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SHiP
Search for Hidden Particles

Summary of Physics Studies

Nicola Serra
Universität Zürich

9th SHiP Collaboaration Meeting - CERN

25th November 2016

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Structure of Physics WG

Chair:	**Physics Coordinator**	N. Serra (Zurich)
	CDR Conveners	
	Hidden sector signals and models	K. Petridis (Bristol)
	Hidden sector background and signal selection	M. Patel (Imperial)
	Tau neutrino and Light Dark Matter	A. Di Crescenzo (Naples)

- The goal is to make an effort to involve more people in the physics studies
- Initial “potential barrier” to contribute (e.g. because of software or not familiar with open issues), we will try to help as much as possible
- Please try to follow the “Joint Physics and Detector Meeting”, discuss with us and present possible new ideas
- With relative modest manpower you can have a large impact on the project

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Planning Papers

- People working on SHiP are sometimes penalised because we are not publishing any papers… but we want to change this

- We are planning a set of papers for physics and detector:
  - Sensitivity to Sterile neutrinos and interpretation
  - Sensitivity to Dark Photon
  - Sensitivity to Dark Scalars
  - Light Dark Matter sensitivity
  - Lepton flavour universality in neutrino interaction
  - …

- We hope that this effort attracts more people to work in the physics working group

- Important to interact with theorists to understand the implication of our measurements

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I. Bezshyiko

Progresses

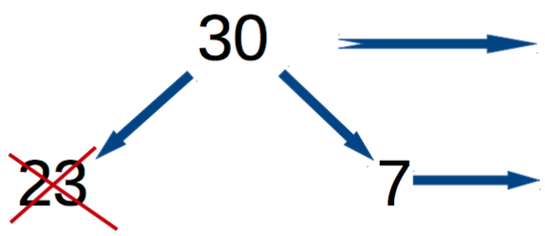
- Without Veto we have some quite a lot of bkg events

Number of simulated HNL candidates	Number of HNL candidates in 5 years
58	284

- All these bkg seem to come from the air, no bkg from walls (more stat)

Interaction in the wall	Interaction in the air
0	58

- If we look for sterile neutrinos



Only 7 (~4) events are compatible with the final state

<u>We need to do this for all channels, so we have people responsible on each channels for the CDR (get in touch)</u>

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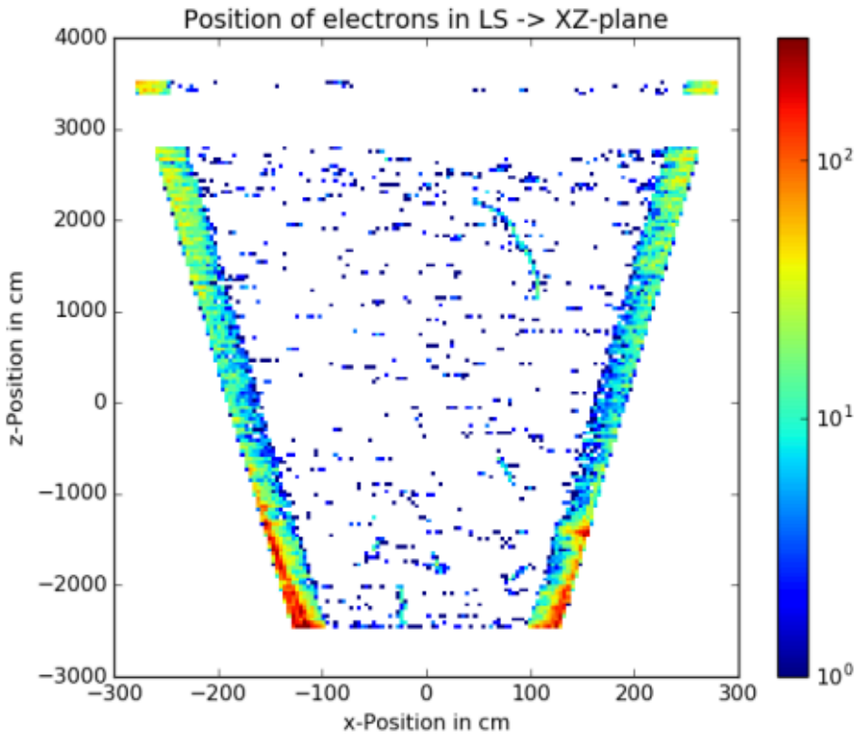
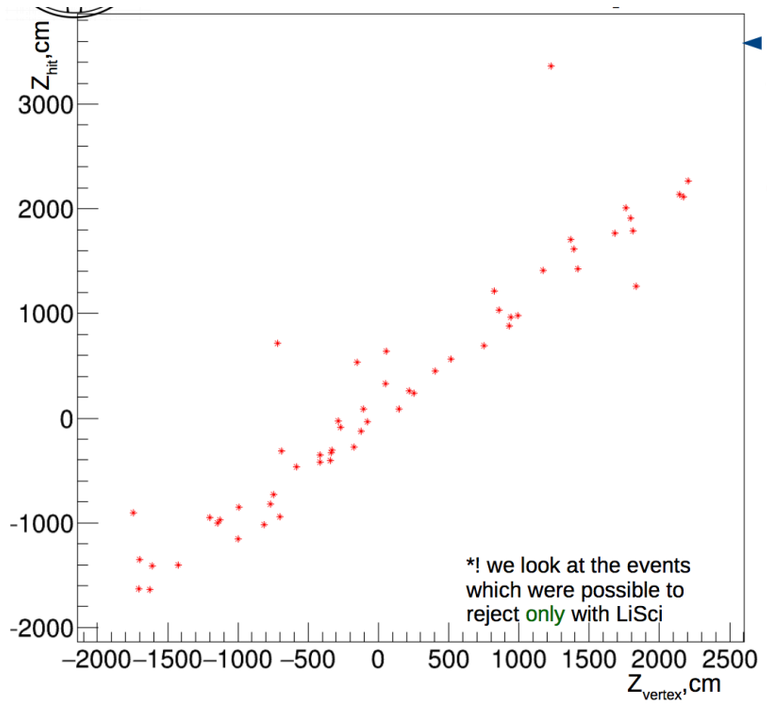
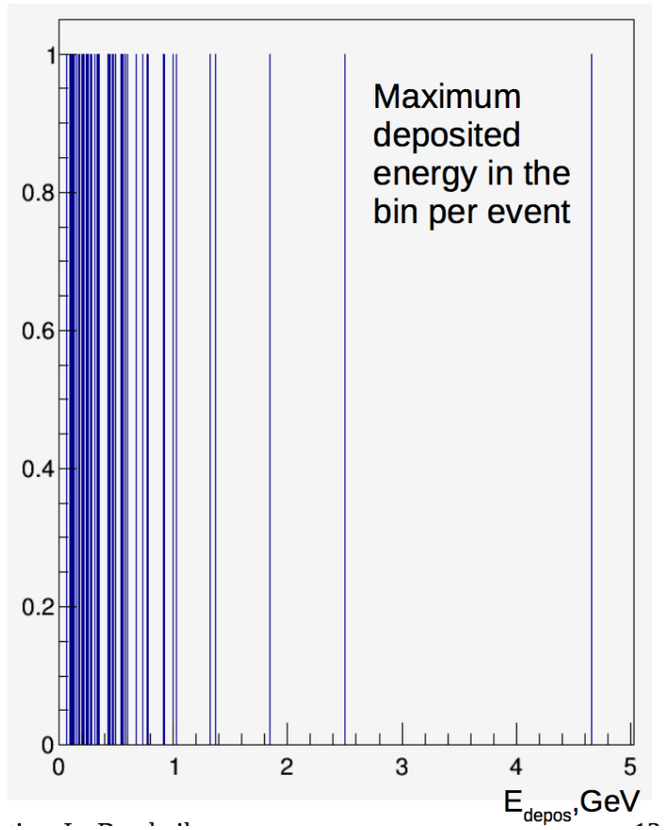
I. Bezshyiko, H. Lacker

Progress

- For the TP we vetoed all events that had signal in the SBT
- This is not realistic, since we will be vetoing all the time (maybe)







- We started to look if we can veto only some regions of the SBT
- We should also take into account timing
- More studies in collaboration with people working at the muon bkg and SBT are needed

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Bkg studies

- We need to study carefully the veto requirements for all background, can we avoid to veto all the time?

- We need to study the background with the most realistic configuration:
  - Neutrino bkg studies ongoing
  - Cosmic bkg, Muon combinatorial, Muon inelastic, Neutrons(?) manpower needed and very welcome

- If you are interested in contributed to these important studies get in touch with Mitesh and I

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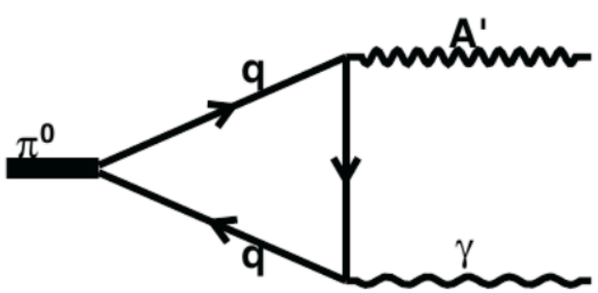
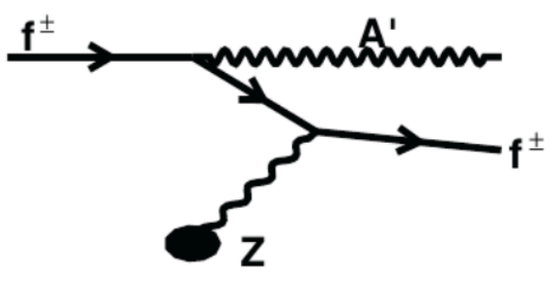
Anne-Marie Magnan

Progress

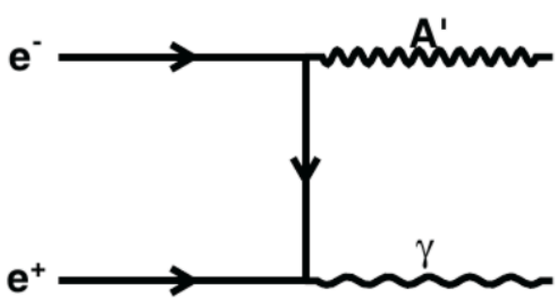
- Implementing this in FairSHiP following E. Graverini note (CERN-SHiP-NOTE-2016-004)



π^0 decay



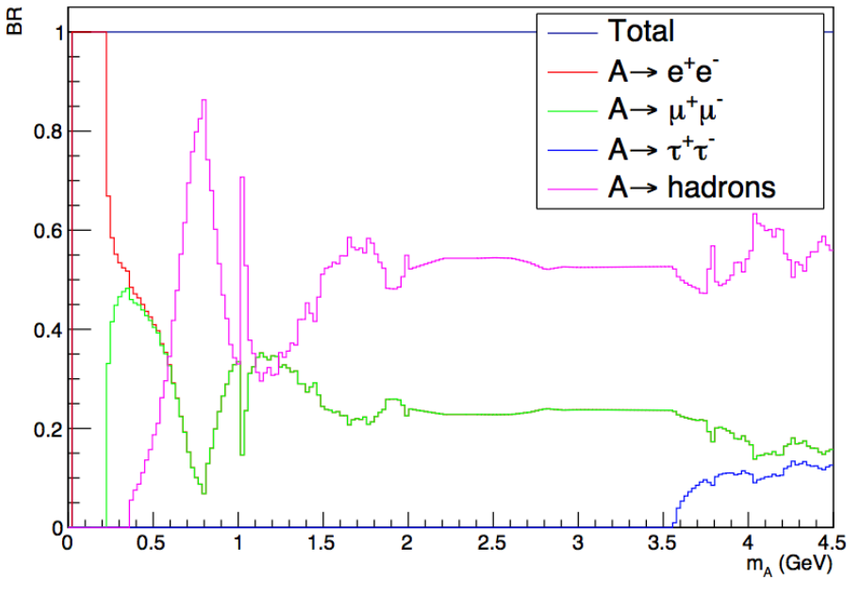
Bremsstralung



Annihilation

In perfect agreement with CERN-SHiP-NOTE-2016-004 (factoring out $\mathcal{B}(\gamma + X)$)

m_A (GeV)	ϵ	$c\tau$ (m)	meson	$\mathcal{B}(\gamma + X)(\%)$	n_A	n_{Coll}	n_A/n_{Coll}
0-0.135	1.2e-7	56	$\pi^0 \to \gamma'\gamma$	98.823	5746	1007	5.7
0.135-0.548	8e-8	63	$\eta \to \gamma'\gamma$	39.41	1407	1884	0.75
0.548-0.648	2.5e-8	66	$\omega \to \gamma'\pi^0$	8.28	1474	1740	0.85
0.648-0.958	1.5e-8	77	$\eta' \to \gamma'\gamma$	2.2	1039	13155	0.08



- Production via meson decay implemented
- Other production mechanism work in progress
- Decay of DP photon implemented and first checks done
- Well on track to make a complete analysis and publish a paper

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Kostas Petridis

Progress

- Model implemented in FairSHiP

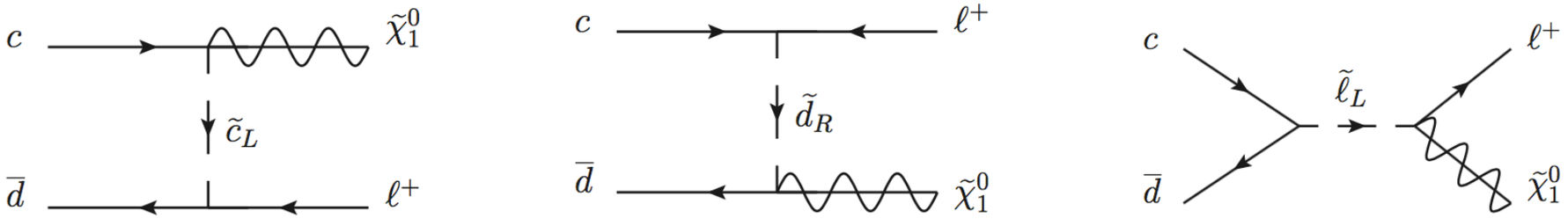
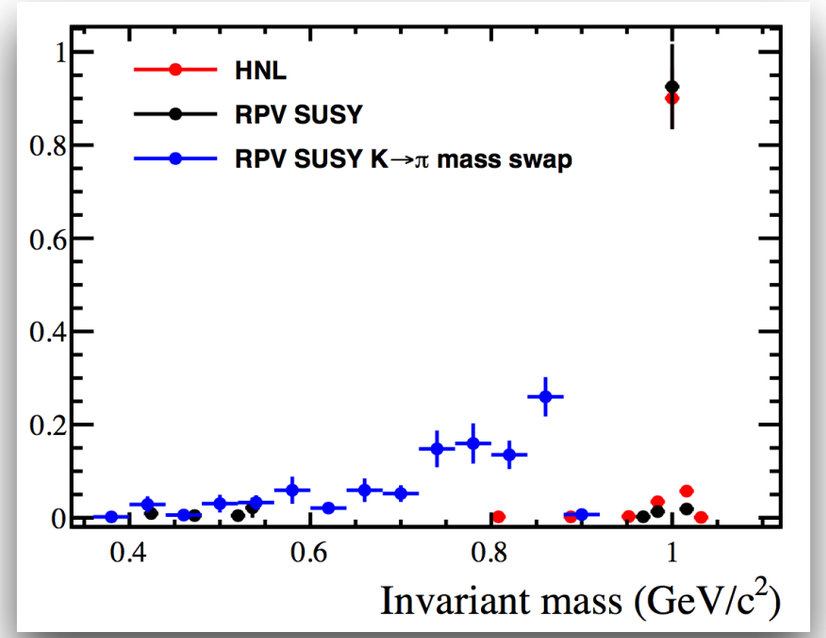


FIG. 1. Relevant Feynman Diagrams for $D^+ \to \tilde{\chi}_1^0 + \ell^+$

Decay	Gen. Frac. (%)	BF (%)
$\chi^0 \to K^+\mu^-$	47.2 ± 0.9	47.8
$\chi^0 \to K^{*+}\mu^-$	8.2 ± 0.5	7.6
$\chi^0 \to K^0\nu_\mu$	5.2 ± 0.4	5.3
$\chi^0 \to K^{*0}\nu_\mu$	35.6 ± 0.9	35.5
$\chi^0 \to \eta\nu_\mu$	3.6 ± 0.3	3.7
$\chi^0 \to \eta'\nu_\mu$	0.0	0.004
$\chi^0 \to \phi\nu_\mu$	0.0	0.0



- Currently if we observe something we might not be able to establish if it is a neutrino or an HNL
- Well on track to prepare a physics sensitivity paper

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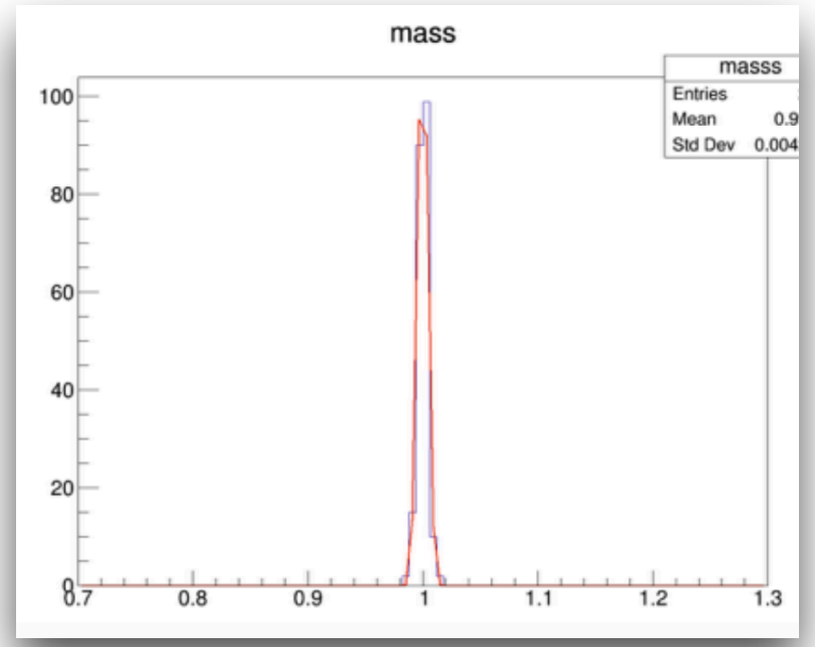
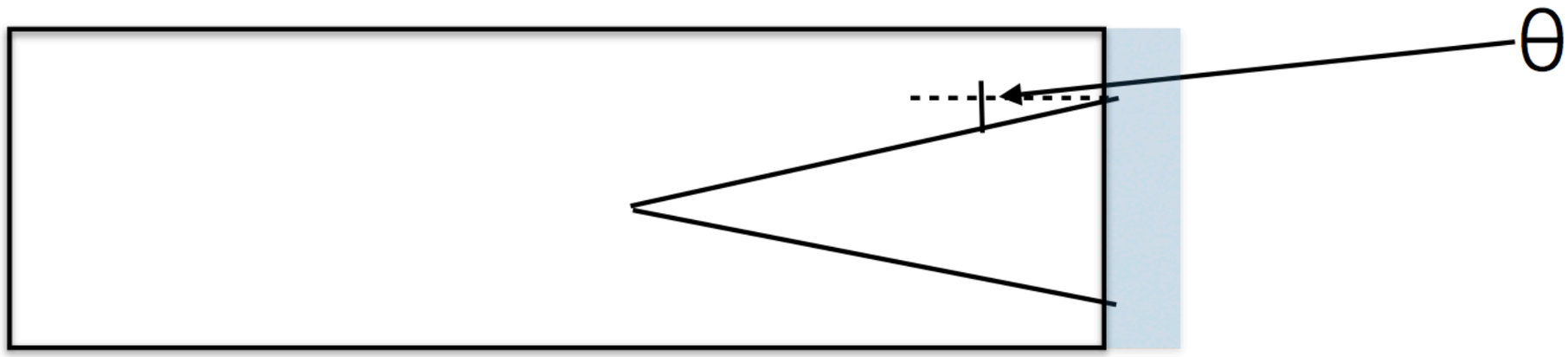
W. Bonivento

Progress



- To have five sigmas we need 4-5 events in one bin in the case of He
- With vacuum we gain a factor in luminosity
- For the partially reconstructed background you need 5 (with Veto) and 7 (without veto) events to have a discovery
- With vacuum we will need 3 (with veto) and 4 (without veto) events
- Seems like that with vacuum the discovery potential is not affected by non-vetoing, but we need to study ALL channels and the take into account redundancy

Progress



- In our physics paper we have also the A—>gamma gamma, which is considered an important channel

- Need a lot of studies about calo design and background (Mainz expressed interest to work on this)

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Signal

- We have made progresses implementing signals in FairSHiP for HNLs (Elena, Eric), Dark Photon (Anne-Marie) and low energy SUSY (Kostas)

- We need to cover the other channels:
  - Dark Scalar
  - ALPS
  - PNGBs
  - …

- If you can devote can contribute with a student or a postdoc or yourself, please get in touch with Kostas and I and we can try to help you to “tunnel” the “potential barrier”

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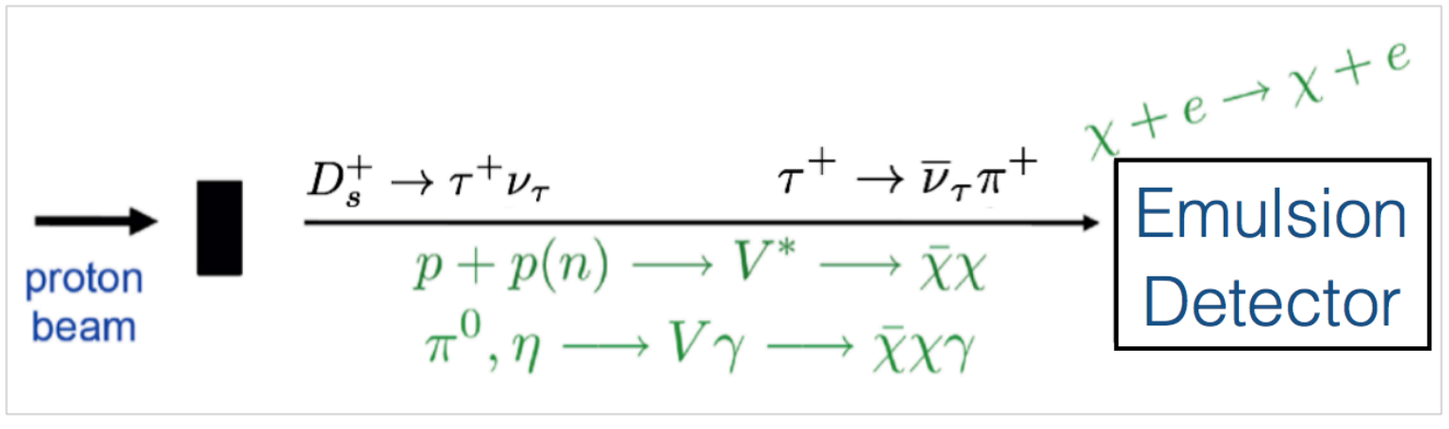
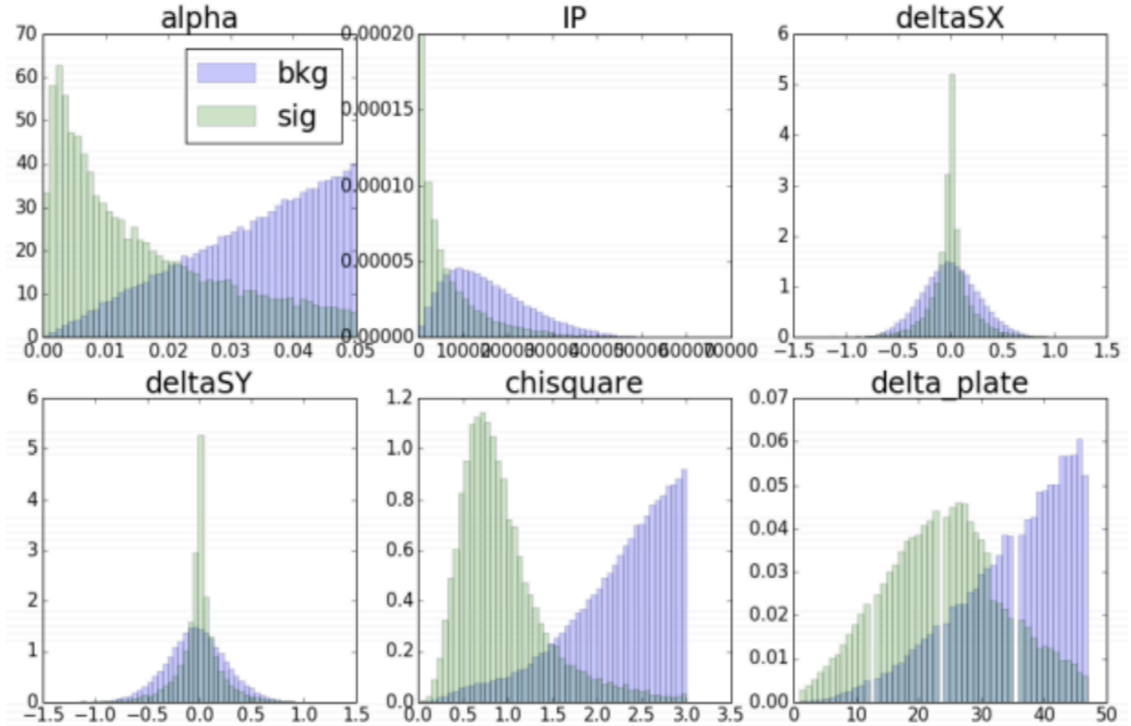
A. Di Crescenzo

Light Dark Matter

- Preliminary studies were already done for the TP, can we optimise further?





- Studies to remove the magnet and increase the mass of the emulsion detector are ongoing
- We need to identify the criteria to decide
- We need manpower to study this physics case and compare with other experiment

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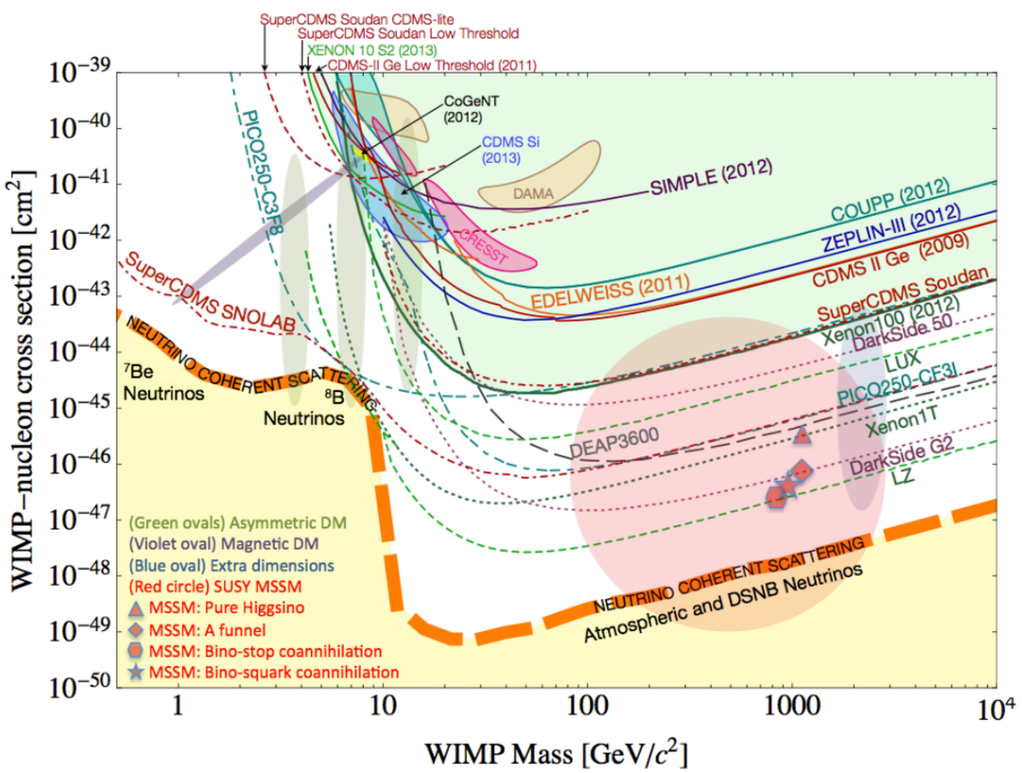
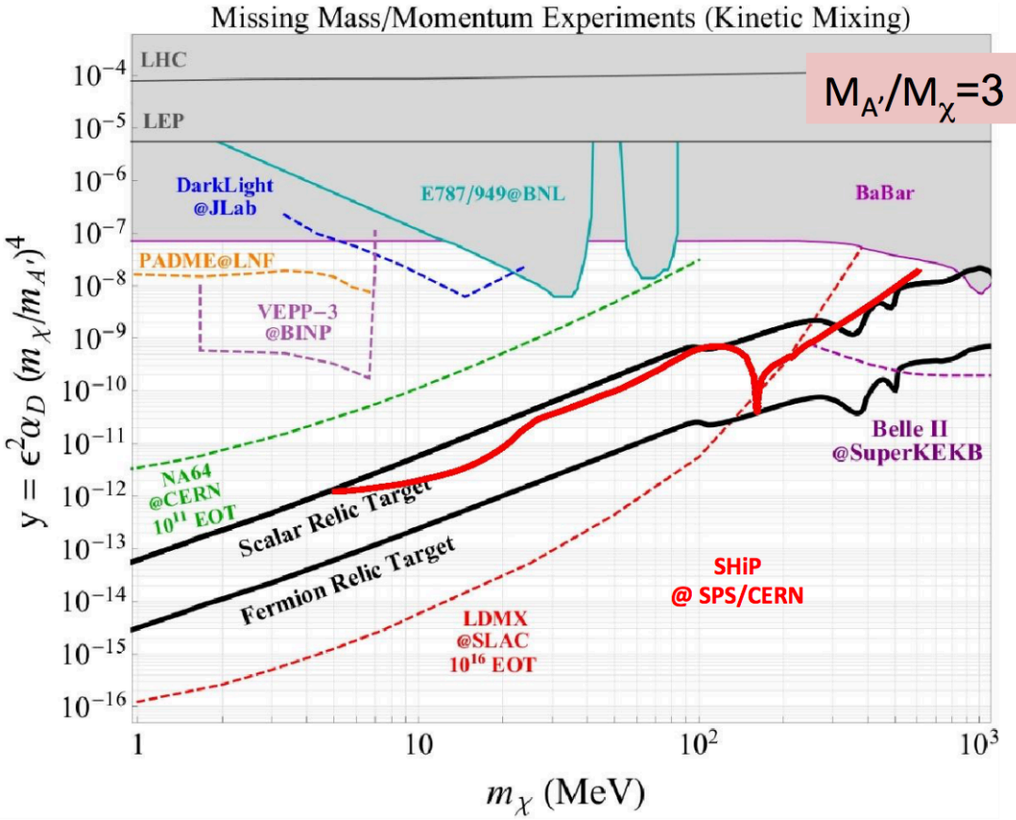
A. Golutvin

Light Dark Matter

- We should understand the SHiP sensitivity compared to other experiments
- Not a zero bkg
- The bkg needs to be studied carefully

	ν_e	$\bar{\nu}_e$	ν_μ	$\bar{\nu}_\mu$	all
Quasi-elastic scattering	105	73			178
Elastic scattering on e^-	16	2	20	18	56
Resonant scattering	13	27			40
Deep inelastic scattering	3	7			10
Total	137	109	20	18	284





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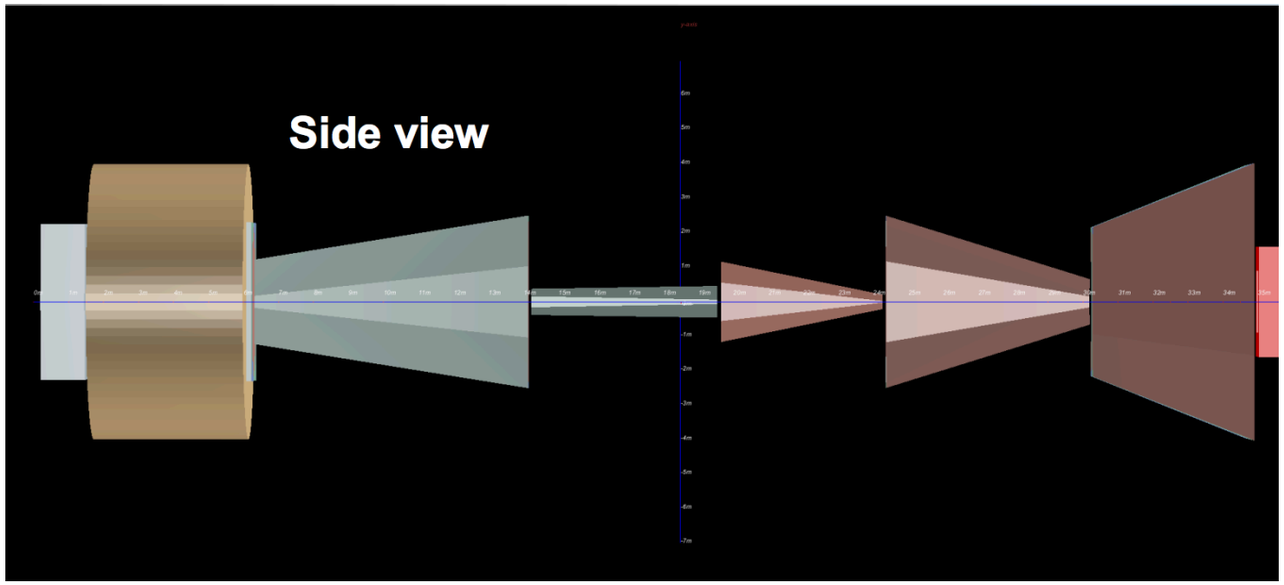
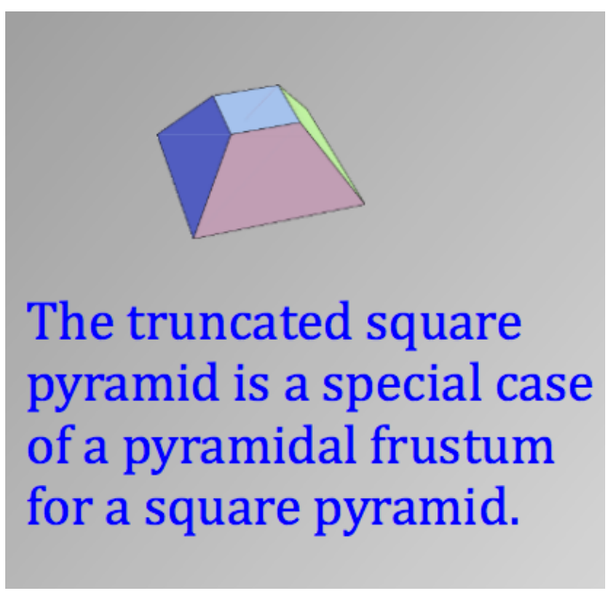
T. Ruf

Simulation & tools

- Short version of the muon shield implemented (Iaroslava)





- Our decay vessel is rectangular! H. Dijkstra
- We have generators for several signals and background (muon comb, muon inelastic, neutrinos, cosmics)
- Need some help also in documentation, tutorials for new people

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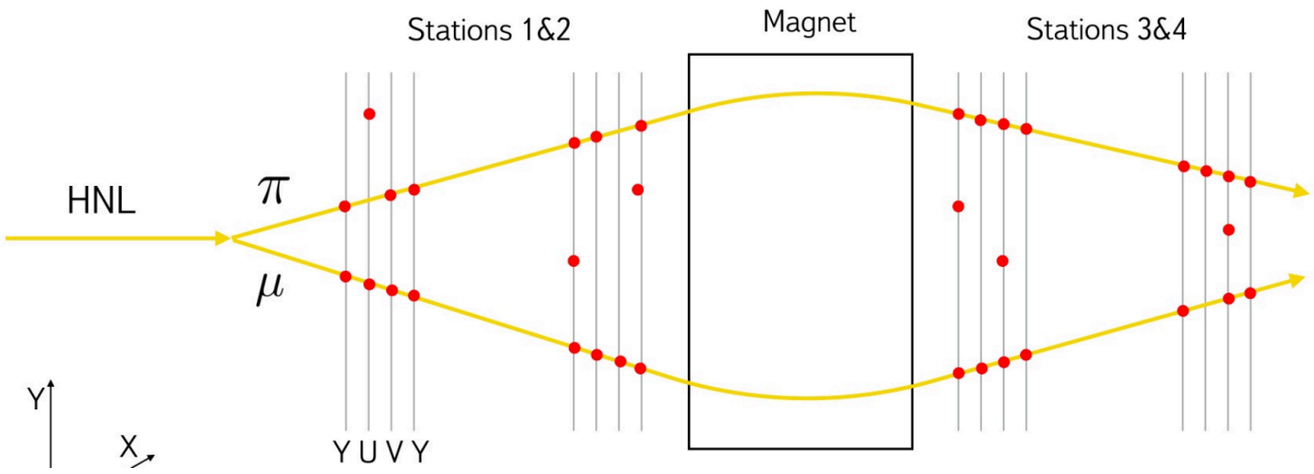
Simulation & tools

M. Hushchyn, O. Alenkin, A/ Ustyuzhanin, E. Van Herwijnen



Method	Max Total RecoEff., %	Min Total RecoEff., %	Momentum Mean Rel. Error, %	Momentum Std. Rel. Error, %
Baseline[1]	94.1	-	3.2	-
RANSAC	94.6	81.2	2.8	12
Artificial Retina	96.8	83.7	2.2	14.9
Hough Transform	97.2	80.2	2.7	10.3
Artificial Retina in 3D	99.4	83.6	2.5	11.5

- Studied on patter recognition advanced
- We should document this in a note and maybe publish together with a set of papers describing the SHiP detector

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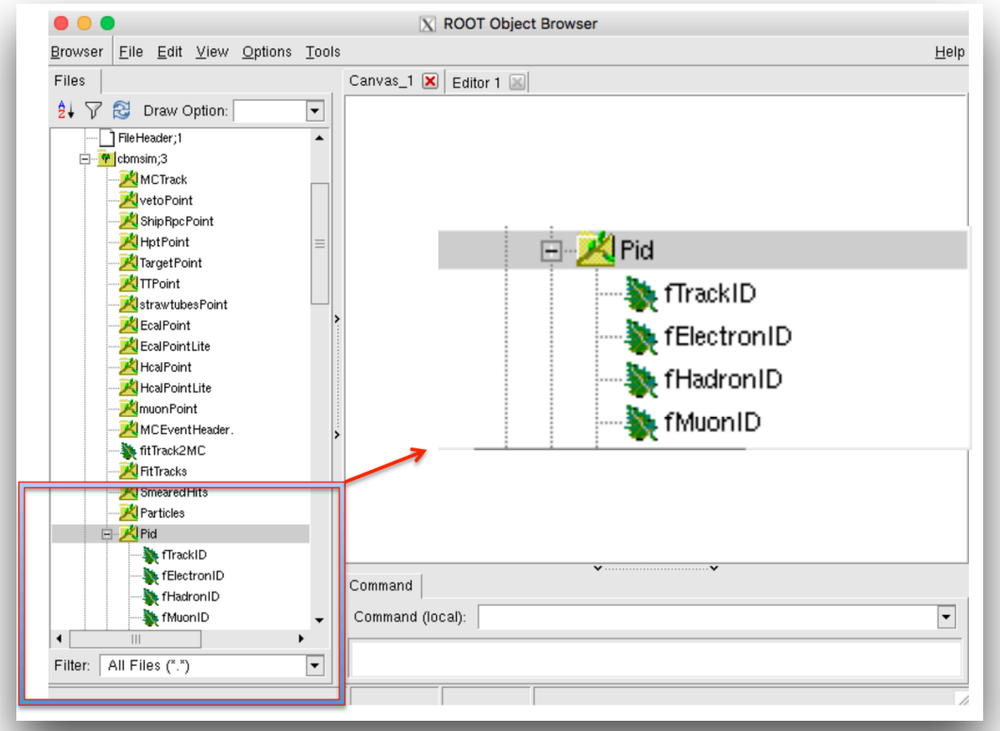
Simulation & tools

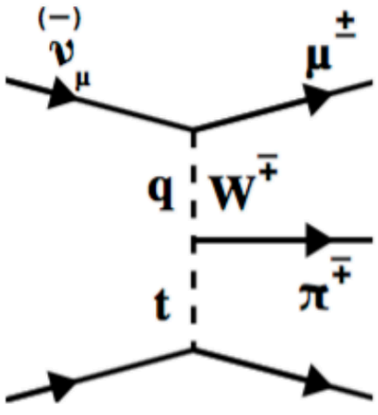
B. Hosseini, W. Bonivento, M. Villa

- The code generates PID values for all hypothesis



REC → / GEN ↓	μ-μ	e-e	π-π	μ-π	π-e	μ-e
μ-μ 2 body	357/361 **98.89%**			4/361 **1.11%**		
e-e 2 body		342/346 **98.84%**	1/346 **0.29%**		3/346 **0.87%**	
π-π 2 body			311/332 **93.67%**	8/332 **2.41%**	13/332 **3.92%**	
μ-π 2 body	4/312 **1.28%**		3/312 **0.96%**	297/312 **95.19%**		8/312 **2.56%**
π-e 2 body		8/328 **2.44%**	1/328 **0.3%**		316/328 **96.34%**	3/328 **0.91%**

- PID essential to reject the background (we have been studying this with HNLs, but we need to do it for all signalS)



	μ-μ IP>10	e-e IP>10	μ-e IP>10	μ-π IP>10	π-π IP>10
Rec	**14**	**14**	**37**	**746**	**278**

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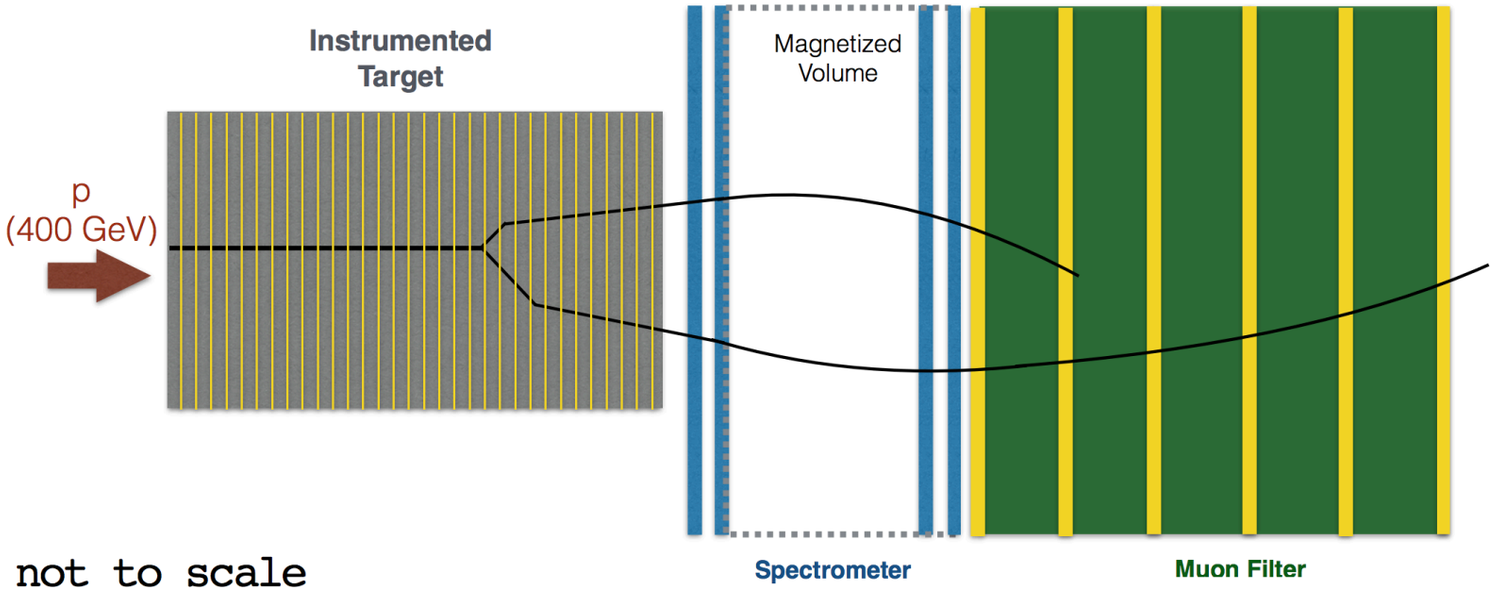
Simulation & tools

A. Di Crescenzo



- 1000 charm pairs expected with 7×10^6 pot and 25 m^2 emulsions
- Important to test SHiP target
- Important having an intermediate goal and physics measurements (charm xsection and cascade)
- Start tuning MC and studying bkg (low stat)

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Summary

- New structure of the PWG, including 3 conveners
- Aim to write a certain number of papers (in collaboration with theorists)
- Signal implementation and sensitivity studies ongoing, but several interesting models not covered—> We need this not only to make sensitivity plots, but also because they are crucial input to bkg studies and detector design
- Thanks a lot to people working on the implementation of tools that other people can use in the analysis
- Bkg studies ongoing (mainly for neutrino backgrounds) but we need people working on all background sources
- Studies ongoing for ν_{tau} , LFUV and measurement of the charm x-section

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Person Power

- We are making lots of progresses with limited manpower
- We need a few more people to row in some places —> get in touch with us