

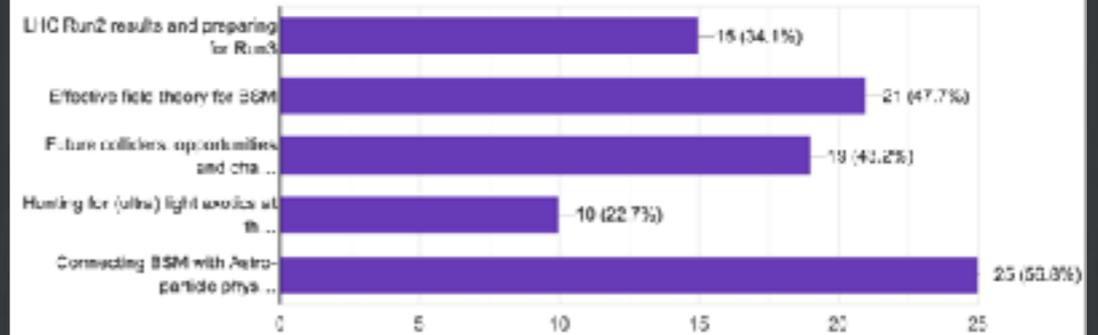
WG-1 WHEPP 2019

Biplob Bhattacharjee, Seema Sharma & Tirtha Sankar Ray

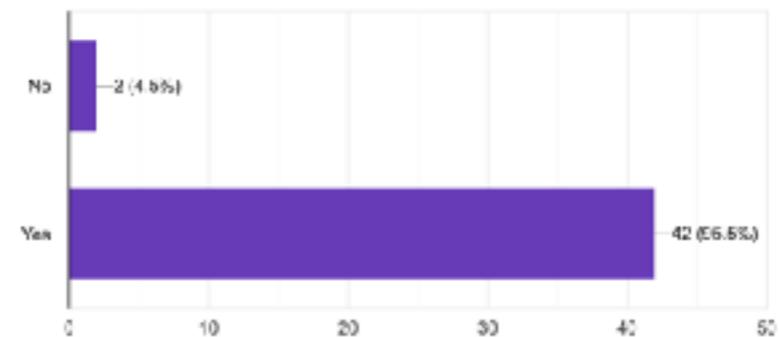
Seniors ~ 24 Post Docs ~ 10 Students ~ 30

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The focus themes of the working group I is listed below. Kindly choose up to two themes
44 responses



Are you interested to participate?
44 responses



Note: DM is most popular, but we are still hopeful for ILC.
Worried Collider Physicists?

Broad Themes

Collider Physics

- **Machine Learning**
- **Recasting**
- **DM search @ LHC/
ILC**

Beyond Colliders

- **DM-BSM
connections**
- **BSM Models**

Note: In future we suggest that we make a hard choice to identify focused themes, well before the workshop, to have more directed discussions!

Discussion Leaders with domain knowledge ran the show

Tentative Schedule for WG-1:

2nd December: Monday

LHC Updates : Discussions lead by **Jyothsna R Komaragiri** and **Aruna K Nayak**

WG Session 1 (14.00-15.30): Discussions Session I

WG Session 2 (16.00-17.30): Discussion Session II

3rd December: Tuesday

Machine Learning: Discussions lead by **Partha Konar** and **Ritesh Singh**

WG Session 1 (14.00-14.30) : Overview talk by Michael Spannowsky

(14.30-15.30): Discussions Session I

WG Session 2 (16.00-17.30): Discussion Session II/ Short talks

4th December: Wednesday

BSM Searches: Discussions lead by **Monoranjan Guchait** and **Santosh K Rai**

WG Session 1 (14.00-15.30): Discussions Session I

WG Session 2 (16.00-17.30): Discussion Session II/ Short talks

5th December: Thursday

ILC Session

WG Session 1 (14.00-15.30): Presentations by: T Saeki, Y Okada,

WG Session 2 (16.00-17.30): Presentations by: K Kawagoe, Rohini Godbole, Ritesh Singh, Poulouse Poulouse,

6th December: Friday

DM-Collider: Discussion Lead by **Nishita Desai** and **Suchita Kulkarni**

WG Session 1 (11.00-12.30): DM Talk by Bohdan Grzadkowski

WG Session 2 (14.00-15.30): Discussions Session I

7th December : Saturday

WG Session 1 (9.00-10.30): DM collider: Discussions Session II /Short Talks

DM-Astro/Cosmo : Discussion Lead by **Subhaditya Bhattacharya Ujjal K Dey** and **Arunansu Sil**

WG Session 2 (11.00-12.30):): Discussions Session I

WG Session 3 (14.00-15.30): Discussions Session II /Short Talks

9th December: Monday

BSM-Models: Discussions lead by **Srihari Gopalakrishna** and **Baradhvaj Coleppa**

WG Session 1 (11.00-12.30): Discussions Session I

WG Session 2 (14.00-15.30): Discussions Session II / Short talks

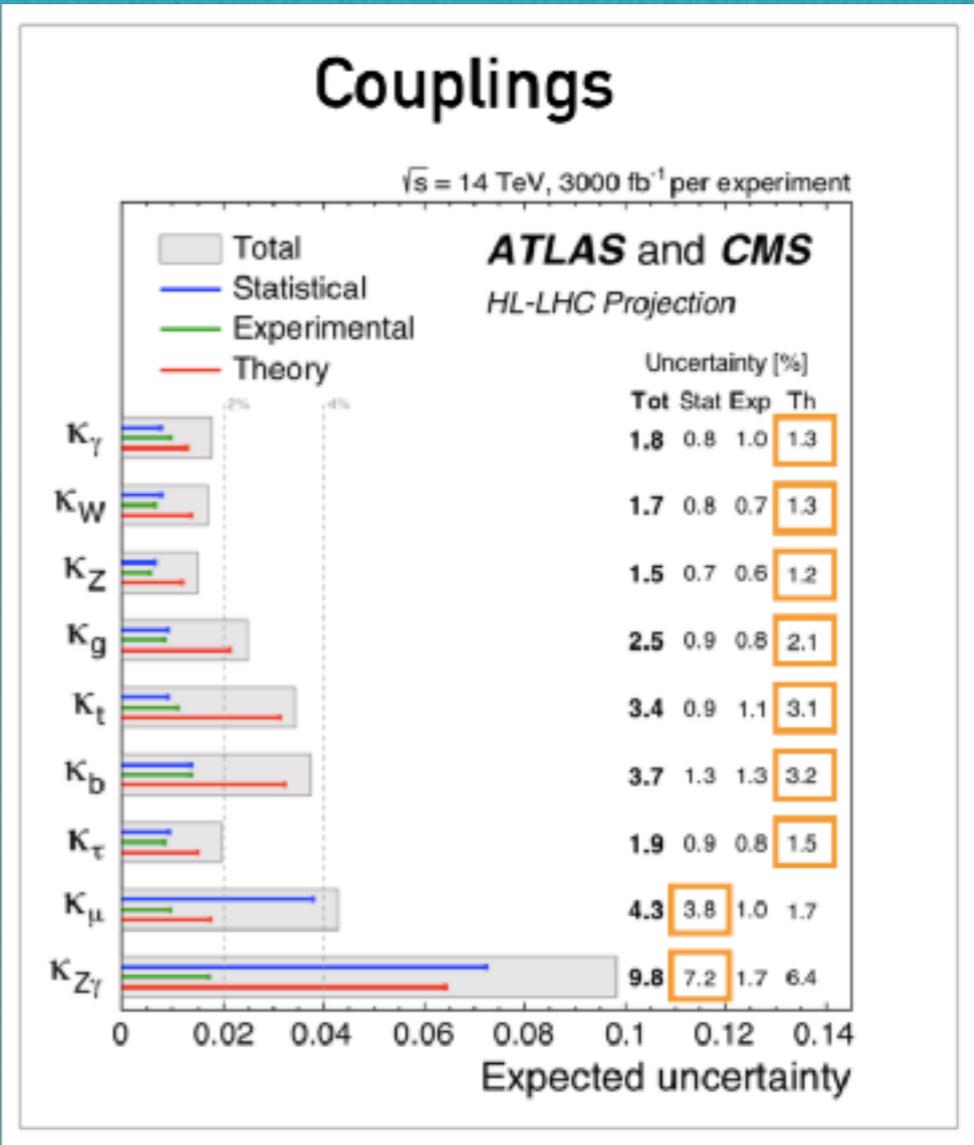
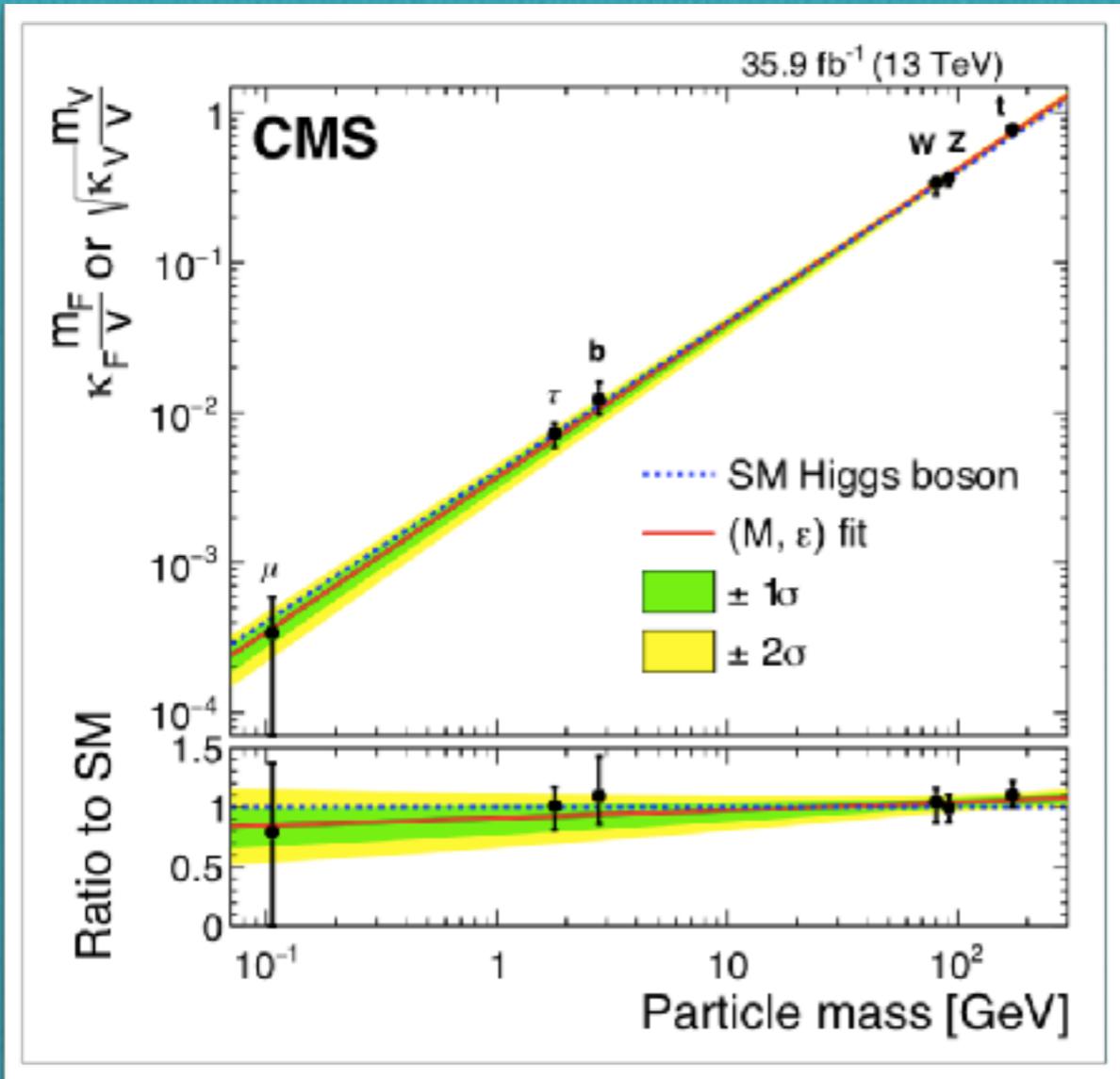
WG Session 3 (16.00-17.30): **Informal Discussion**

10th December: Tuesday

WG Sessions: **Informal Discussions and Summary**

LHC Updates!

Update on Higgs :Arun Nayak



Higgs Couplings increasingly looking like SM; Further improvement expected from HL-LHC is interestingly limited by theoretical uncertainty

Effective field theory approach: may be the way to go?

Minimal extension of SM, assumes

- i) no new states
- ii) new operators with dim > 4

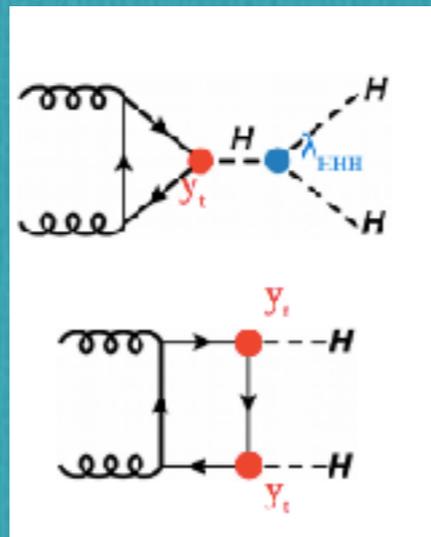
Already trending in LHC community!

Kajari Mazumdar

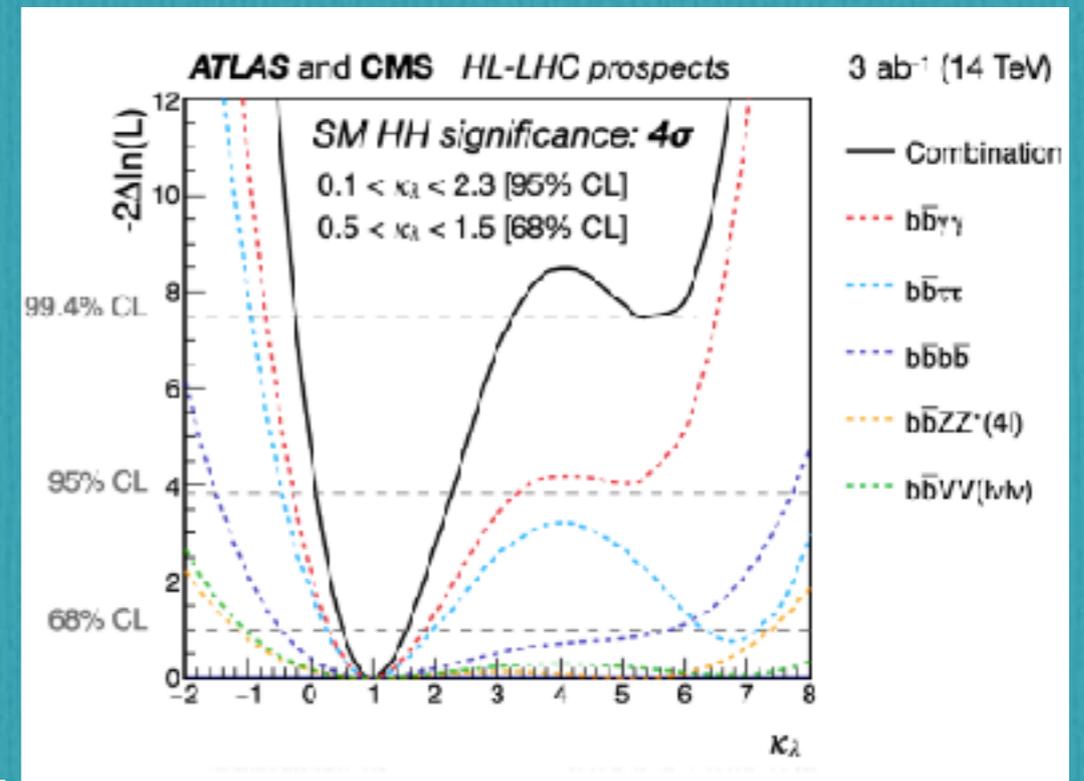
Universal model-independent parametrization of new physics above mass reach → modified coupling

Physics potential for HL-LHC/HE-LHC: Jyothsna Rani Komaragiri

Di-Higgs :
a very sensitive
channel to study
NP
Will be within
reach at
HL-LHC



EFT



Talk by Rahoo Kumar Barman

Talking Points generated

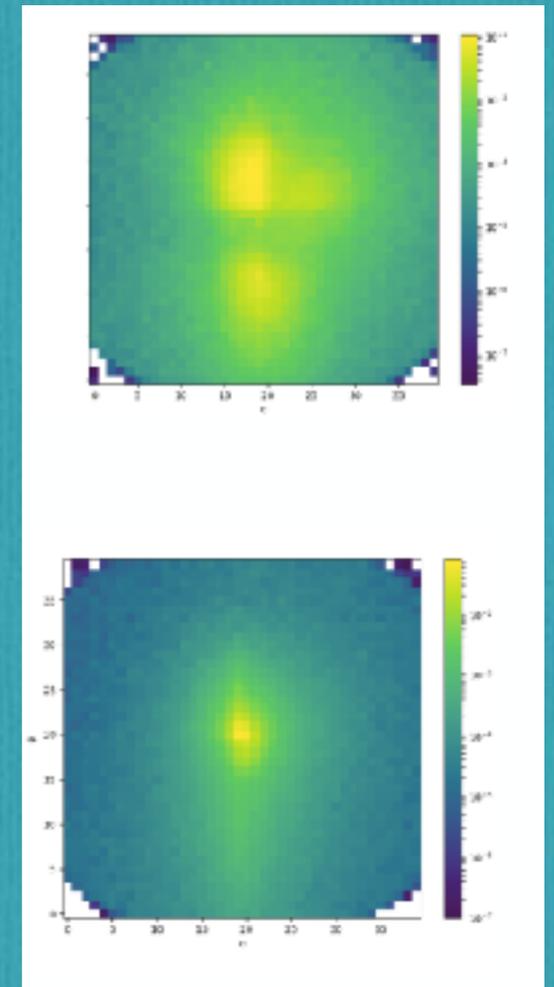
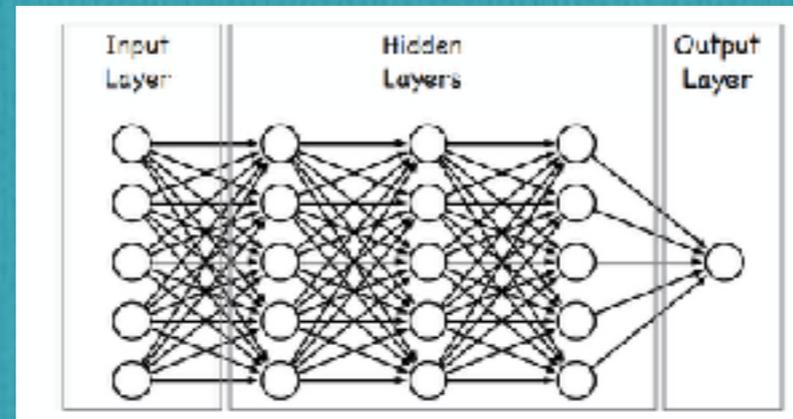
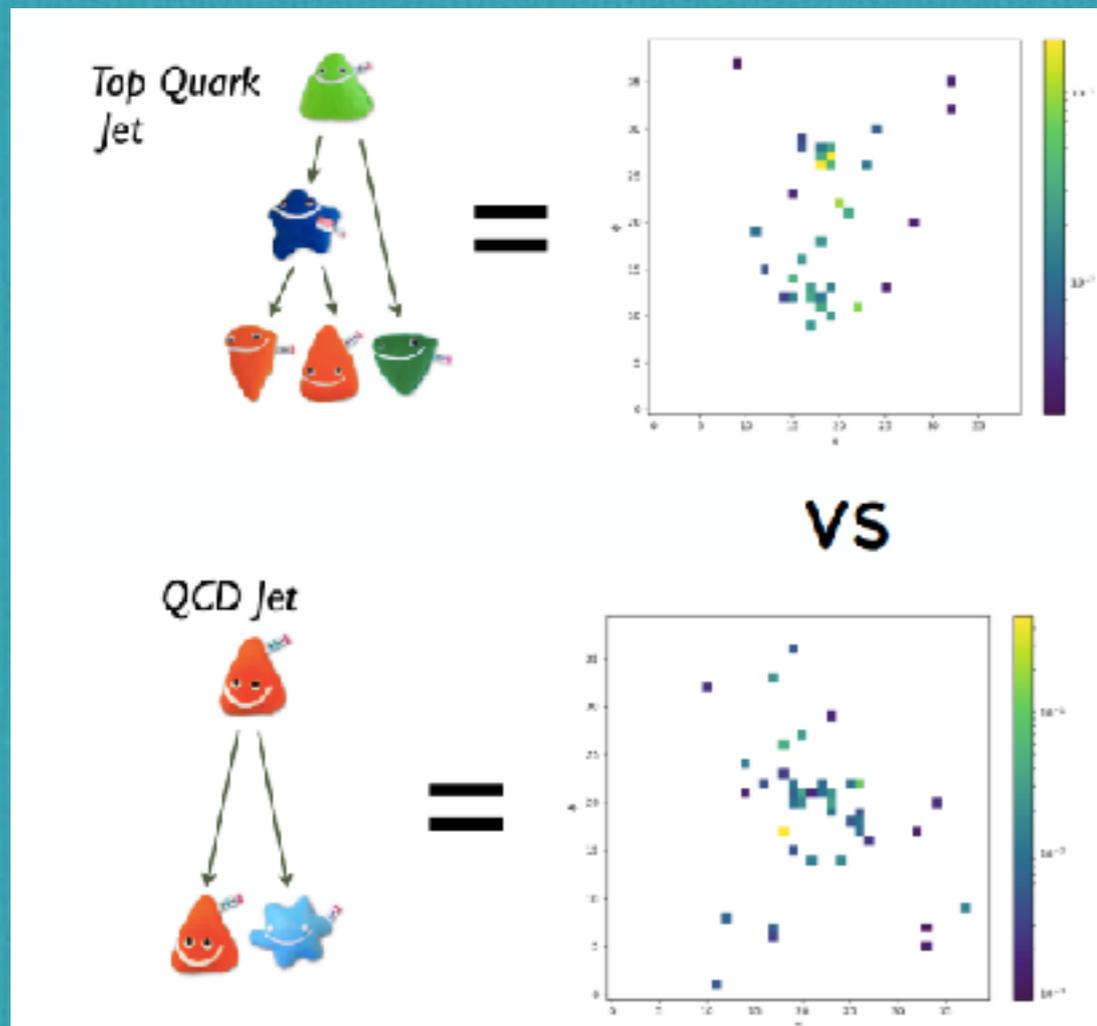
- Interpretation of Dark-Matter limits from LHC: Translating collider limits (DM Mass, XSec) or (DM Mass, Mediator Mass) into direct detection limits to (DM Mass, DM-nucleon x-section) plane.
- Reduction in theory uncertainties for HL-LHC/HE-LHC studies (PDF is the dominant one for the majority of Higgs production processes). Check Section 2 in arXiv:1902.00134**
- Studies on compressed SUSY spectrum from LHC run-3.
- Improvement in low mass Z' searches in di-jet channel. Most limitations are due to the trigger rate. A possible option is to use scouting data and a further improvement in designing the triggers.
- How to use parking data (mostly used for B-physics studies) for other purposes, like low mass searches. A request was made to provide the trigger menu used for parking data.**
- Large discrepancies observed between measured and predicted cross-sections for $t\bar{t}b\bar{b}$ (arXiv:1909.05306). Work on understanding the experimental interpretations in the two frameworks and the observed differences.
- Observable for CP properties of Higgs
- Understanding the assumptions on deriving/measuring couplings (model dependences etc...)
- How are topness and Higgsness defined in the proposed alternative methods for $HH \rightarrow b\bar{b}WW(l\nu l\nu)$. Check Section 3.3.1 in arXiv:1902.00134**
- Getting information about the geometry (granularity) of the HL-LHC (CMS-Phase-2) detector and implementing it in Delphes framework for phenomenology studies. Also implementing object efficiencies, fake rates etc.. for HL/HE-LHC scenarios in Delphes.
- Any suggestions to work on improvising the existing Run-II analyses?

**Collider Physics
@LHC and beyond!**

Machine Learning in Particle Physics: Michael Spannowsky

In particle physics, mostly used in context of
Regression and Classification

(upcoming clustering and anomaly detection)



Talking Points generated: Discussions lead by Partha Konar & Ritesh Singh

Experimental Side

Improved Trigger with real time reconstruction

Event simulation and detector simulation

Offline event reconstruction and object identification

Theory Side

Jet-physics and QCD

QCD jets and new physics, Deep-learning Top Taggers or The End of QCD? Jet algorithm

Colliders

SM and BSM, prompt and long-lived particles

Neutrino/Cosmic

Nova, Ice cube, Cosmic jet

Going beyond classification and regression

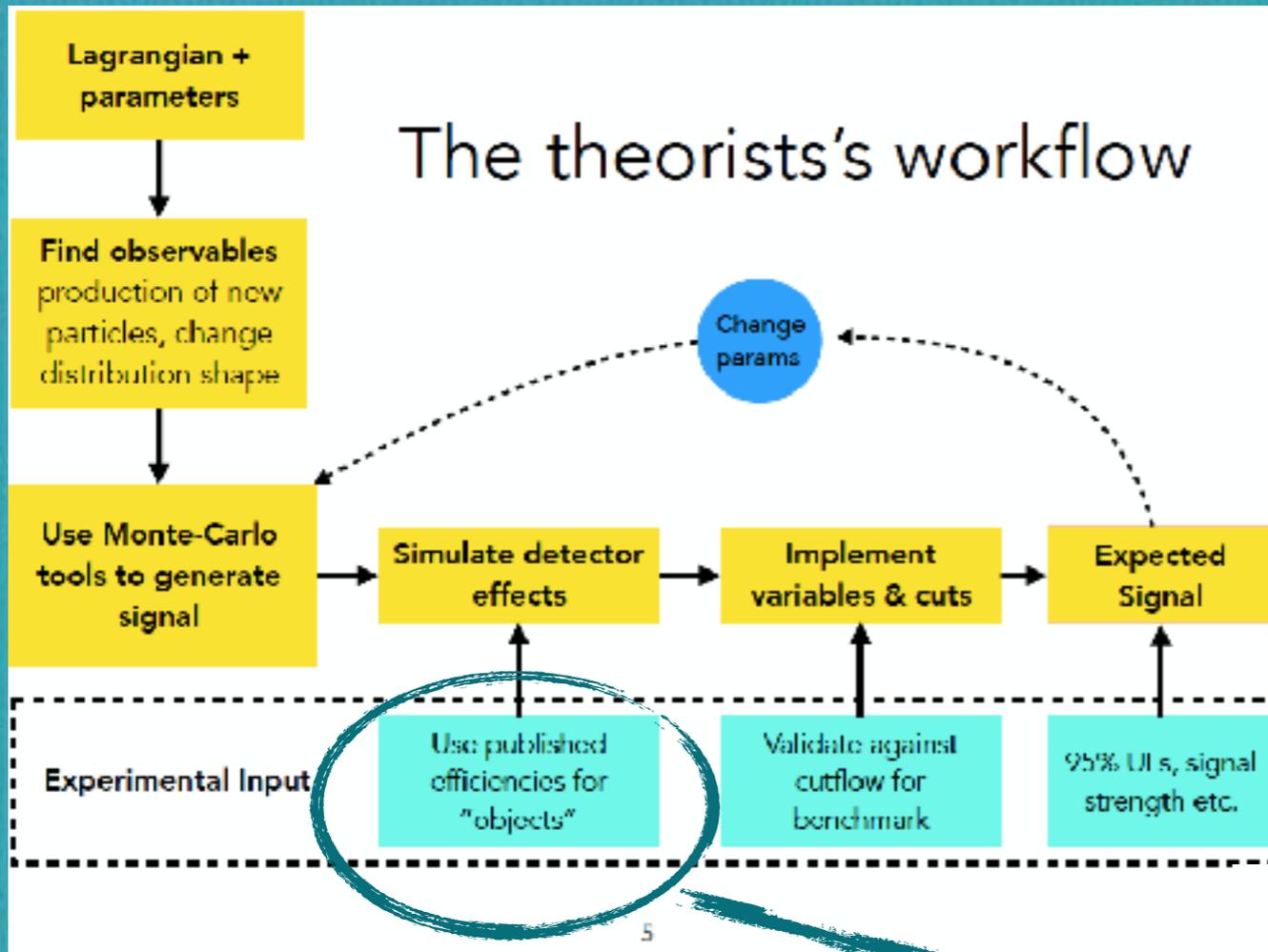


Sub-group formed

Note: Need to have dedicated algorithm building for HEP
instead of being end users of Google!

Recasting

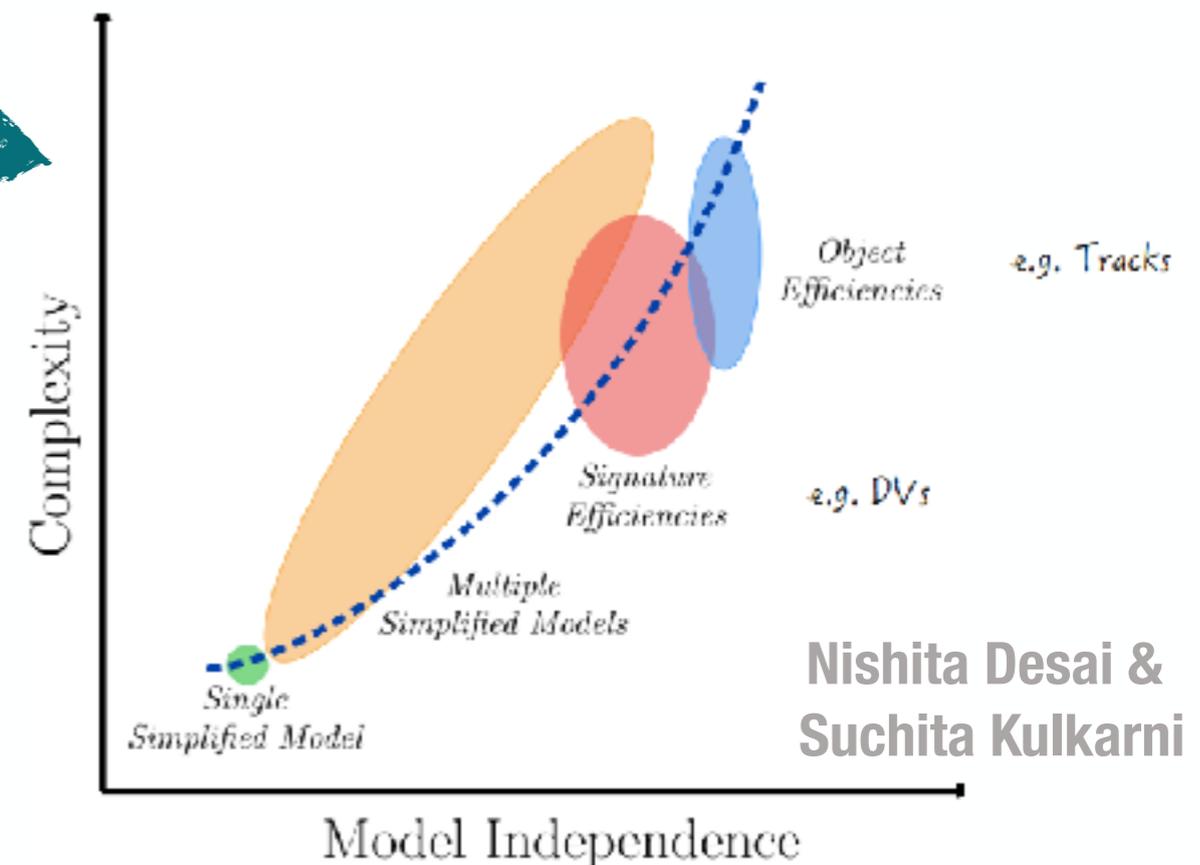
Recasting experimental results to motivated BSM scenario is one of the main goal of collider phenomenology



Theory-Experiment Cross Talk



Sub-group formed

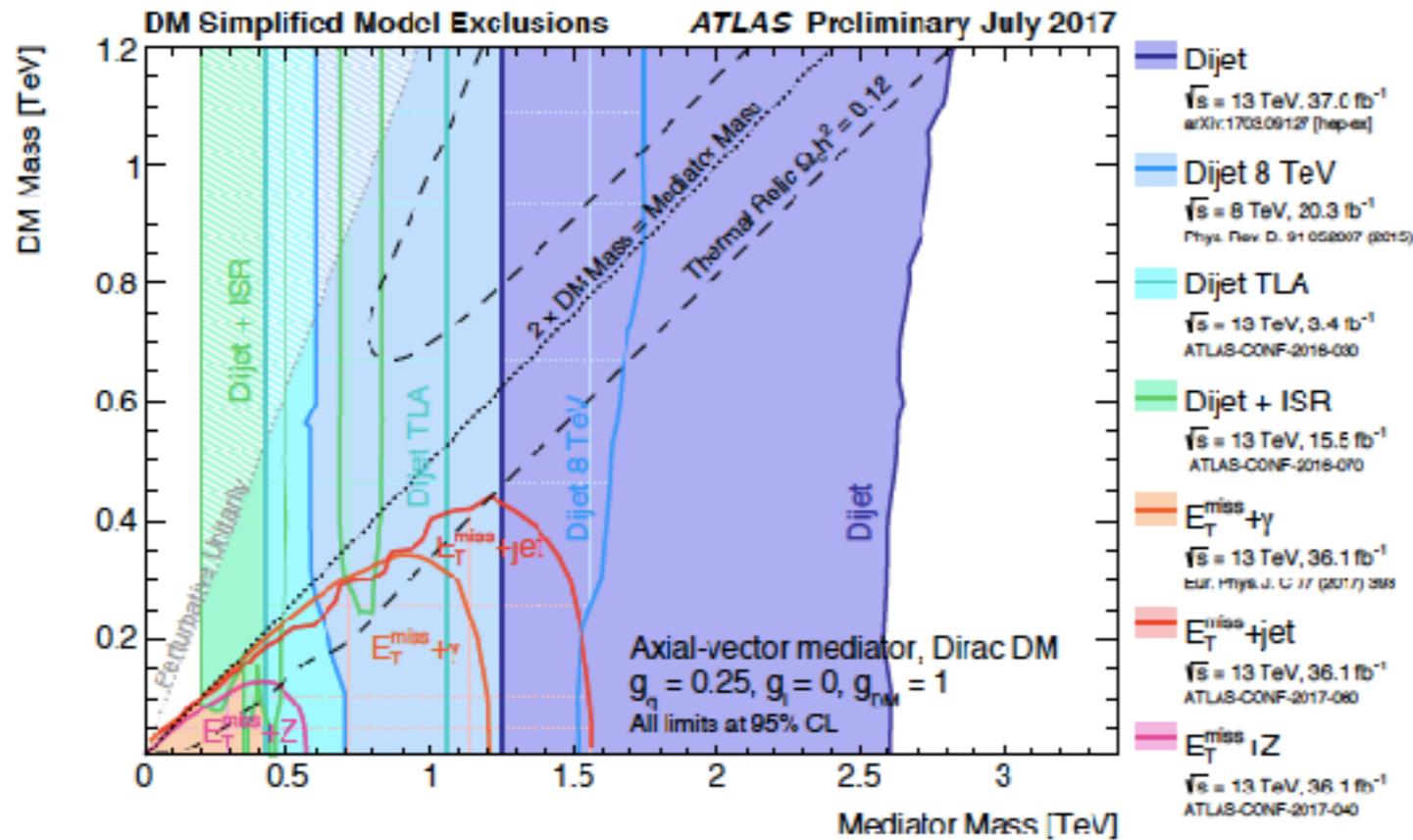


**Talking Points generated: Discussions
lead by Monoranjan Guchait and Santosh Rai**

- Writing a Delphes module that will include efficiency for CMS LLP searches**
- How to modify the upper limits if a signal model is found to populate the control regions?**
- Using analyses implemented in CheckMATE, derive efficiency maps for electroweakino sector.**
- Using hadronic analyses implemented in CheckMATE, derive efficiency maps for gluino asymmetric decays.**
- Global Analysis of Z' mediators**

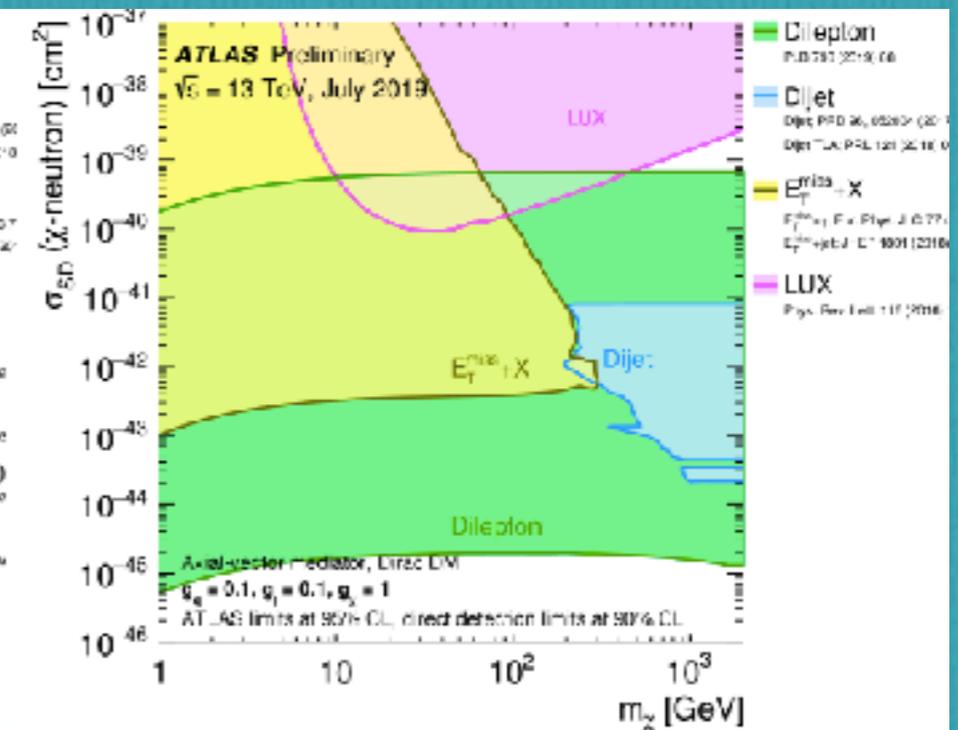
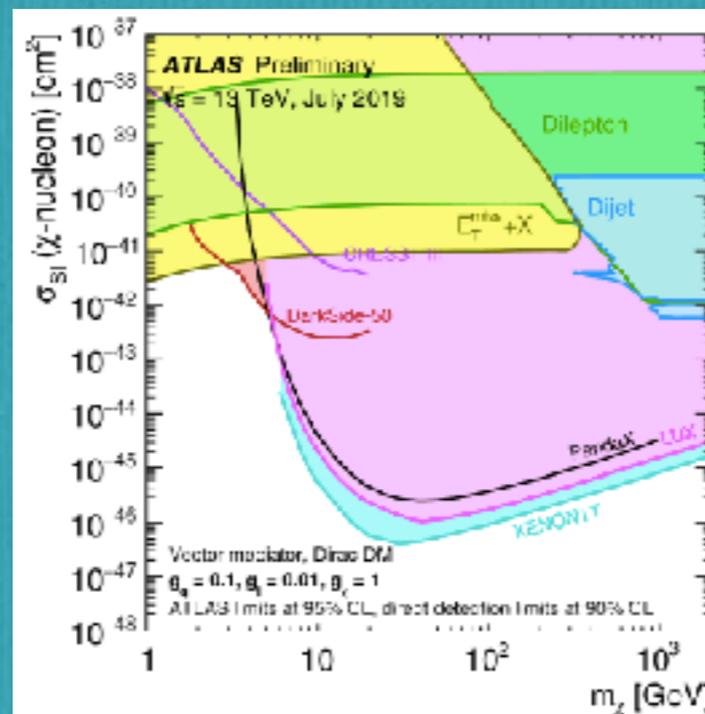
DM example @ Colliders

DM Searches are not not competitive with most mediator searches



Nishita Desai & Suchita Kulkarni

Note: How honest it is to interpret mediator hunts as DM searches?



Z' @ ILC: Talk by Arindam Das

DM Searches @ ILC

Universal framework for “simplest” DM: pNGB scalar, vector (with SSB) and Majorana (with scalar mediator) DM

$$V_{\text{pGDM}}(H, S) = -\mu_H^2 |H|^2 + \lambda_H |H|^4 - \mu_S^2 |S|^2 + \lambda_S |S|^4 + \kappa |S|^2 |H|^2 + (\mu^2 S^2 + \text{H.c.})$$

$$V_{\text{VDM}}(H, S) = -\mu_H^2 |H|^2 + \lambda_H |H|^4 - \mu_S^2 |S|^2 + \lambda_S |S|^4 + \kappa |S|^2 |H|^2$$

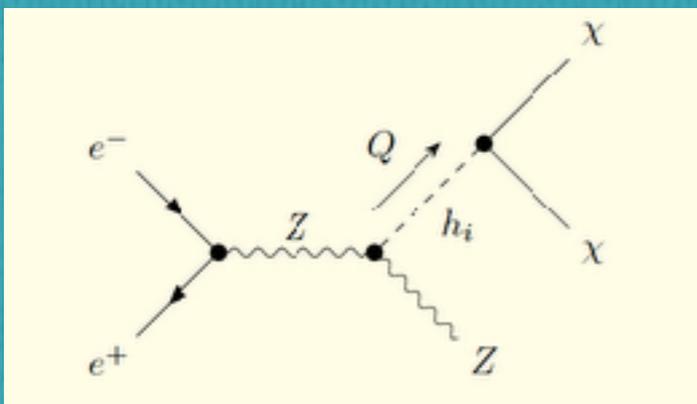
$$V_{\text{FDM}}(H, S) = -\mu_H^2 |H|^2 + \lambda_H |H|^4 - \frac{\mu_S^2}{2} S^2 + \frac{\lambda_S}{4} S^4 + \frac{\kappa}{2} |H|^2 S^2$$

$$S = v_S + \phi (+i\Lambda), \quad H = \begin{pmatrix} \pi^+ \\ v + h + i\pi^0 \\ \sqrt{2} \end{pmatrix}$$

$$\begin{pmatrix} h_1 \\ h_2 \end{pmatrix} = \mathcal{R}^{-1} \begin{pmatrix} h \\ \phi \end{pmatrix}, \quad \mathcal{R} = \begin{bmatrix} \cos \alpha & -\sin \alpha \\ \sin \alpha & \cos \alpha \end{bmatrix}$$

It is convenient to use the same input parameters for all the models:

$$m_2, \sin \alpha, m_{\text{DM}} \equiv (m_A, m_X, m_{\psi}) \quad \text{and} \quad v_S$$



Possible searches and
spin disentanglement at
ILC

Bohdan GRZADKOWSKI

Talking Points generated: Discussions lead by Nishita Desai & Suchita Kulkarni

- **LHC limits on Z' from dijet/dilepton are (potentially) far more constraining than direct DM search**
- **Neutrino-mass inspired $U(1)_{B-L}$ models can be simply extended to include Dark Matter and lead to so called Neutrino-portal dark matter. It may be possible to look for these at the LHC in vector-boson fusion channels with like-sign dileptons.**
- **Multi-partite dark matter at colliders**
- **Geant4 geometry and validation against Delphes**
(Akanksha, Partha, Nishita, Satyaki and Suchita)



Projects-Set I

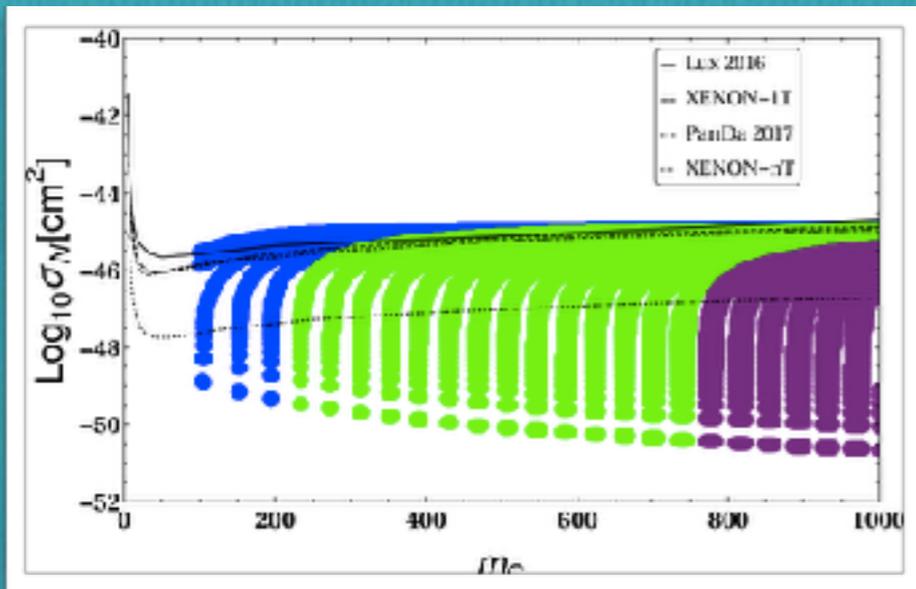
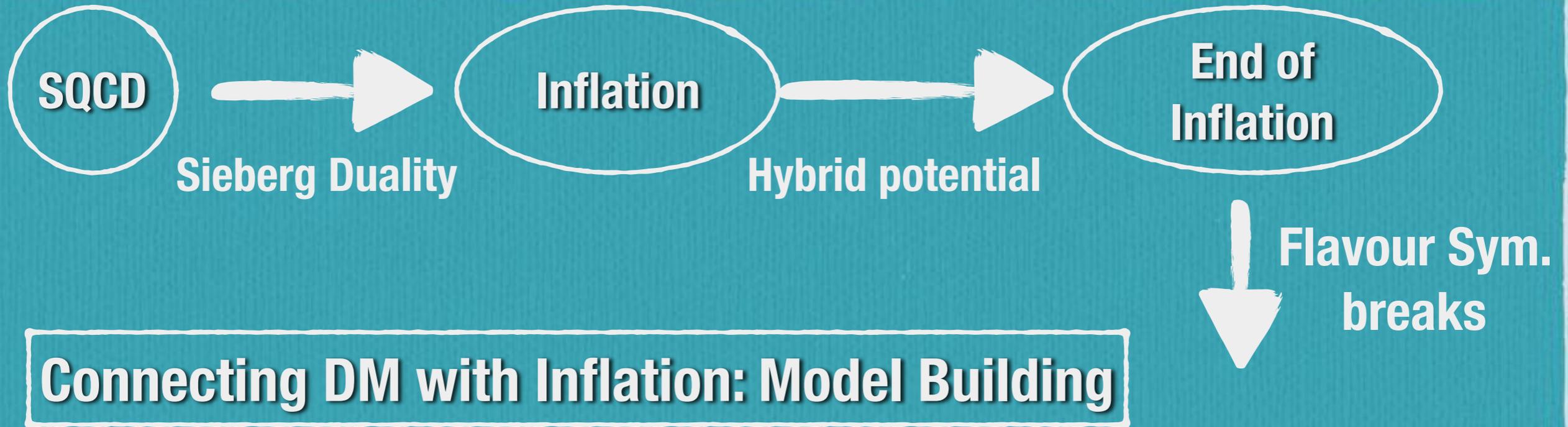
7 projects were suggested

Kindly acknowledge WHEPP, 2019

Let the emailing begin!

TOPIC	SIGNUP (with email)
DELPHES back searches (disappearing track $\frac{dE}{dx}$ etc)	Avinav Ghosh (avinav.ghosh1992@gmail.com) Rishika (arankaha@prl.res.in) Shashwat
E^2 (wide vacuum) + Dark Matter	S. K. Rai (skrai@hri.res.in) P. K. Dhuc (pikd.k.dhuc@gmail.com) JYOTHSNA (jyothsna@cern.ch) Ritesh Singh Manoranjan Datta (dattamanoranjan2015@gmail.com)
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CP violation of Higgs (Baryogenesis)	S. K. Rai (skrai@hri.res.in) P. K. Dhuc (pikd.k.dhuc@gmail.com) Ashish (055932@gmail.com)
Neutrinoless DM @ LHC	T. Ghosh (ghoshitaha@gmail.com) JYOTHSNA (jyothsna@cern.ch) Rishika (arankaha@prl.res.in) Jyotshna (jyotshna@cern.ch) T. Ghosh (ghoshitaha@gmail.com)
COMPRESSED MASS SPECTRA @ LHC	T. Ghosh (ghoshitaha@gmail.com)

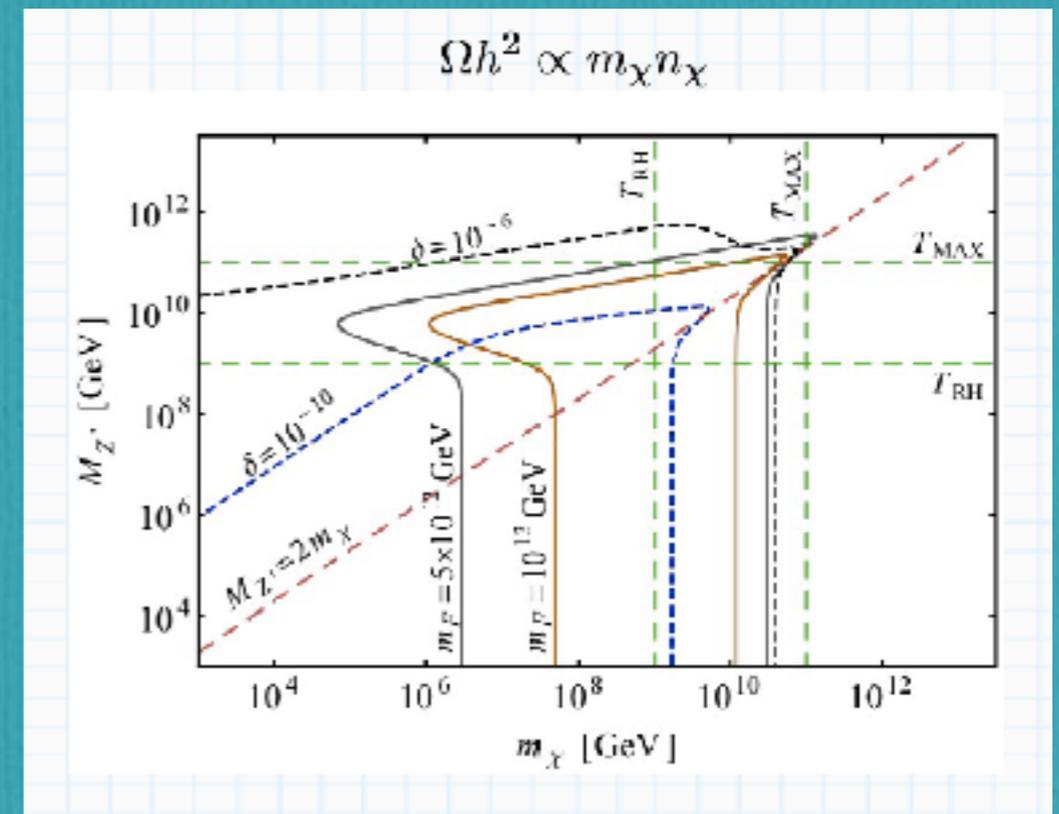
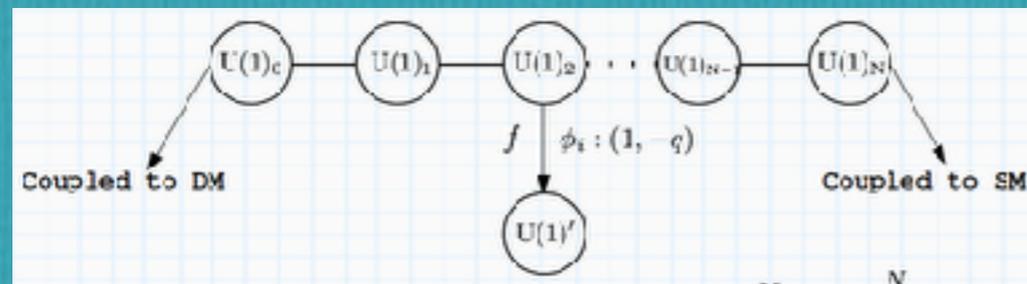
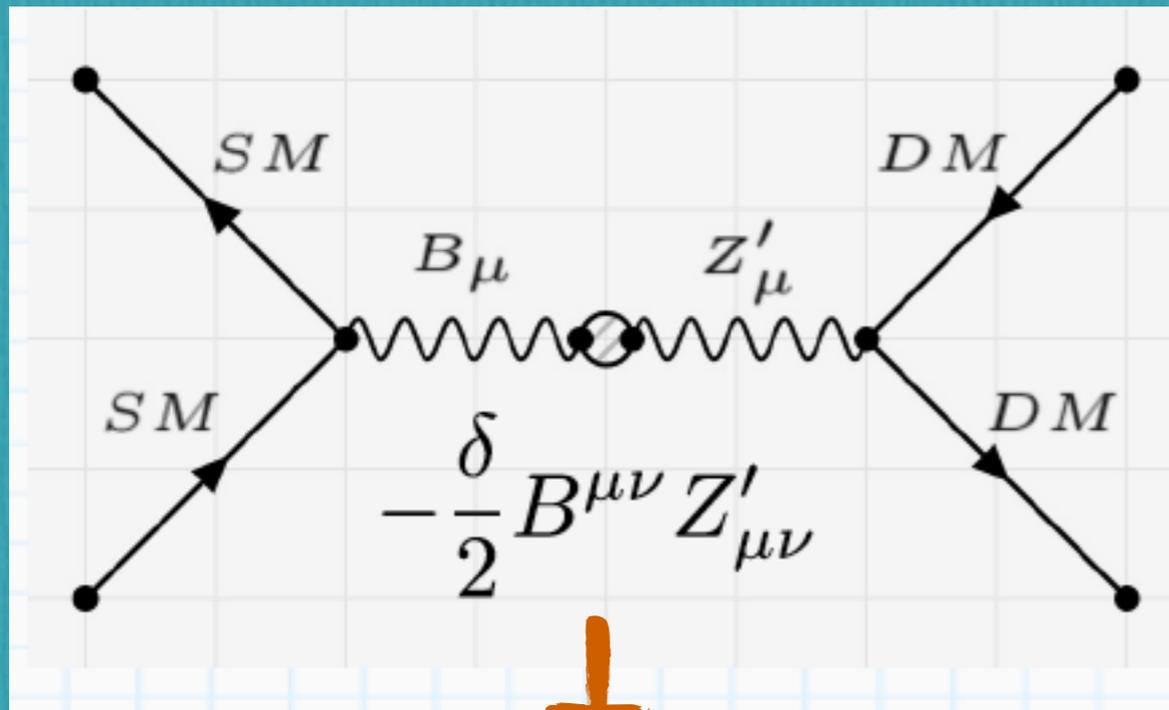
Dark Matter and Models



Note: Efforts have been made to harmonise traditional BSM activities with DM need to enlarge to other Astro/Cosmo issues

**Abhijit Kumar Saha,
Arunansu Sil**

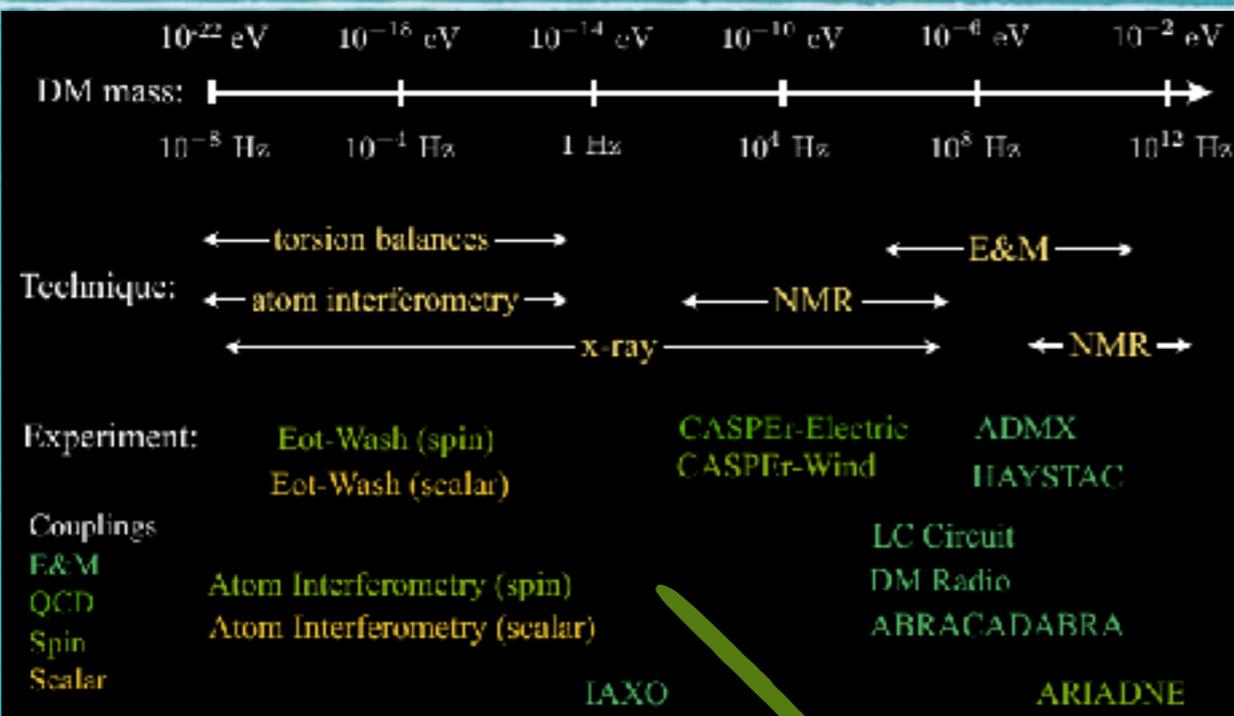
Freeze-in DM



Questions

- ✓ Initial conditions?
- ✓ Experimental signatures? GW from dark phase transition?
- ✓ Thermal effects?
- ✓ Freeze-out with dynamic mixing?

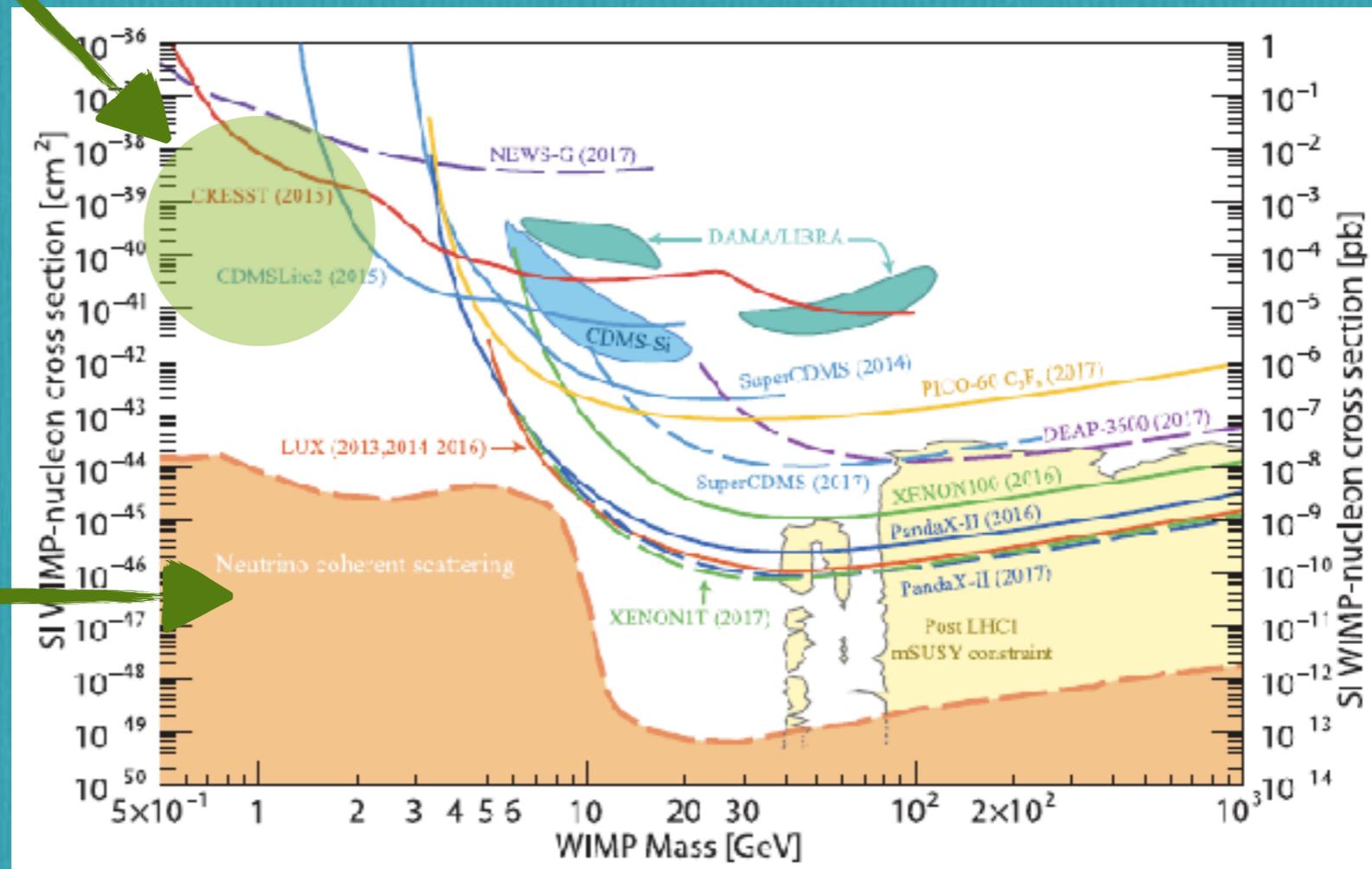
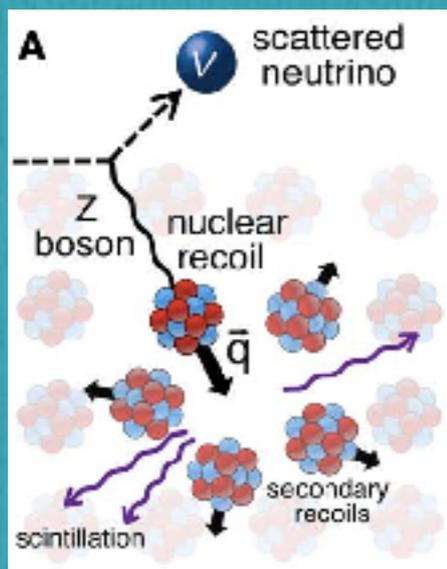
Avik Banerjee



Direct detection of sub-geV DM New techniques

Ujjal Dey

Re-evaluation of ν floor with NSI



NSI @ LHC: Talk by Tathagata Ghosh

**Talking Points generated: Discussions
lead by Subhaditya Bhattacharya and Ujjal K Dey**

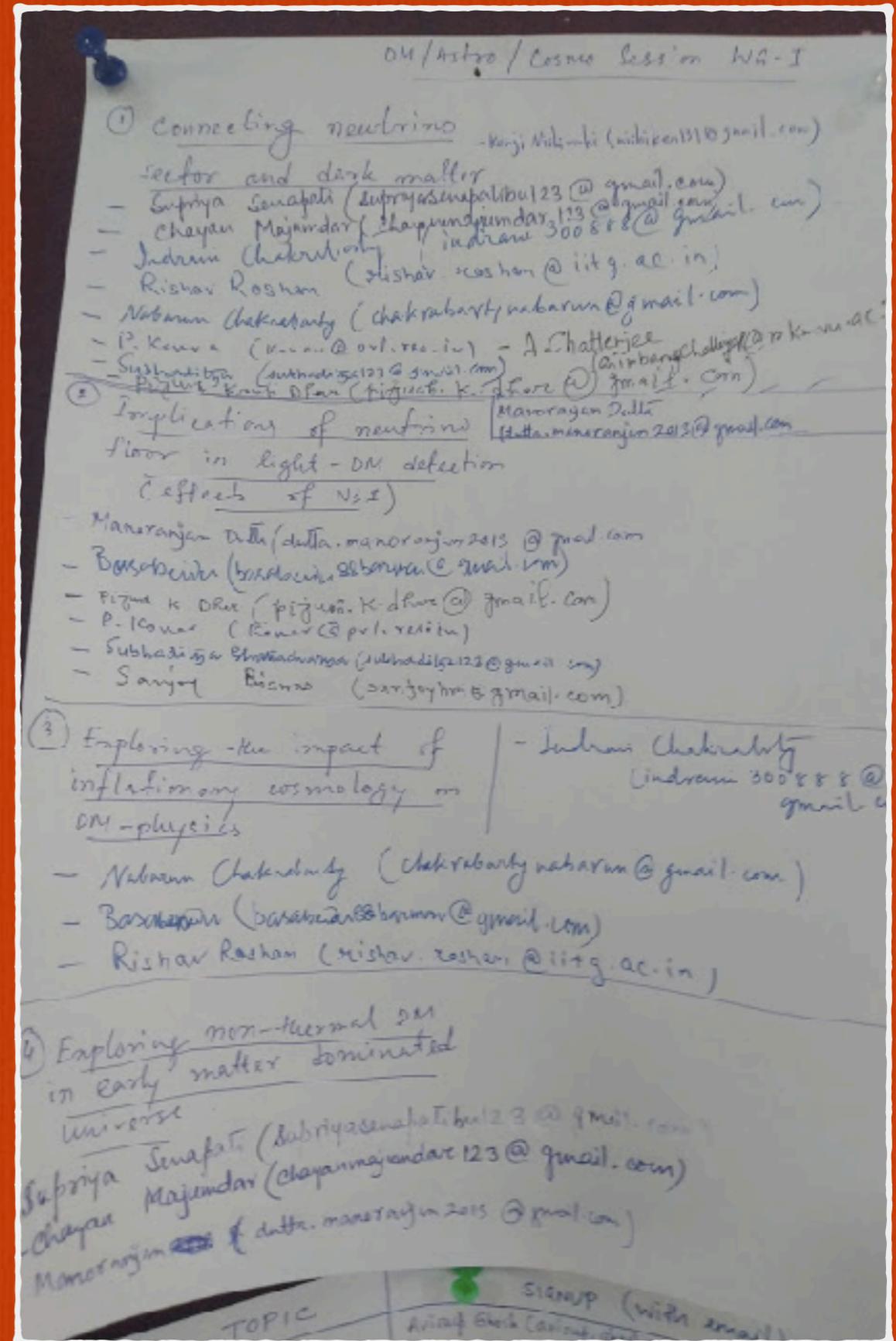
- Connecting neutrino sector and dark matter : Neutrino floor recalibration in direct detection experiments with NSI**
- Connecting DM and inflationary cosmology**
- Freeze-in DM scenario: the crucial nature of dependence on initial conditions is a subject of further studies**
- Light DM: It was proposed to construct and/or constrain models having intrinsic implications on neutrino floor physics**

Projects-Set II

4 projects were suggested

Kindly acknowledge WHEPP, 2019

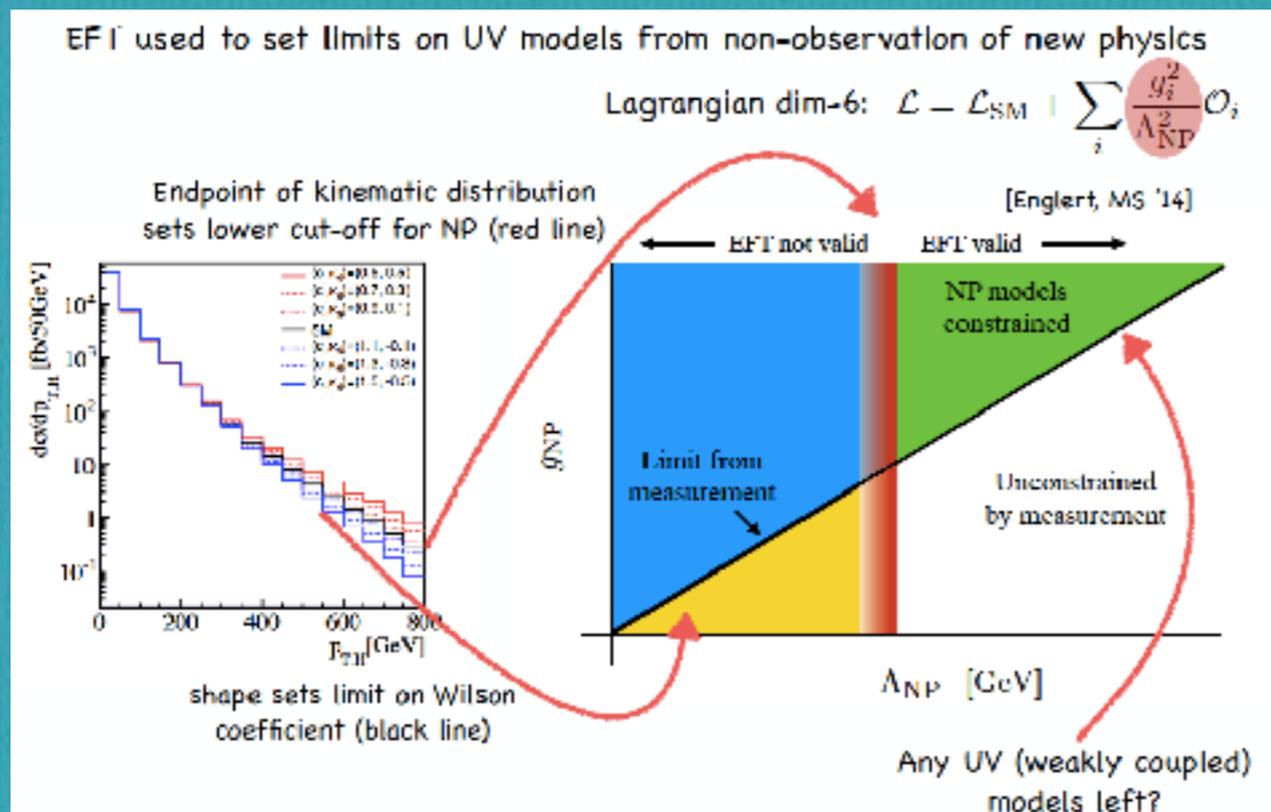
Let the emailing begin!



Why EFT?

Model Independent Interpretation of Collider Results

Modeling Non-Perturbative Physics



Michael Spannowsky

Topic: 11/EFT/SCET

(TS, KT, VL) (FSL)

Problem: MiniBooNE

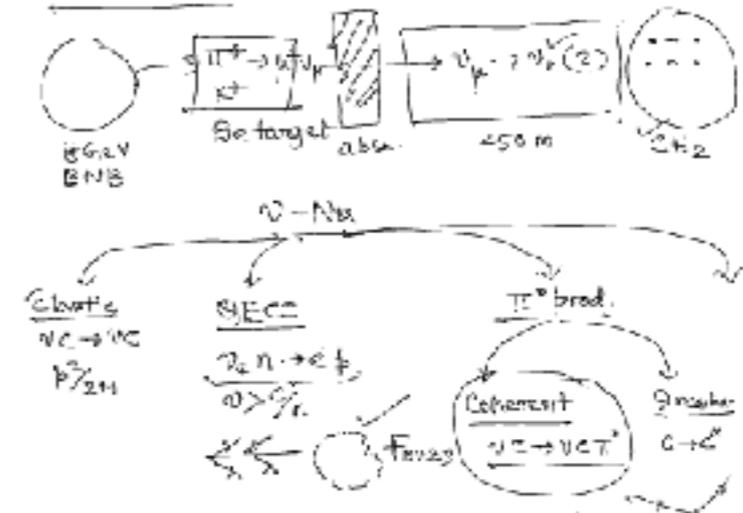
$$P_{\nu_{\mu} \rightarrow \nu_{\tau}} = \sin^2 2\theta \sin^2\left(\frac{\Delta m^2 L}{2E}\right) \left. \begin{array}{l} \text{Solar} \\ \text{atmosph.} \end{array} \right\}$$

(a) Oscillation (long)

(b) Sterile Neutrinos (M=keV)

(c) NP

MiniBooNE:



Sabyasachi Chakraborty

EFT: Model independent approach to BSM

- The following terms are **not constrained by LEP**. First time probed at the LHC

$$\mathcal{L}_h^{\text{primary}} = g_{VV}^h h \left[W^{+\mu} W_{\mu}^{-} + \frac{1}{2c_{\theta W}^2} Z^{\mu} Z_{\mu} \right] + g_{3h} h^3 + g_{ff}^h (h \bar{f}_L f_R + h.c.)$$

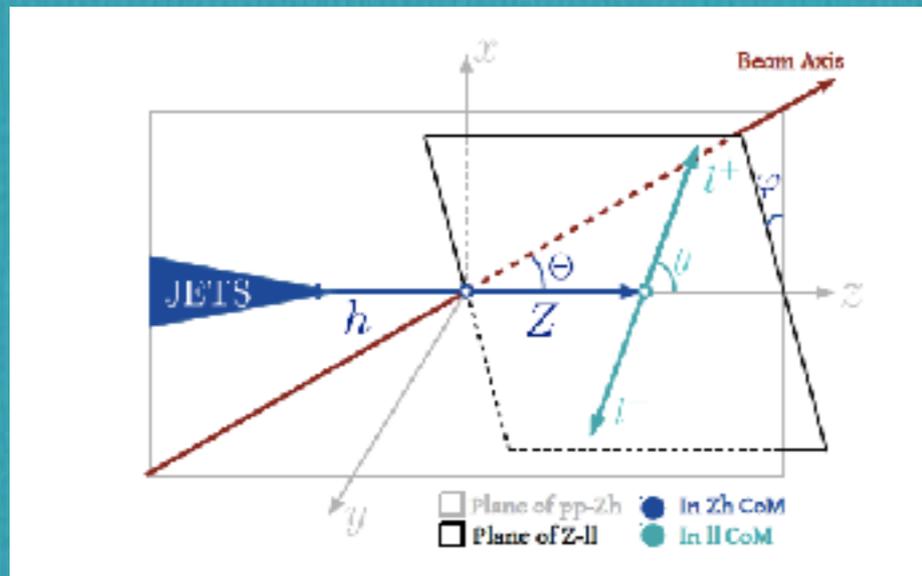
$$+ \kappa_{GG} \frac{h}{v} G^{A\mu\nu} G_{\mu\nu}^A + \kappa_{\gamma\gamma} \frac{h}{v} A^{\mu\nu} A_{\mu\nu} + \kappa_{Z\gamma} \frac{h}{v} A^{\mu\nu} Z_{\mu\nu},$$

- In contrast, the following interactions were **constrained by LEP**

$$\Delta\mathcal{L}_h = \delta g_{ZZ}^h \frac{v}{2c_{\theta W}^2} h Z^{\mu} Z_{\mu} + g_{Zff}^h \frac{h}{2v} (Z_{\mu} J_N^{\mu} + h.c.) + g_{Wff'}^h \frac{h}{v} (W_{\mu}^{+} J_C^{\mu} + h.c.)$$

$$+ \kappa_{WW} \frac{h}{v} W^{+\mu\nu} W_{\mu\nu}^{-} + \kappa_{ZZ} \frac{h}{v} Z^{\mu\nu} Z_{\mu\nu},$$

LEP usually does better in the Higgs sector because of precision measurements



But opportunity remains for processes that grow with energy:

**Example: Probing unitarity preserving couplings
Using Higgs-strahlung processes**

Shankha Banerjee

UV Model: SUSY Talk by Samadrita Mukherjee

Composite Talk by Kenji Nishiwaki; Both alive and kicking!

**Talking Points generated: Discussions
lead by Baradhwaj Coleppa and Shrihari Gopalakrishna**

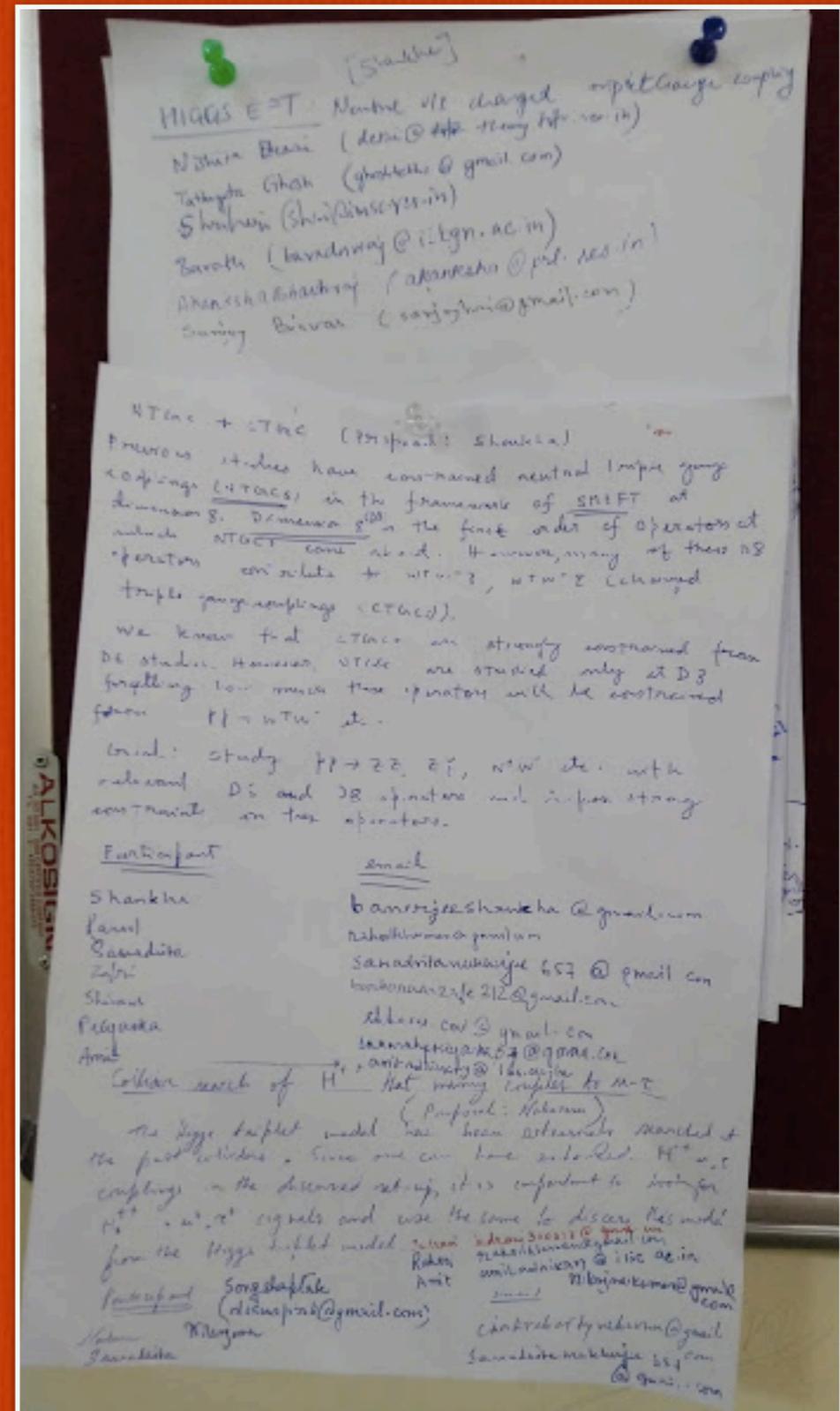
- **Discussion of the measurements of the Higgs couplings to the electroweak bosons in the context of an effective field theory. The potential of the High-luminosity run of the LHC to constrain Wh and Zh couplings to stronger degrees than LEP was explored.**
- **The Zee-Babu type model for the generation of neutrino mass augmented with a scalar triplet and additional singly charged scalar singlets. How the model can explain the experimental observation on the muon anomalous magnetic moment while complying with neutrino masses+mixings and LFV was discussed.**
- **Probing Lepton Flavor Violating decays in MSSM with Non-Holomorphic Soft Terms. Constraining the interaction terms via the experimental limits on LFV.**
- **A dynamical realization of the spontaneous electroweak symmetry breaking of the SM gauge groups in an extended framework of a flavorful vectorlike confinement scenario.**
- **Discussion of a general $U(1)$ extension of the Standard Model and the associated phenomenology of the Z' at the ILC and beyond.**

Projects-Set III

2 projects were suggested

Kindly acknowledge WHEPP, 2019

Let the emailing begin!



Takeaways

- LHC is going to run for the academic lifetime for most of us and this is a great opportunity of our time!
- More careful use of the data available by non-traditional (**machine learning**) approach required to unearth the wealth of (hidden!) information.
- **EFT** is trending and may finally allow experimentalists and theorists to happily coexist at conferences (and hopefully in discussion rooms)!
- A careful synergy between **astrophysics/cosmology** and collider physics is needed
(Note: our bad no joint sessions this WHEPP)



Thank you for participating!

Biplob, Seema & Tirtha