) Single sided- readout



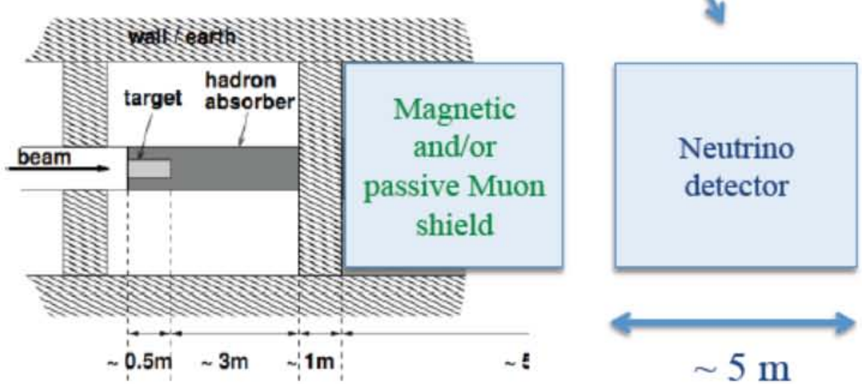
B) Double sided- readout

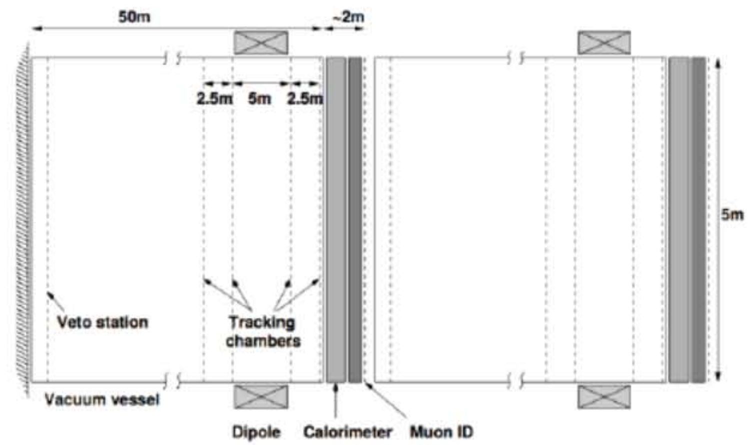


Preferred option:
more light, better time resolution

Add a ν_τ detector

SM: ν_τ physics with 2×10^{20} pot





- Good physics program with a compact neutrino detector *Expect ~3400 ν_τ interactions in 6 tons emulsion target (5% of OPERA)*
- Tau neutrino and anti-neutrino physics
- Charm physics with neutrinos and anti-neutrinos
- Electron neutrino studies (high energy cross-section, only low energy studies for oscillations) and ν_e induced charm (~1000 events)

5. Pros and Cons for LPNHE and next steps

+ νMSM attractive
+ Early in the project
+ CERN
+ Run in 2023
+ Serious proponents
+ LHCb commonalities
+ A few in IRFU/IN2P3
+ Technical opportunities
  - Tracking
  - Electronics + DAQ
  - UT, Timing D.

– Physics breadth
– Not (yet) leaders
– TP to be written mid 2015

± No technological challenge

Next steps (1)

- SHiP a medium term experiment (~ 15 yrs) *just starting*
- A **superb physics case**
  - Not only **DM**
  - But also **BAU, ν masses**
- Several other physics cases
- Timing well matched between now and next Big project
  - Synergies exist among physics studies
  - Complementary physics reaches with LHC, Big projects
- Well matched to IN2P3/IRFU lab expertise
- Several lab projects bound to free active conceptors soon
- Can benefit of new infrastructure (hall de montage)

I am willing to participate in the TP

Next steps (2)

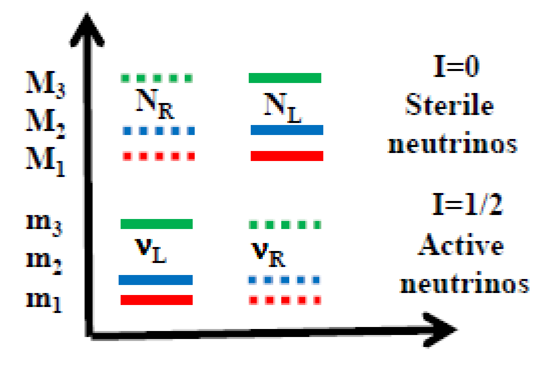
I am willing to participate in the TP

- Share my conviction with younger people that *SHiP has a (the) leading physics case for dark matter*. And then,
- Define an optimum preparatory effort at LPNHE.
- Devise a sensible path for approval <=2017 written up in the December roadmap.

Extra

Neutrinos : the New Physics there is… and a lot of it!

forgive the confusion between fields and particle notations

SM	Dirac mass term only ≡ «Yukawa»	Majorana mass term only	Dirac AND Majorana mass terms
ν_L I= ½ ; $\bar{\nu}_R$ ½	ν_L ½ ; ν_R 0 ; $\bar{\nu}_R$ ½ ; $\bar{\nu}_L$ 0	ν_L ½ ; '$\bar{\nu}_R$' ½	
X 3 Families	X 3 Families	X 3 Families	
6 massless states **wrong**	3 masses 12 states 3 active neutrinos 3 active antinu's **6 sterile neutrinos…** 3 mixing angles 1 CP violating phase **0νββ = 0**	3 masses 6 active states **No steriles** 3 mixing angles 3 CP violating phases **0νββ ≠ 0**	6 masses (Majorana) 12 states 6 active states **6 sterile neutrinos…** More mixing angles and CPV phases **0νββ ≠ 0** (different than pure Majorana case if m_N<100 MeV) → Leptogenesis and Dark matter

Mass hierarchies are all unknown except $m_1 < m_2$

Preferred scenario has both Dirac and Majorana terms …

… many physics possibilities and experimental challenges

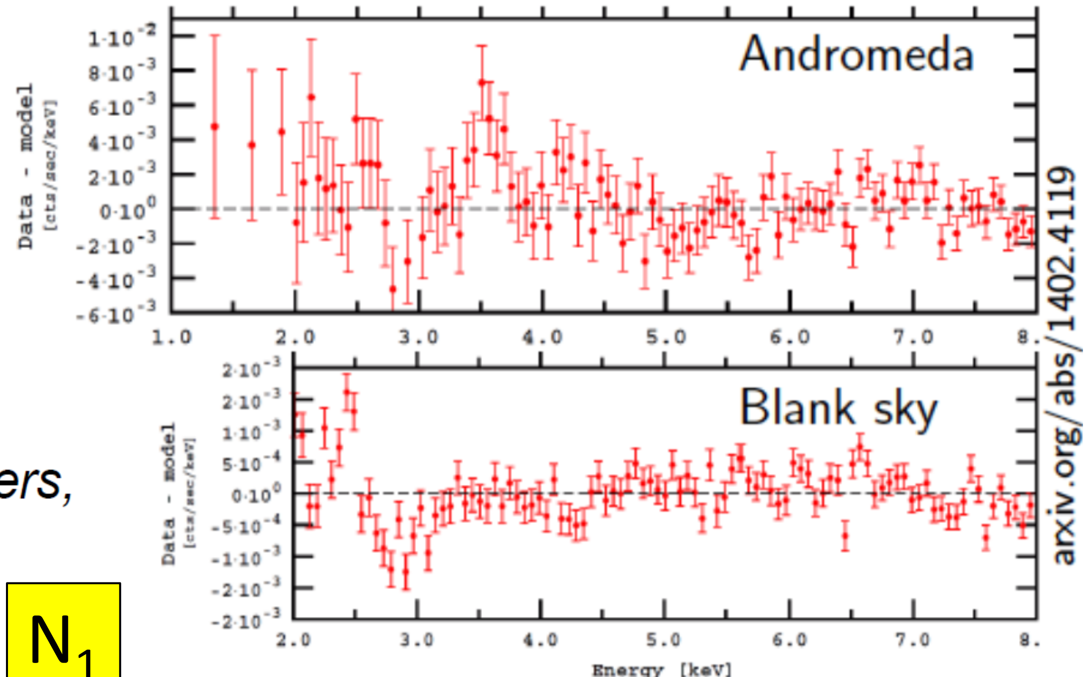
New line in photon galaxy spectrum ???

Two recent publications in arXiv:

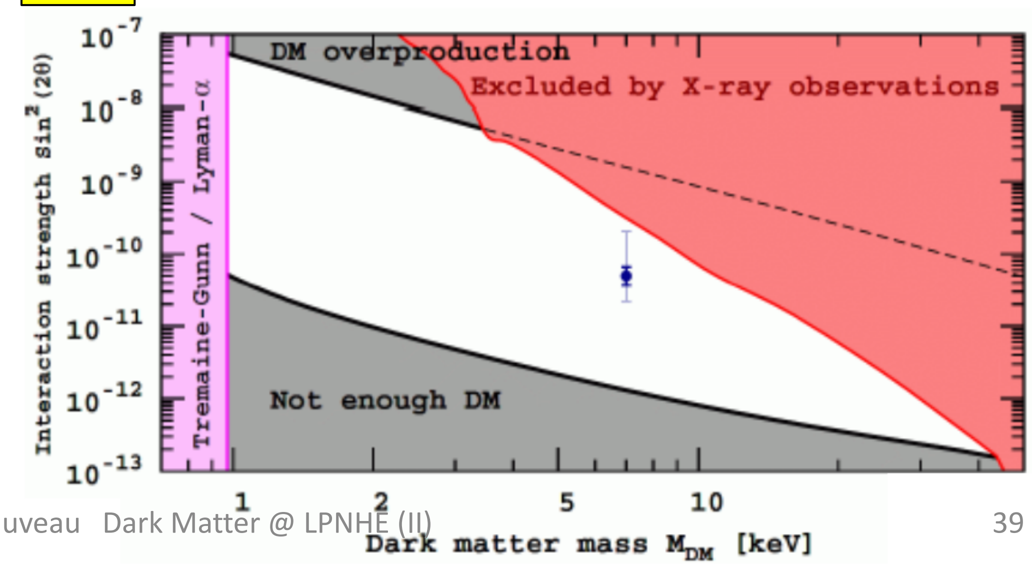
- *arXiv 1402.2301*
Detection of an unidentified emission line in the stacked X-ray spectrum of Galaxy Clusters, $E_\gamma \sim 3.56$ keV

- *arXiv 1402.4119*
An unidentified line in X-ray spectra of the Andromeda galaxy and Perseus galaxy cluster, $E_\gamma \sim 3.5$ keV

Will soon be checked by Astro-H with better energy resolution



N_1



Golutvin seminar

Collaboration matters

1st workshop in Zurich
10-12 June 2014

Three stages in the preparation of the experiment: first the work for the TP which should be completed early 2015, then the TDRs to be finished by 2018, and finally the construction to start data taking in 2022.

✓ ***Contribution to the Technical Proposal to be completed by March 2015***

This document requires mainly an intellectual contribution. The current detector choices are based on existing technologies, so no essential R&D is required for the TP. Expect a tangible contribution to the detector conceptual design, evaluation of the physics reach, or software, simulation and computing activities. If considered necessary by the group, this phase may also include eventual R&D and test beam activity

✓ ***Assuming that the TP is approved by the CERN committees, the time scale for the preparation of the TDRs is 2016-2018. In particular the groups are expected***

- formulate an interest in a hardware and software contribution for the construction;
- give an estimate of the strength of their group during the work for the technical proposal and for the preparation of the TDR

✓ ***Assuming that the TDRs are approved by 2018, it would be valuable to understand the groups' prospects for contributing to the construction of the SHIP detector in 2018-2022***

Working groups

Appendix 2: List of working groups and contact persons

1. Theoretical support
   Misha Shaposhnikov (mikhail.shaposhnikov@ep
   Dima Gorbunov (Dmitry.Gorbunov@cern.ch)

2. Experimental facility
   Richard Jacobsson (Richard.Jacobsson@cern.ch

   - interface with beam lines, target and infrastructure
   - muon shield
   - vacuum vessel
   - spectrometer magnet
   - ...

3. Tracking

   - tracking in the decay volume
     Massimiliano Ferro-luzzi (massi@mail.cern.ch)
   - tracking in the emulsion based spectrometer
     Giovanni De Lellis (Giovanni.de.Lellis@cern.ch)

4. PID
   Walter Bonivento (Walter.Bonivento@cern.ch)

   - muon detector
   - calorimetry
   - ...

5. Computing and Software
   Fons Rademakers (Fons.Rademakers@cern.ch)
   Thomas Ruf (Thomas.Ruf@cern.ch)

   - Computing model
   - ...

6. Online & Trigger
   Hans Dijkstra (dyk@mail.cern.ch)

7. Physics performance
   Nico Serra (nicola.serra@cern.ch)

8. Miscellaneous
   Andrey Golutvin (andrey.goloutvin@cern.ch)

   Contains detectors for which nobody has expressed clear interest so far:

   - Timing Detector to provide time measurement
   - Upstream tagger

We have already started a process of identifying contact persons for the various sub-tasks. Thus, your prompt input would be very timely and well appreciated!

The following persons have already expressed interest:

Mitesh Patel (Imperial College) for the muon shield optimization,
Gaia Lanfranchi (LNF) for the MUON detector,
Mauro Villa (Bologna) and Victor Egorychev (ITEP) for calorimeter electronics and modules,
Andrey Ustyuzhanin (Yandex Data Analysis School) for computing model.

Prevessin North Area site

- From task force report:

Experimental setup

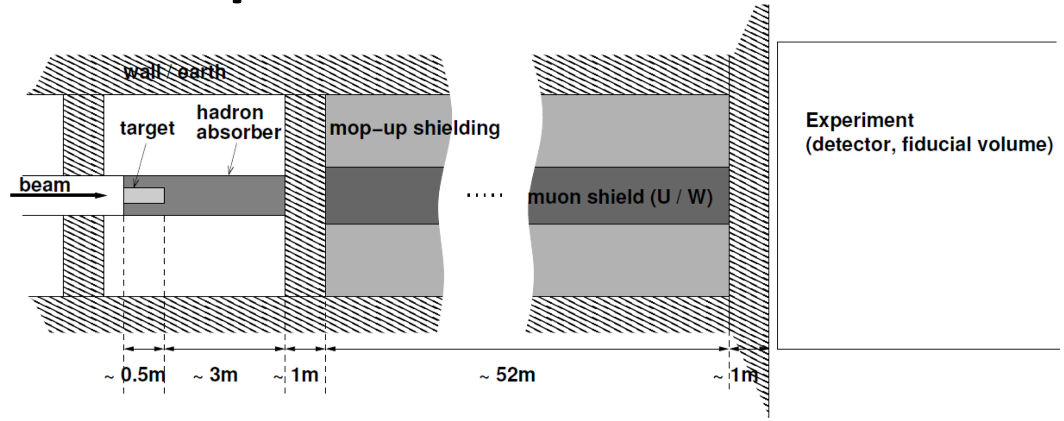
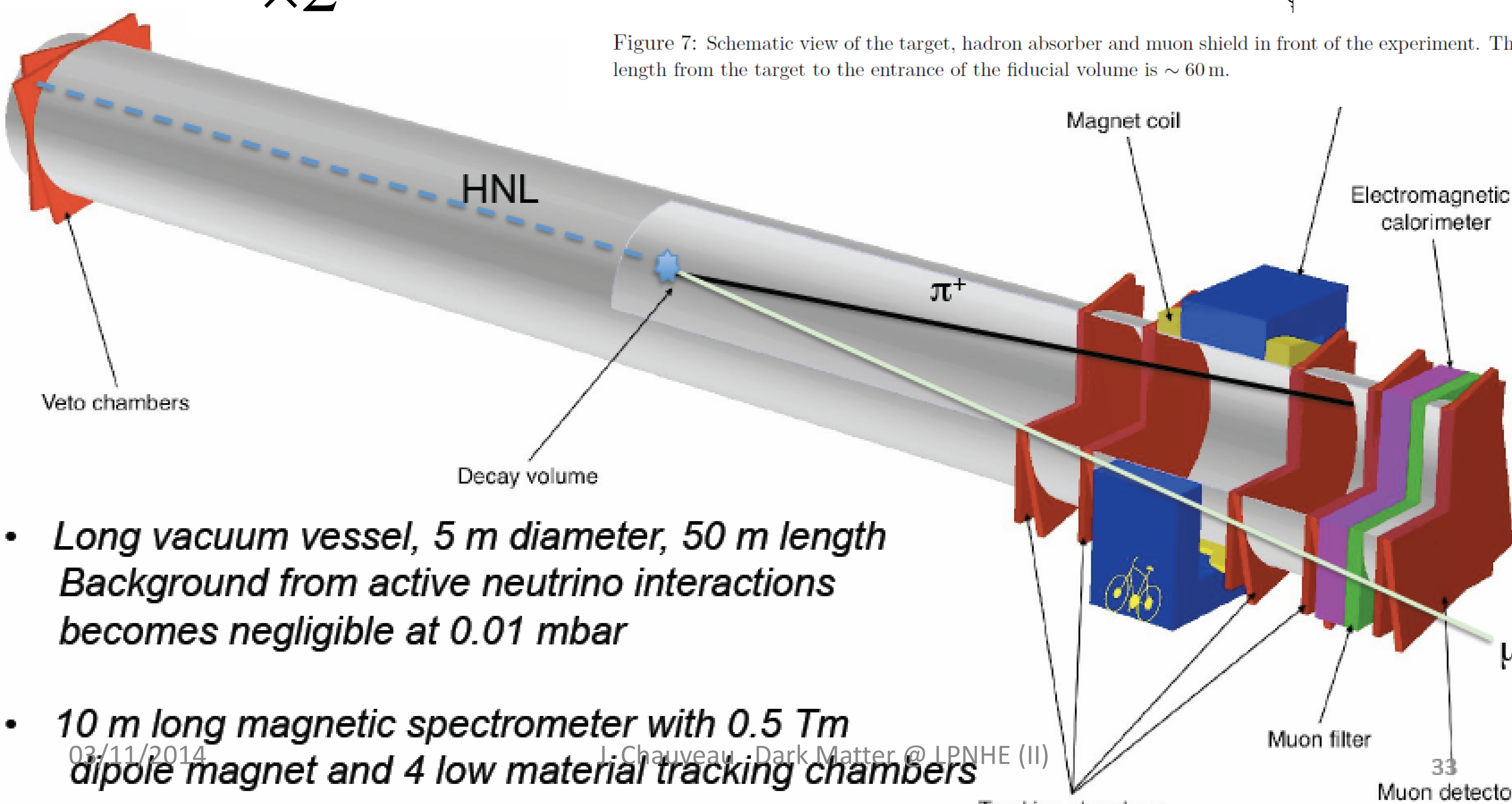


Figure 7: Schematic view of the target, hadron absorber and muon shield in front of the experiment. The total length from the target to the entrance of the fiducial volume is ~ 60 m.

×2



- *Long vacuum vessel, 5 m diameter, 50 m length Background from active neutrino interactions becomes negligible at 0.01 mbar*
- *10 m long magnetic spectrometer with 0.5 Tm dipole magnet and 4 low material tracking chambers*

Assumptions for now … (as of EOI)

Item	NA62	SHiP
Diameter	2.5 m	5 m
Design rate max	500kHz/straw	2kHz/straw (ø1cm)*
Vacuum requirement p <	1e-5 mbar	1e-2 mbar
Views	X, X+45°, X-45°, Y	X, X+few°, X-few°, X
spatial resolution per coord per space point	 ≤ 130um ≤ 80um	similar or better
average track efficiency	near 100%	similar or better :-)

* assumed ~1e6 muons in whole aceptance per 1s spill and pitch=diameter=1cm

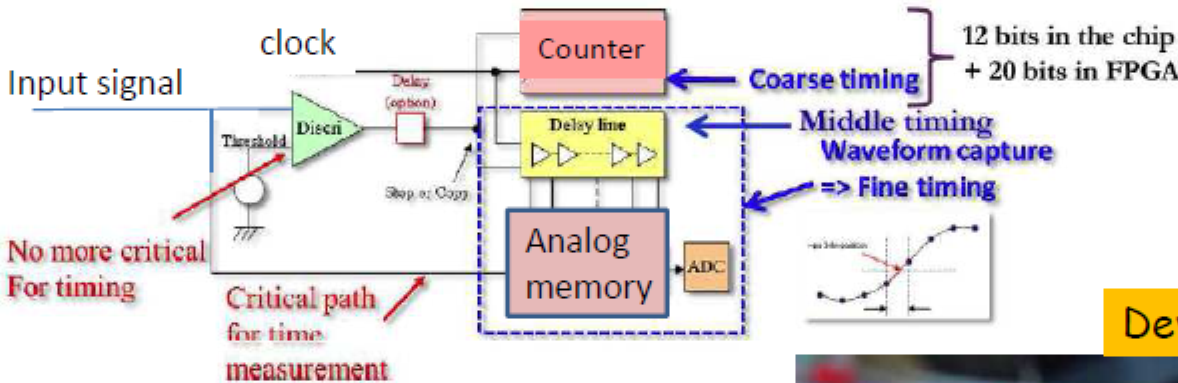
- How do these impact the design ?
- What needs to be modified from NA62 to SHiP ?

Work packages (includes writing up for TP)

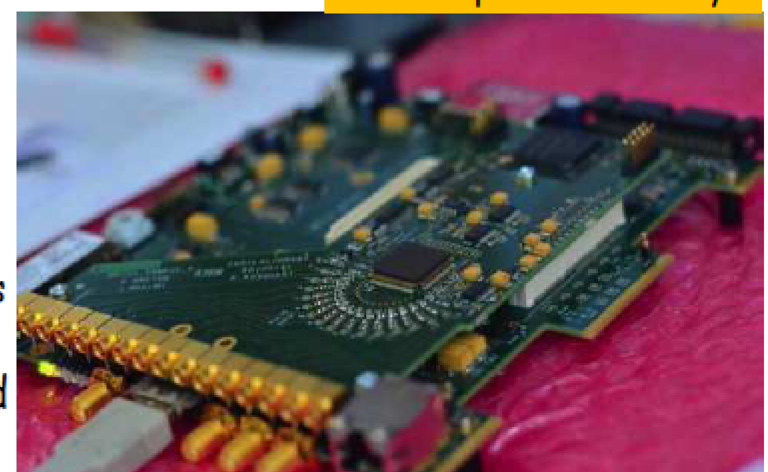
- Requirements from (bkg) simulation — CERN / H. Dijkstra, T. Ruf
  - req'ed straw resolution, material budget
  - spectrometer layout (integral B*dl, distances)
  - expected maximum straw rate per cm^2 (profiles per chamber)
  - req'ed stereo angle
- Detector description in simulation — CERN / E. van Herwijnen
  - baseline design + other ?
- Define/develop electronics/readout system — ???
  - is double-sided readout needed ? do we ~~need the ADC ? (vs only TDC)~~
- Study of critical params with GARFIELD — CERN-EPFL / I. Bereziuk
  - straw/wire diameter, wire deflection, gas pressure & mixture, HV, ...
  - other (non-NA62) design (must be motivated by phys simulation)
- Produce 5m straw prototypes, baseline geometry as NA62 — Dubna / S. Movchan et al.
- Make relevant prototype straw tests at CERN — CERN-EPFL-Dubna (?)
  - optical measurements of wire location
  - resolution from test beam ? probably after TP, late 2015 ? (depends also on electronics)
- Preliminary mechanical design of a chamber — ???
  - 5m diameter vacuum chamber holding the 4544 straws+wires
  - FEA, deformations, etc.

The SAMPIC chip for FADC

FADC and time measurement with the SAMPIC chip



Developed in Saclay



- 16 channel FADC with time stamps
- FADC with tunable characteristics
  - Sampling tunable
  - Resolution vs dead time
  - 1.6 us for 11 bits; 200 ns for 8 bits
  - Time resolution <20 ps on TB
- Only triggered channels are in dead time for a given event

Important component to contain costs

M. Bruschi, M. Villa

25/09/2014 V. Egorychev, M. Villa - Electromagnetic calorimeter 12

Requirements: Muon detector

Goal: identify muons with high efficiency and reject hadrons/electrons from the decays of weakly interacting long-lived particles (mostly $N_{2,3} \rightarrow \pi\,\mu$ for masses 0.250-2 GeV, but also sGoldstinos $\rightarrow \pi\pi$, $\mu\mu$, LSP $\rightarrow \mu\mu\nu$, dark photons $\rightarrow$ ee, $\mu\mu$ etc.)

Inputs for the design:

1) momentum spectrum:

$\rightarrow$ low p-spectrum (p~10-20 GeV/c); large multiple scattering (moderate readout granularity: 5x5 cm^2 or 10x10 cm^2)

2) transverse dimensions, number of stations;

$\rightarrow$ 5x5 m^2, 2 (or more) stations per module

3) expected rates:

$\rightarrow$ driven by emulsions, ~ 0.4 Hz/cm^2, ~ 100 kHz per station

4) High efficiency: >95% per station

5) Good time resolution (to be studied)

$\rightarrow$ help in rejecting combinatorial background from halo muons

6) Low cost, high performance, robust and simple construction, maintainance and operation of the detector

Gaia Lanfranchi – First SHiP Workshop 2