Summery talk: Anomalies 2020

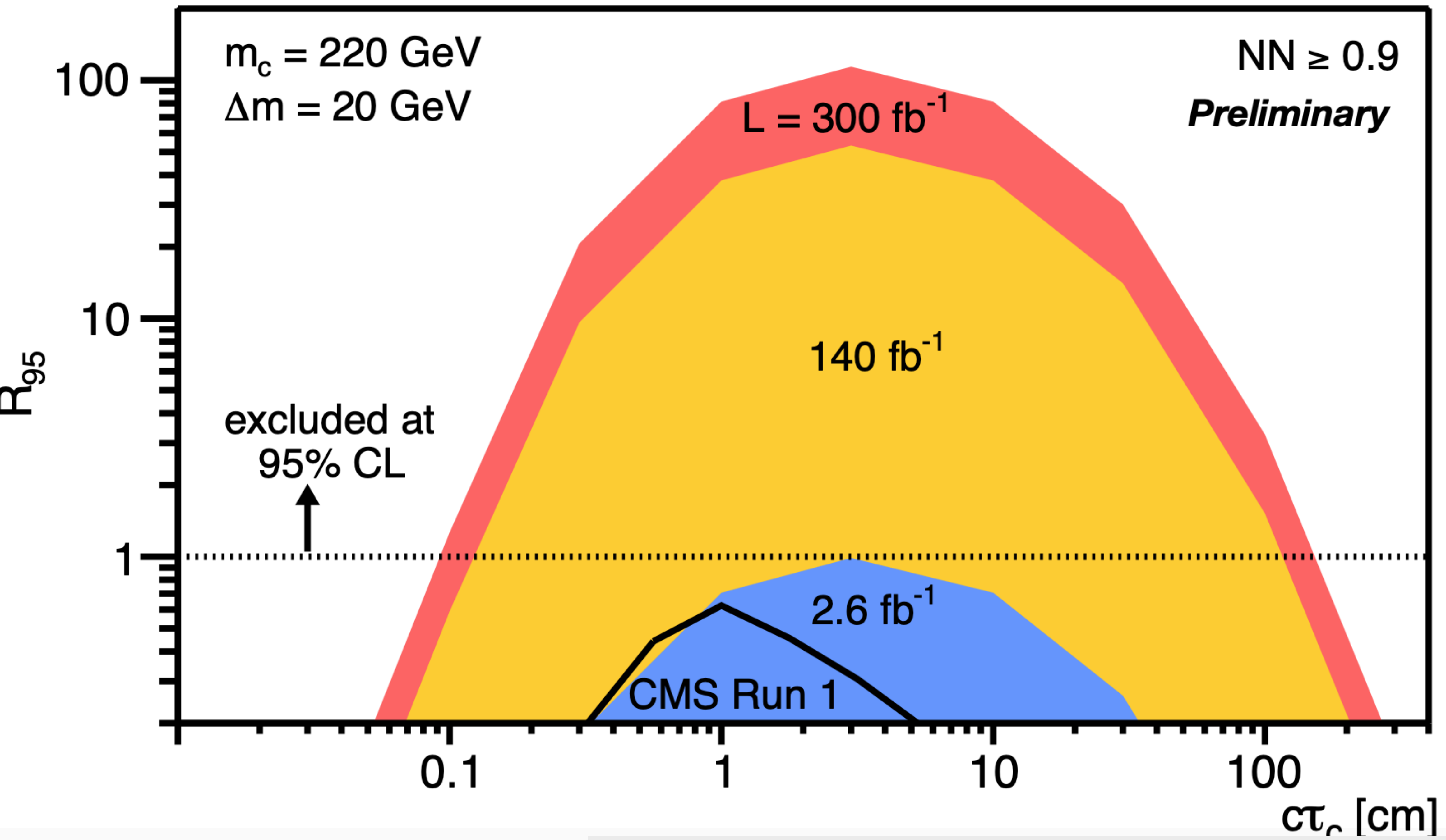
भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

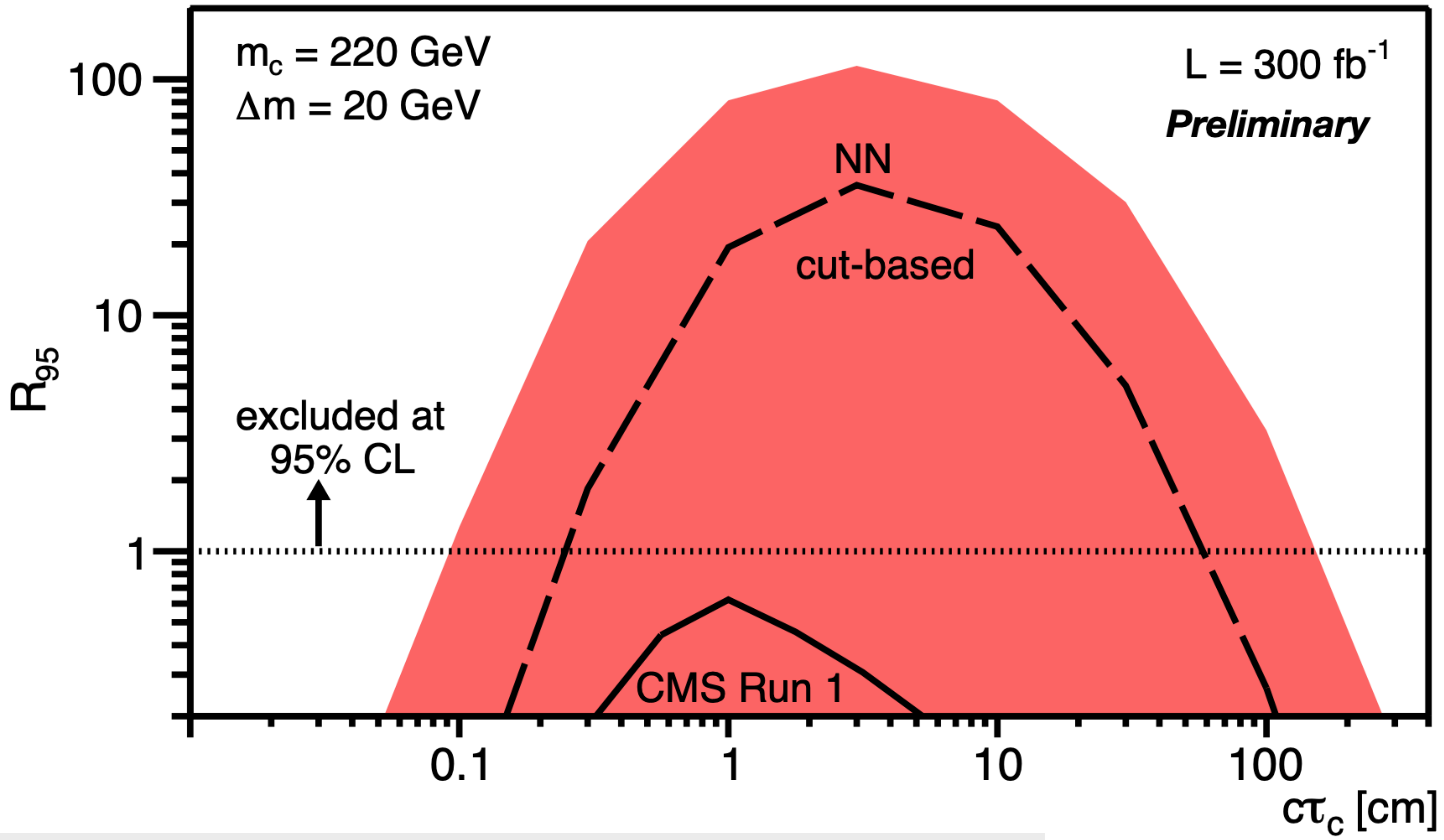
Priyotosh Bandyopadhyay, 13/09/2020

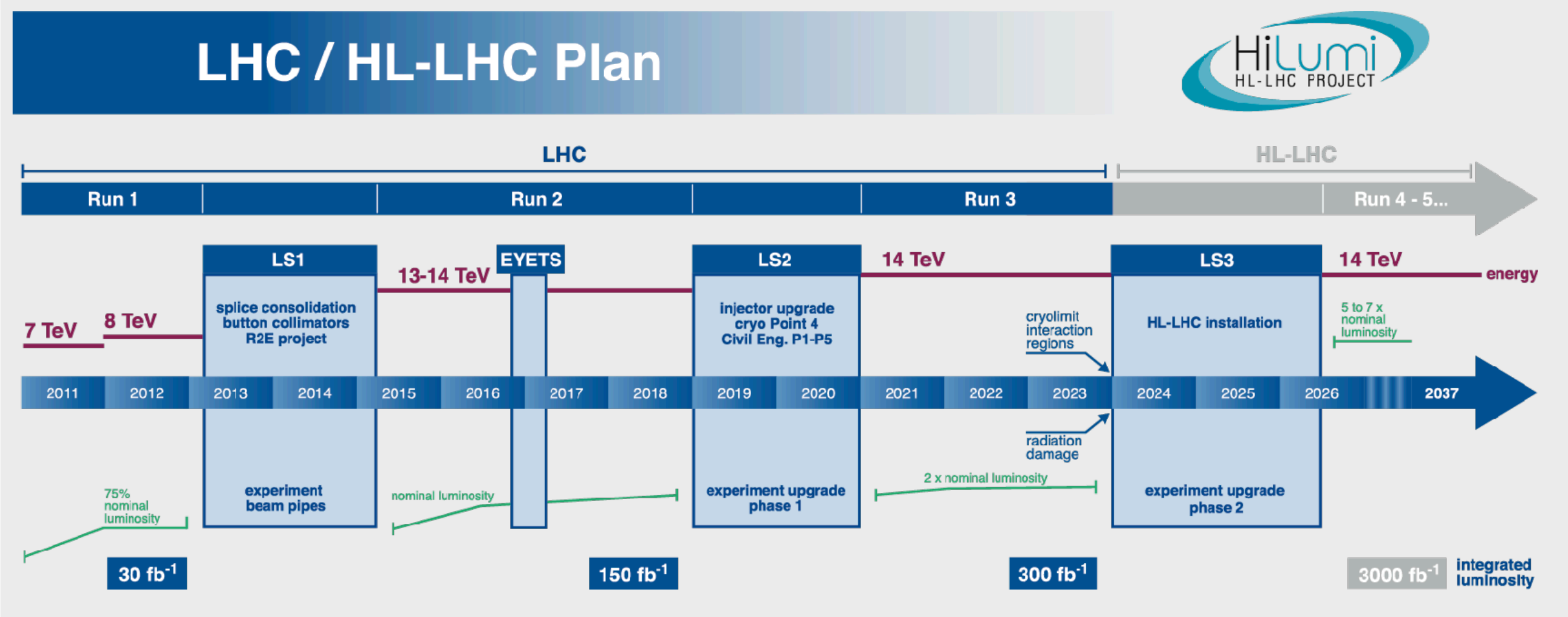
Topics covered:

- *BSM*
- *Dark Matter*
- *Gravitational waves*
- *Flavour*
- *Neutrinos*

BSM: Displaced vertex signature studies: Dr. Nishita Desai's talk







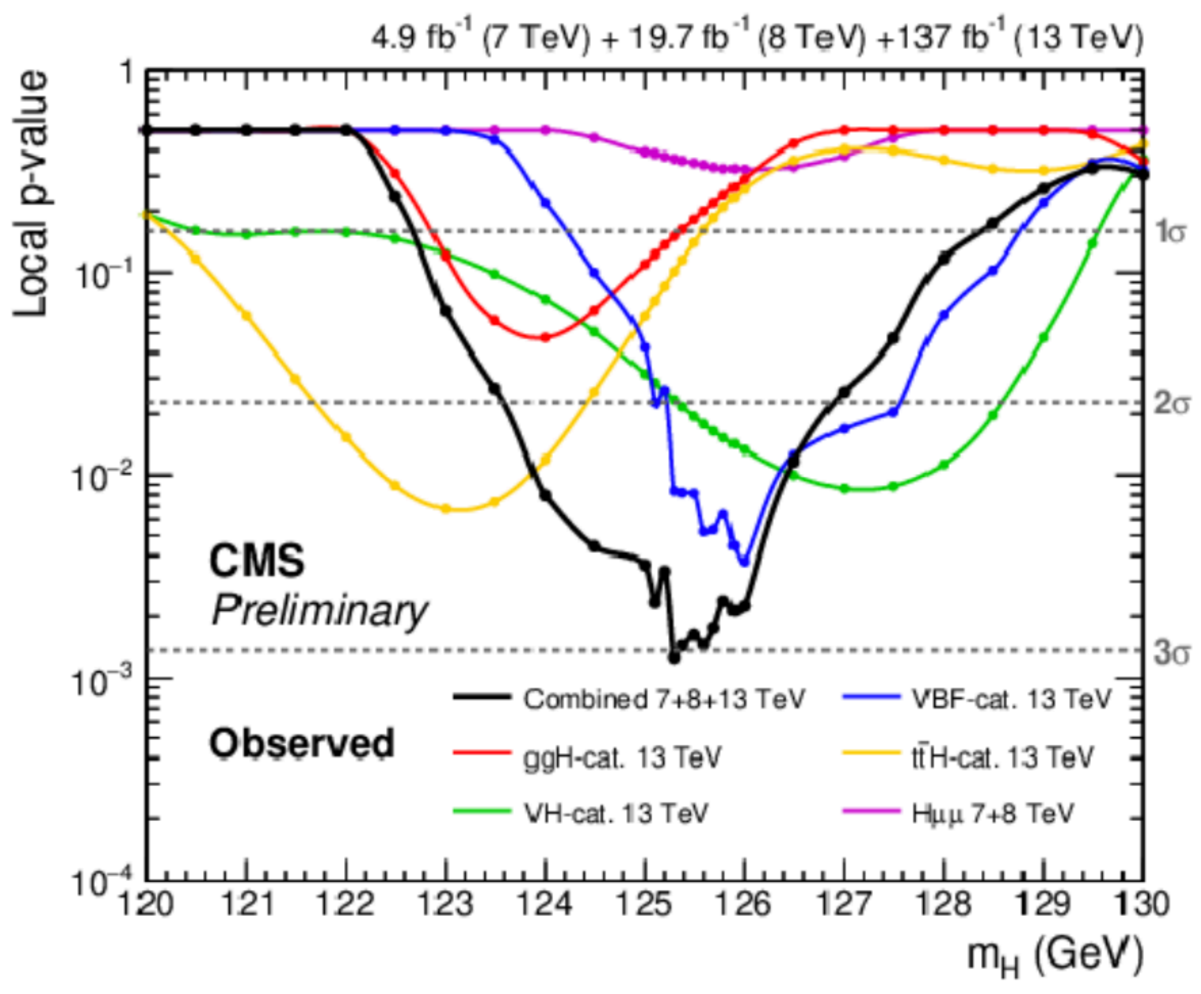
BSM: H -> mu mu observation at CMS: Dr. Arun Nayak's talk

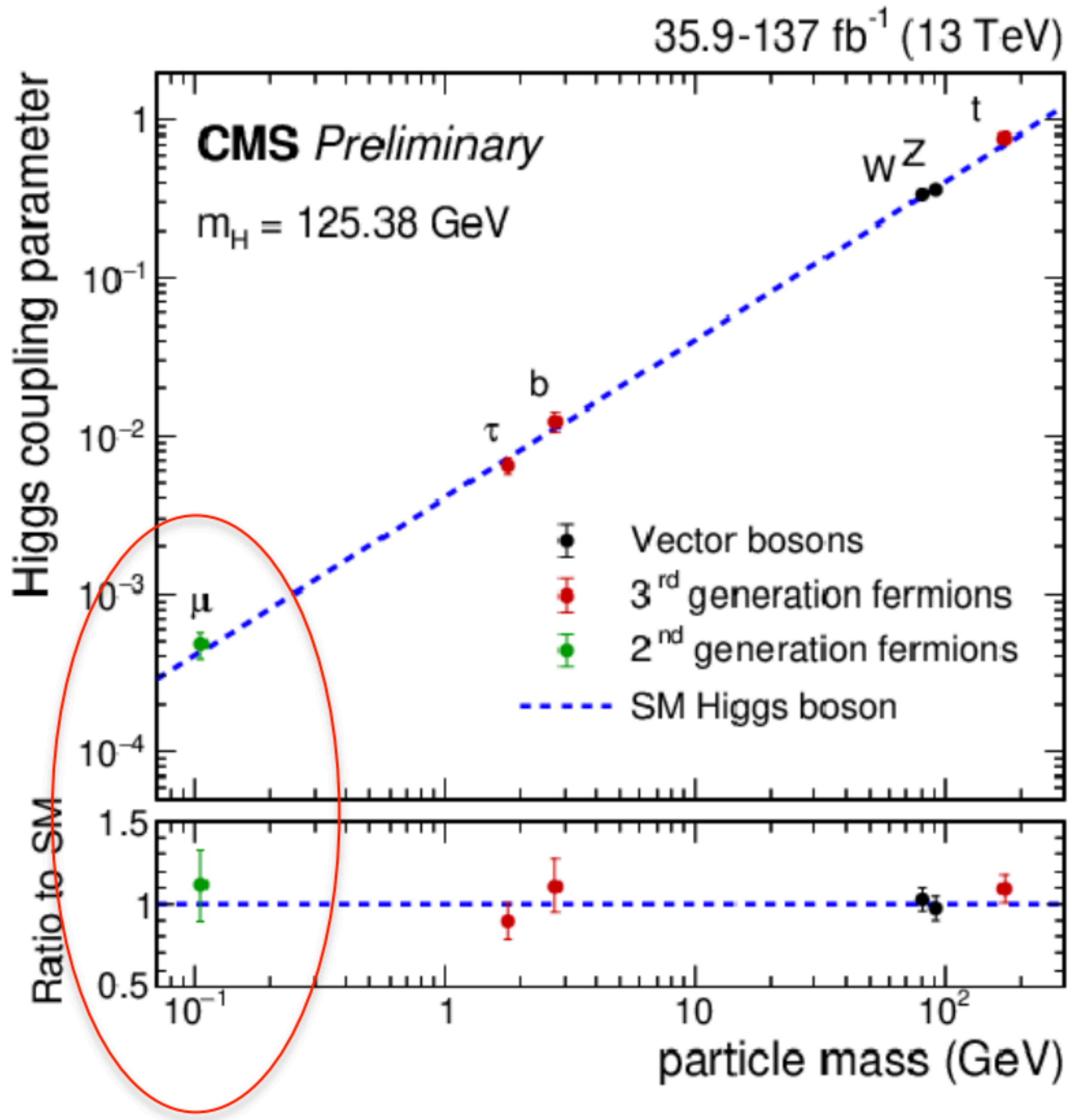
H→μμ results

CMS-PAS-HIG-19-006

Combined with Run-1 measurement (Phys. Lett. B 744 (2015) 184)

The observed excess in data with respect to SM background corresponds to a significance of 3σ

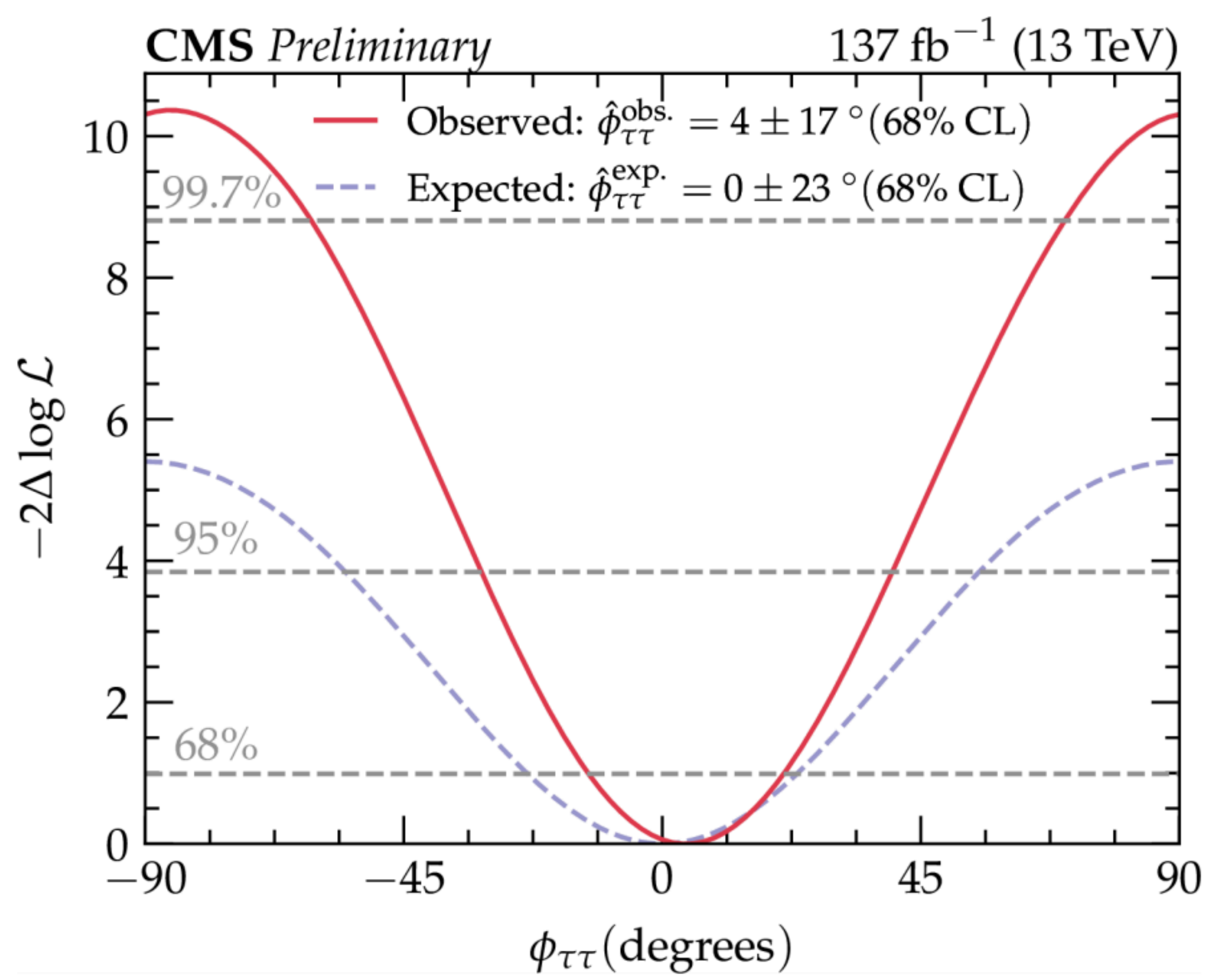


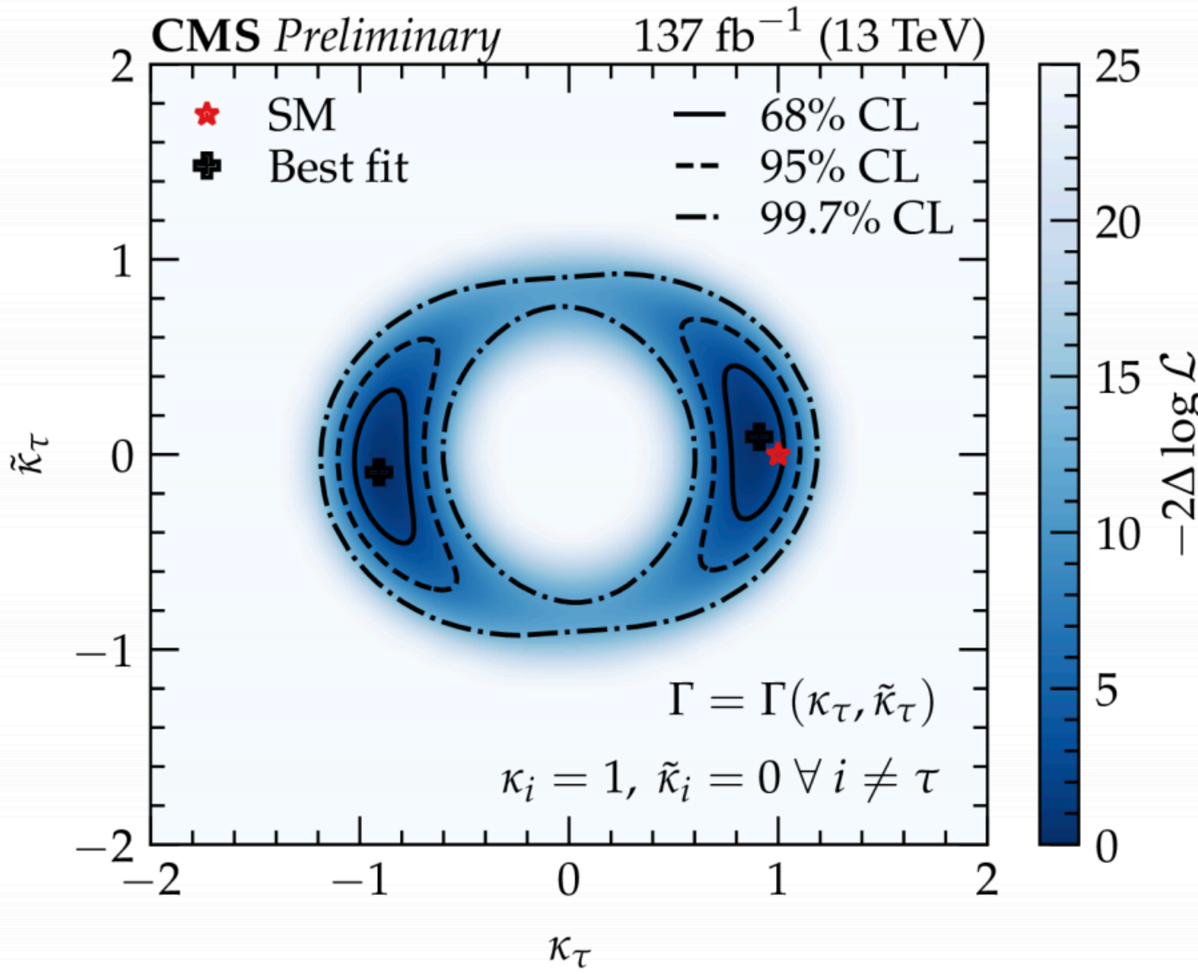


First evidence of H→μμ decay at LHC

CP in H→ττ : Results

- Simultaneous maximum likelihood fit to extract CP mixing parameter
- Measured value of $\phi_{\tau\tau} = 4 \pm 17^{o}$ (mostly dominated by statistical uncertainty)
- Pure CP odd exclusion: 3.2σ significance
- Interpretation in κ_τ framework, assuming all other couplings as SM.





Clearly favours a CP even scenario

- First evidence of H→μμ decay
- CP measurements in H→ττ
- ttH and tH measurements in multileptons
- STXS measurements in H→γγ and anomalous couplings in H→4ℓ

BSM: Jet substructure

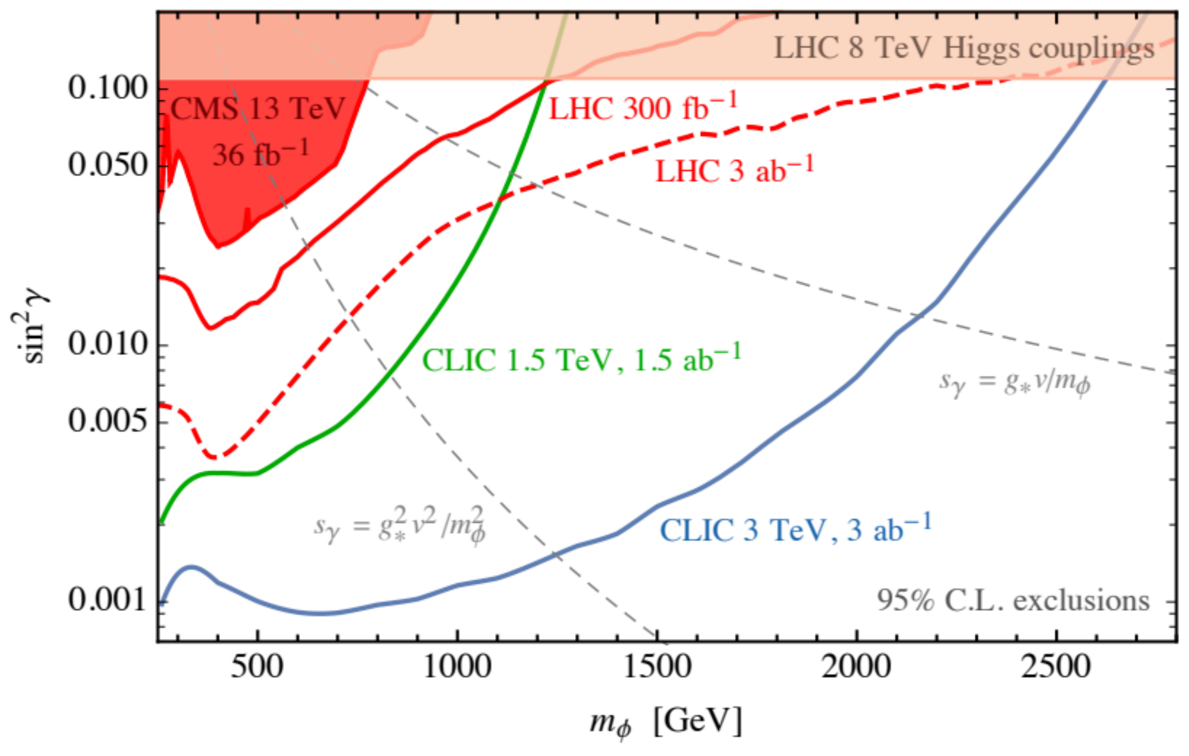
- Dr. Amit talked about the classification of Jets using Jet Morphology and Deep Learning
- Such improvements in Jet analysis are reported.

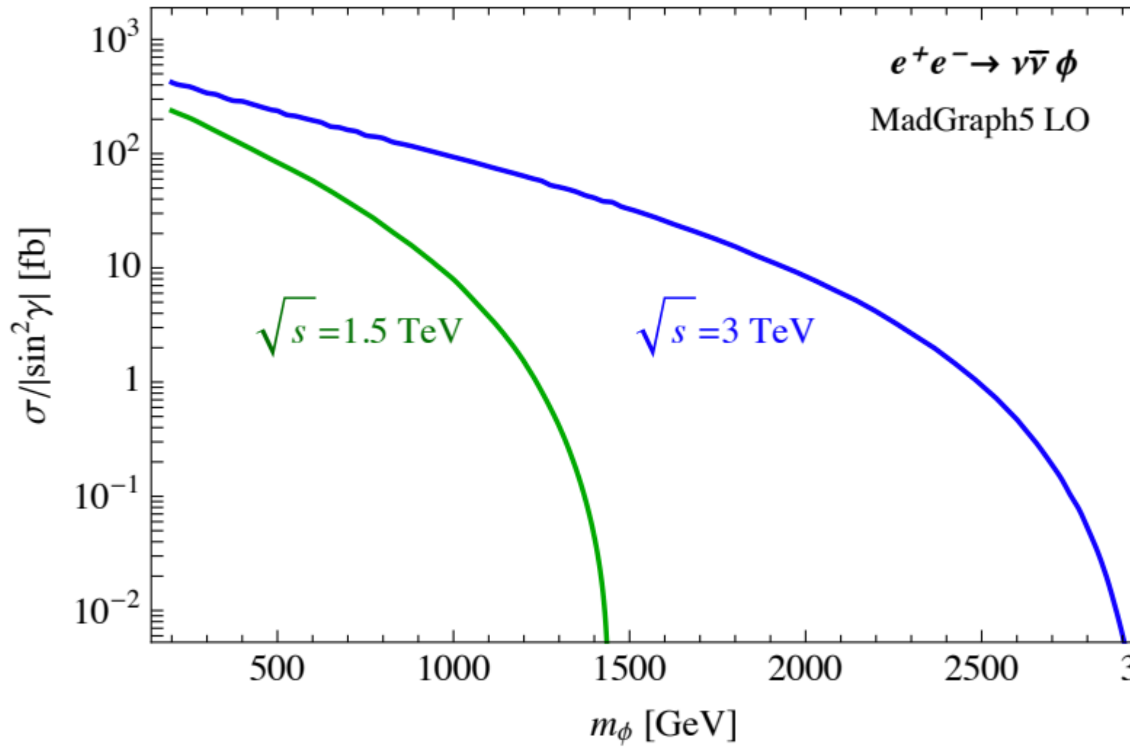
- Dr. Akanksha Bhardwaj showed the usage of jet substructure techniques in graviton LSP scenario
- Dr. Tausik talked about di-jet searches using jet substructure techniques

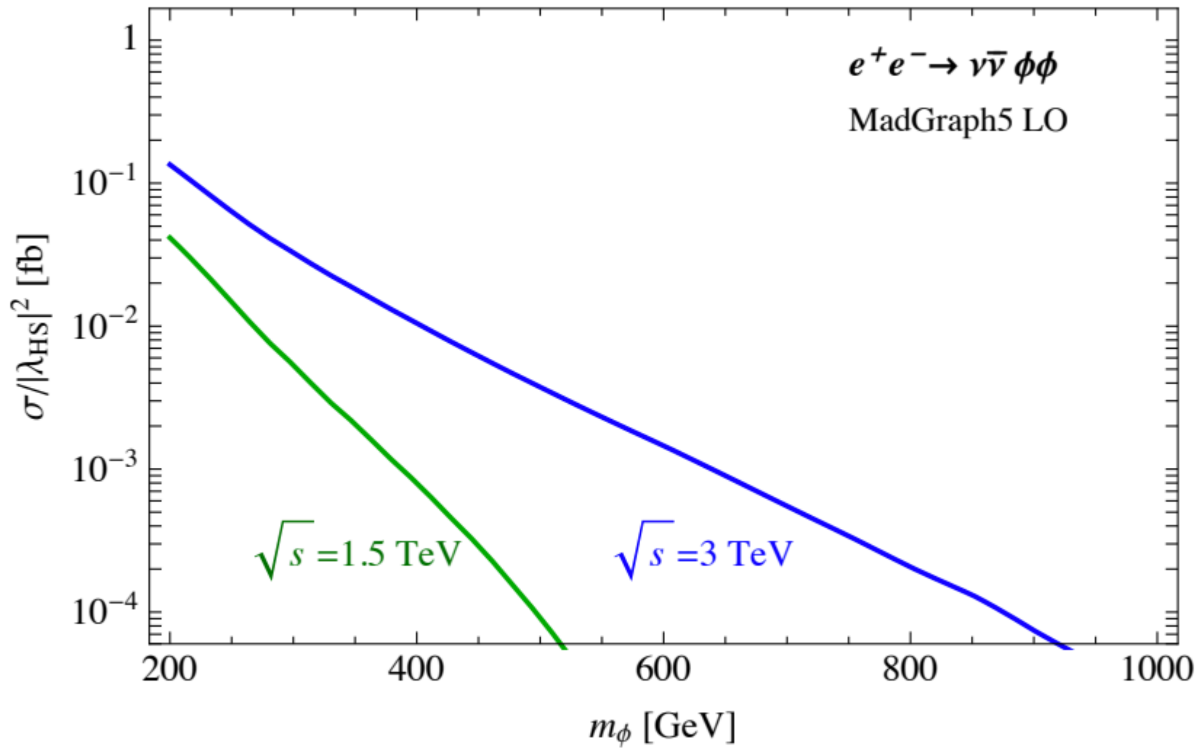
- In BSM1 and BSM2 parallel sessions many other techniques like angular distribution, deep learning in VVF and others were discussed in the search of BSM final states.

Muon Collider: Dr. Antonio Costantini's talk

BSM @ High-Energy Lepton Collider



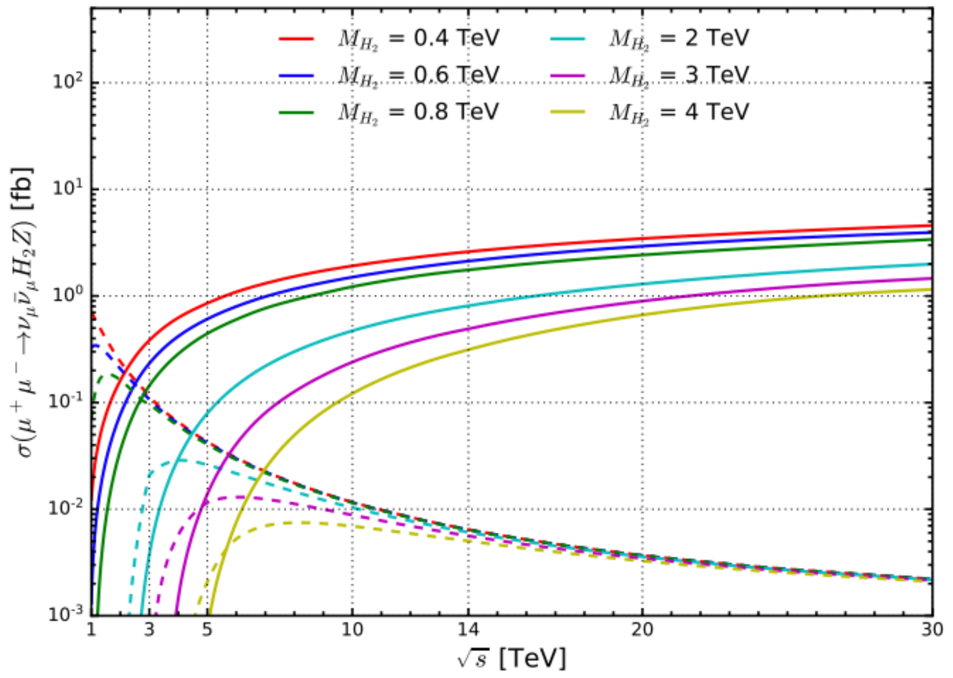


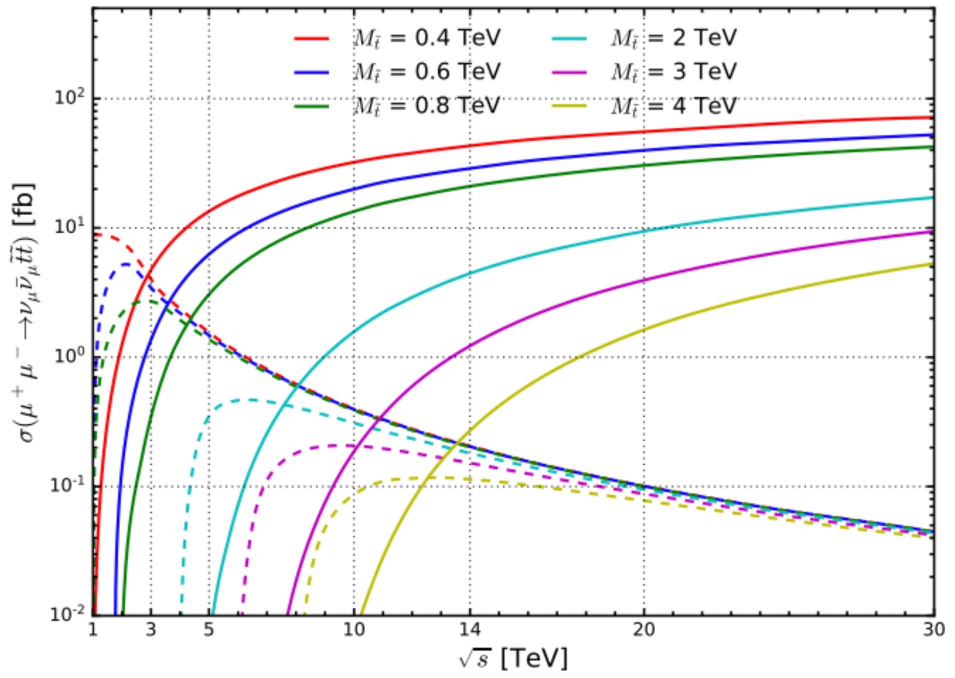


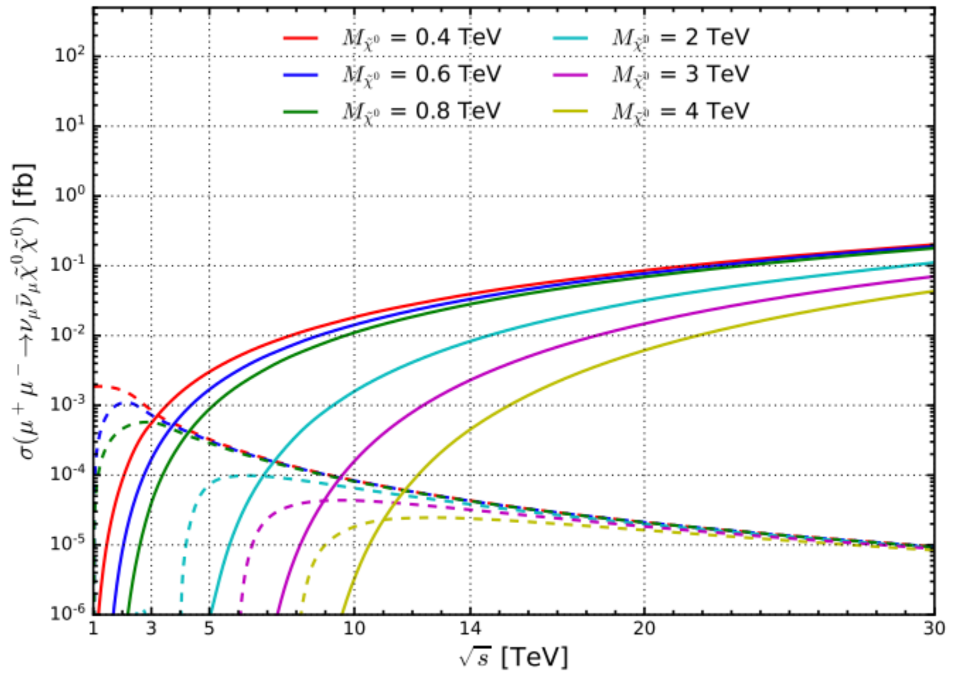
D.Buttazzo, D.Redigolo, F.Sala and A.Tesi
JHEP **11** (2018), 144

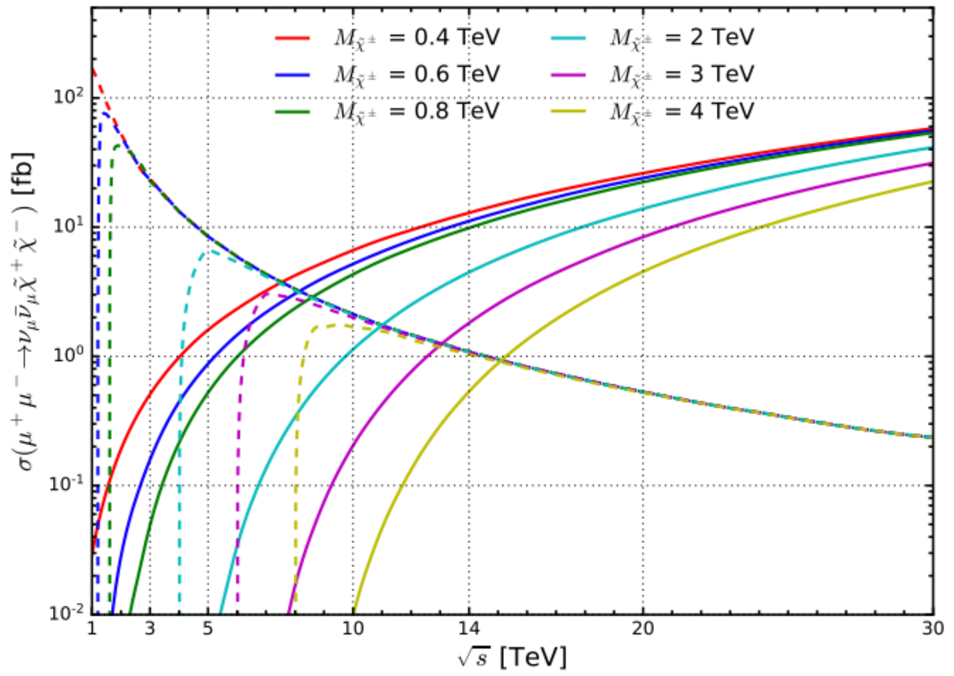
Only Low-Energy Results
($\sqrt{s} \leq 3$ TeV)

VBF for various BSM Models









$$\frac{\sigma^{VBF}}{\sigma^{s-ch.}} \sim \frac{s}{m_X^2} \log^2 \frac{s}{m_V^2} \log \frac{s}{m_X^2}$$

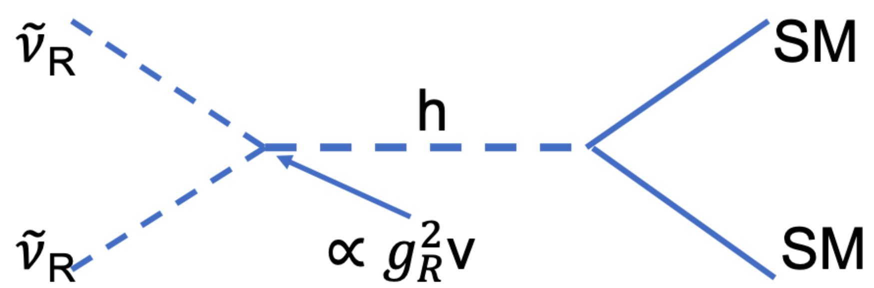
Reach of muon collider has been calculated for various SM and BSM processes

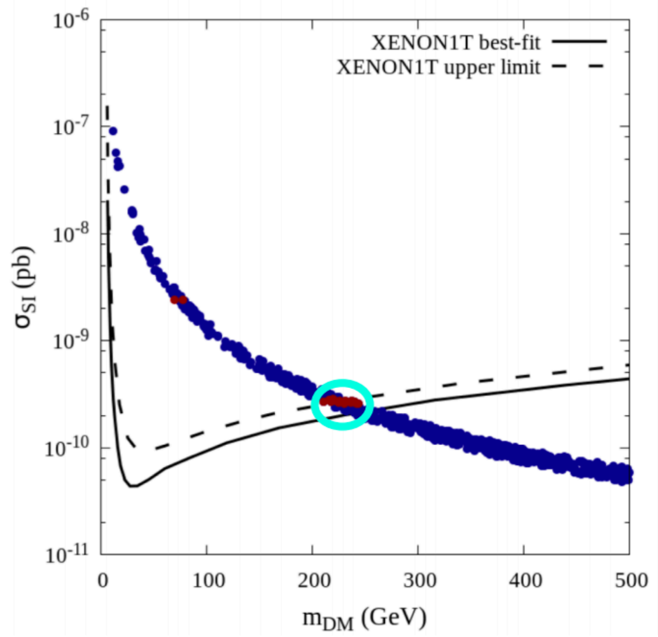
L-R Model: Prof. Katri Huitu's talk

Dark matter in LRSUSY

LRSUSY specific options: sneutrino and higgsino

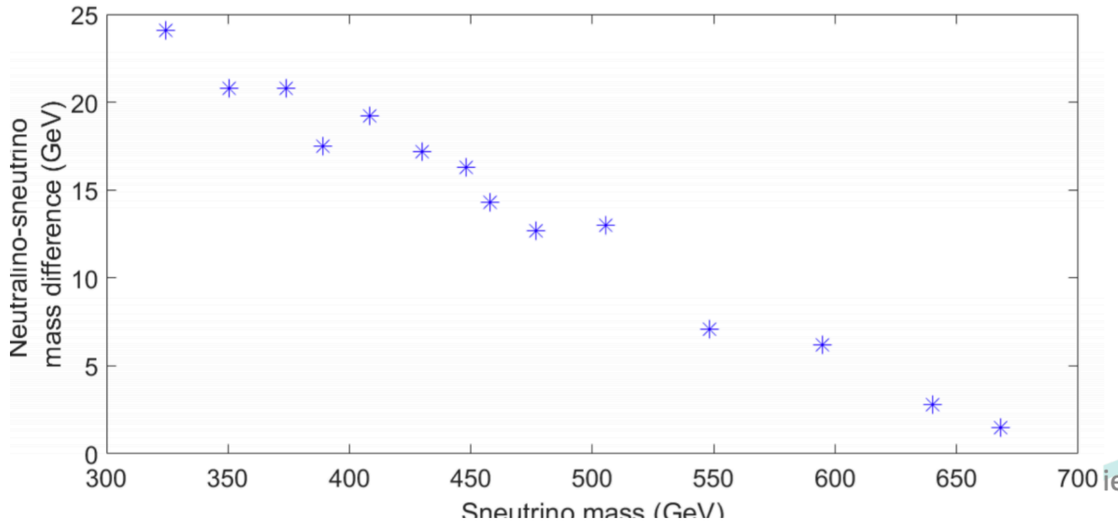
1) $\tilde{\nu}_R$ can produce DM





Right-sneutrino mass is the only free parameter
→ relic density determines $m_{\tilde{\nu}_R} \approx 250 - 300$ GeV

Frank, Fuks, KH, Rai, Waltari (2017);
Chatterjee, Frank, Fuks, KH, Mondal, Rai, Waltari (2019)



$\tilde{\nu}_R$ LSP with coannihilations with neutralinos
→ $m_{\tilde{\nu}_R} \approx 700$ GeV possible

ies2020 / Katri Huitu 16

2) SUSY partners of gauge bosons or Higgses can be the dark matter

Chatterjee, Frank, Fuks, KH, Mondal, Rai, Waltari (2019)

Bidoublet higgsinos form a nearly degenerate set of four neutralinos and two charginos
→ Coannihilations cannot be avoided, when the lightest higgsino is the LSP

The Planck-value for relic density is achieved with 750 GeV LSP higgsino (could be slightly decreased with further coannihilations, with e.g. sneutrino)

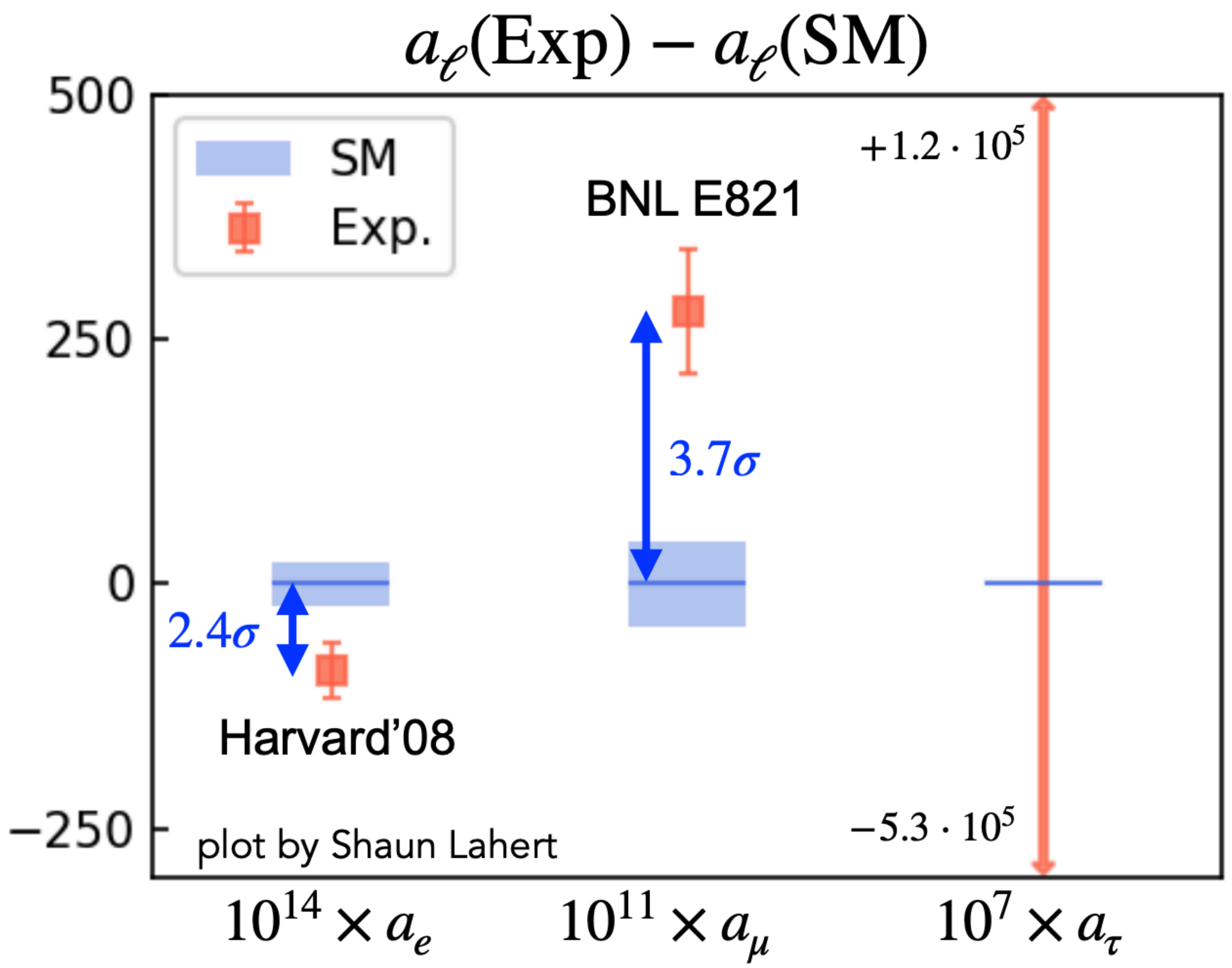
Note that in this case the spectrum is rather heavy and compressed
→ difficult to detect

Dominantly bino-like neutralino with mass $m_h/2$.
"Bino" refers to B-L –gaugino.

- L-R Model with SUSY and different phenomenological aspects and bounds are shown.

g-2 from Lattice and phenomenology:

Lepton moments summary



Sensitivity to heavy new physics:

$$a_\ell^{\rm NP} \sim \frac{m_\ell^2}{\Lambda^2}$$

$$(m_\mu/m_e)^2 \sim 4 \times 10^4$$

Prof. Aida's talk

Ongoing experimental programs for improved measurements of α

- ☆ Lepton moments are interesting
- ☆ To make the most out of the Fermilab and J-PARC experiments, theoretical SM predictions must be improved to stay commensurate with experimental uncertainty.
  - ➠ Muon g-2 Theory Initiative accelerated progress
    ongoing cross checks/tests and comparisons of different methods
- ☆ plan to publish updated SM predictions ahead of each new major experimental update of a_μ
- ☆ improvements to SM evaluations from
  - better experimental inputs for data-driven HVP
  - more experimental measurements for disp HLbL evaluations
  - improved lattice QCD+QED calculations for HVP and HLbL

The muon may provide a window to new discoveries.

- Dr. Ipsita et al: DM and muon (g-2) constraints put upper limit on EW SUSY scale while LHC limits restrict the mass ranges from below with ample room for sub-TeV SUSY
- Dr. Sudip et al: Large Neutrino Magnetic Moment with small neutrino Mass is possibility
- Dr. Dibyakrupa's talk: Muon g-2 at BESIII

XENON1T: Prof. Rohini Godbole's talk

A light LSP in pMSSM is still possible: light $\tilde{\chi}_1^0$. Only h_{125} funnel region is allowed.

pMSSM extended with a $\tilde{\nu}_R$: a light $\tilde{\nu}_R$ still possible. Characteristic signals.

We can see that this WIMP paradigm for a light LSP in pMSSM and NMSSM can be tested at the HL/HE LHC, ILC/CEPC and DD experiments.

XENON1T: Prof. Jiji Fan's talk

Clearly we need more experimental efforts to confirm or rule out the Xenon1T excess.

Independent of Xenon1T excess, we have got some conservative generic upper bounds on galactic flux of relativistic weakly-coupled bosons. They could be comparable (axion case) or dominate over (dark photon case) the solar flux.

Questions for experimentalists:

Any other experimental information (e.g., in terms of S1:scintillation/S2:ionization) to distinguish between relativistic and non-relativistic particles?

Any way to collect directional information to tell the origin of the incoming particles?

XENON1T/Dark Matter:

- Rhitaja et al: Contamination from backgrounds can be misunderstood as signal for XENON1T observation.
- So model builder should take the excess with pinch of salt.

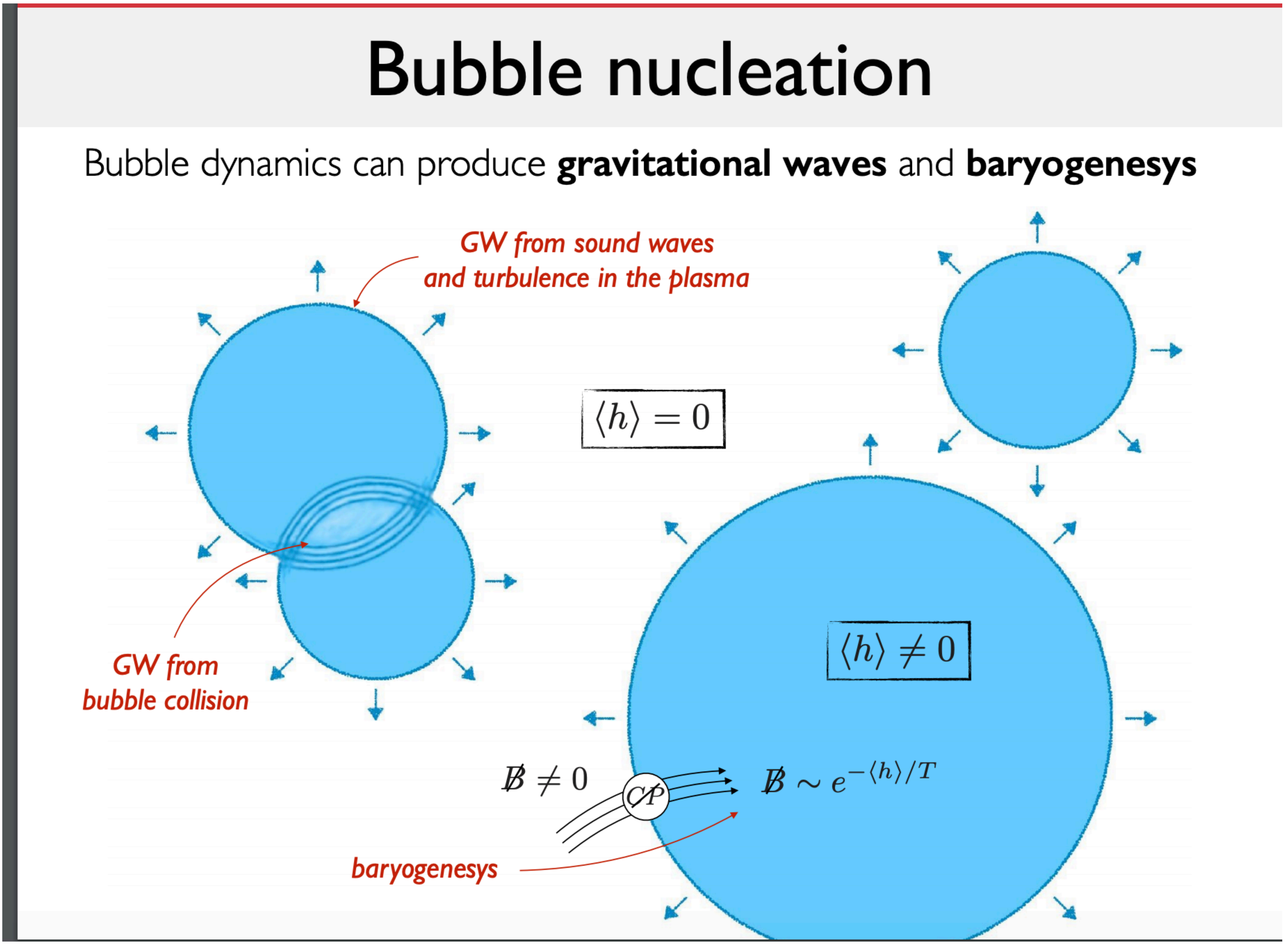
- Divya et al: Axion like particles can be produced at early universe which can affect the energy density contribution for BSM scenarios
- Bounds also obtained for ALPs-electron and ALPs-muon interactions.

- Julia et al: An interesting scenario of light dark matter explaining XENON1T
- There are also some interesting models which claimed to have explained XENON1T excess with heavy neutrinos

Gravitational waves: Prof. Eibun Senaha's talk

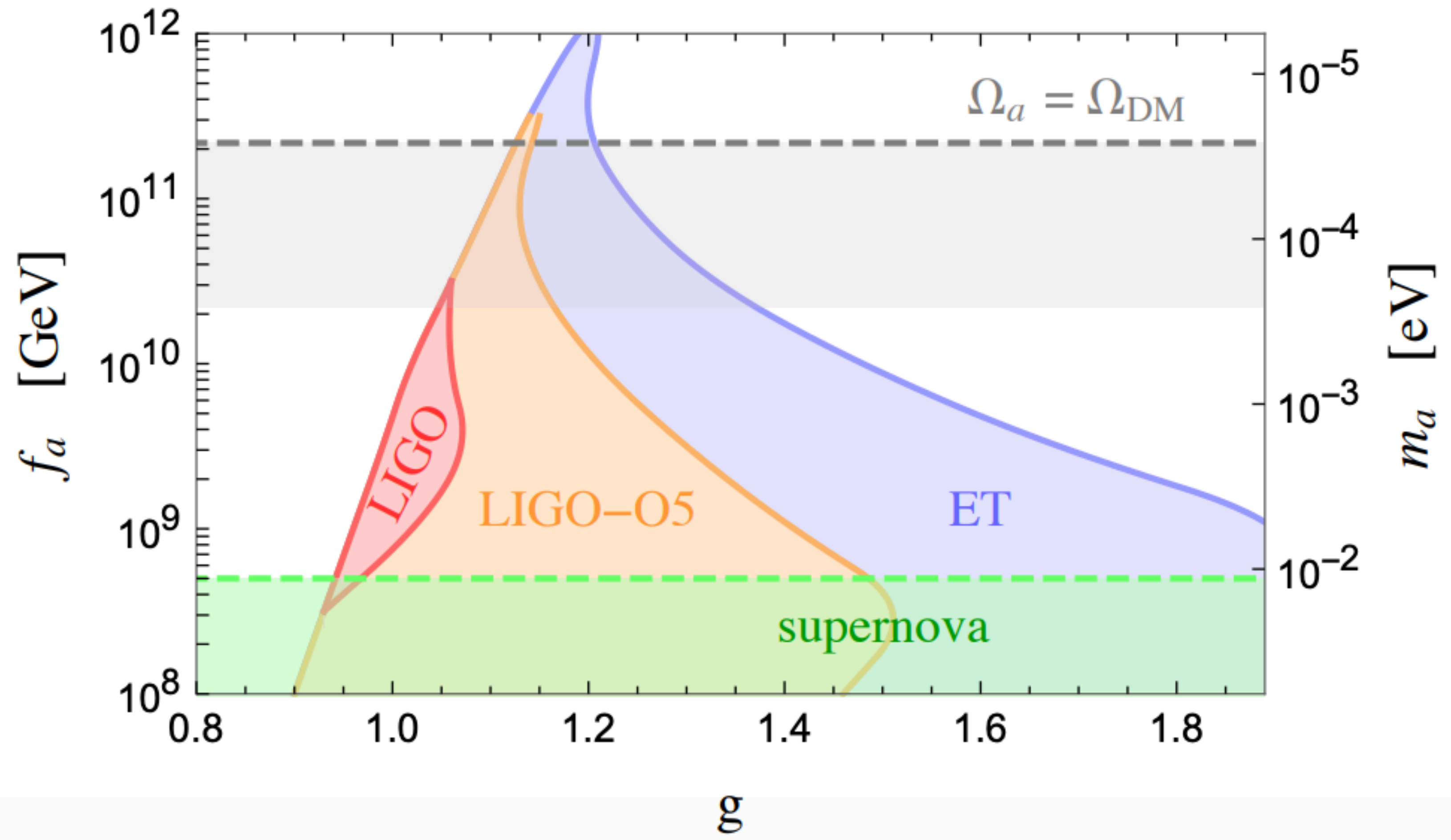
- Effective potential at finite temperature is gauge dependent
- Such gauge dependence can eventually give rise to gravitational waves.
- Gauge invariant method with constant thermal resummation is necessary
- Such gauge fixing parameter dependence on GW from 1st order PT has been calculated.

Gravitational waves from bubble collisions: Dr. Luigi Delle Rose's talk



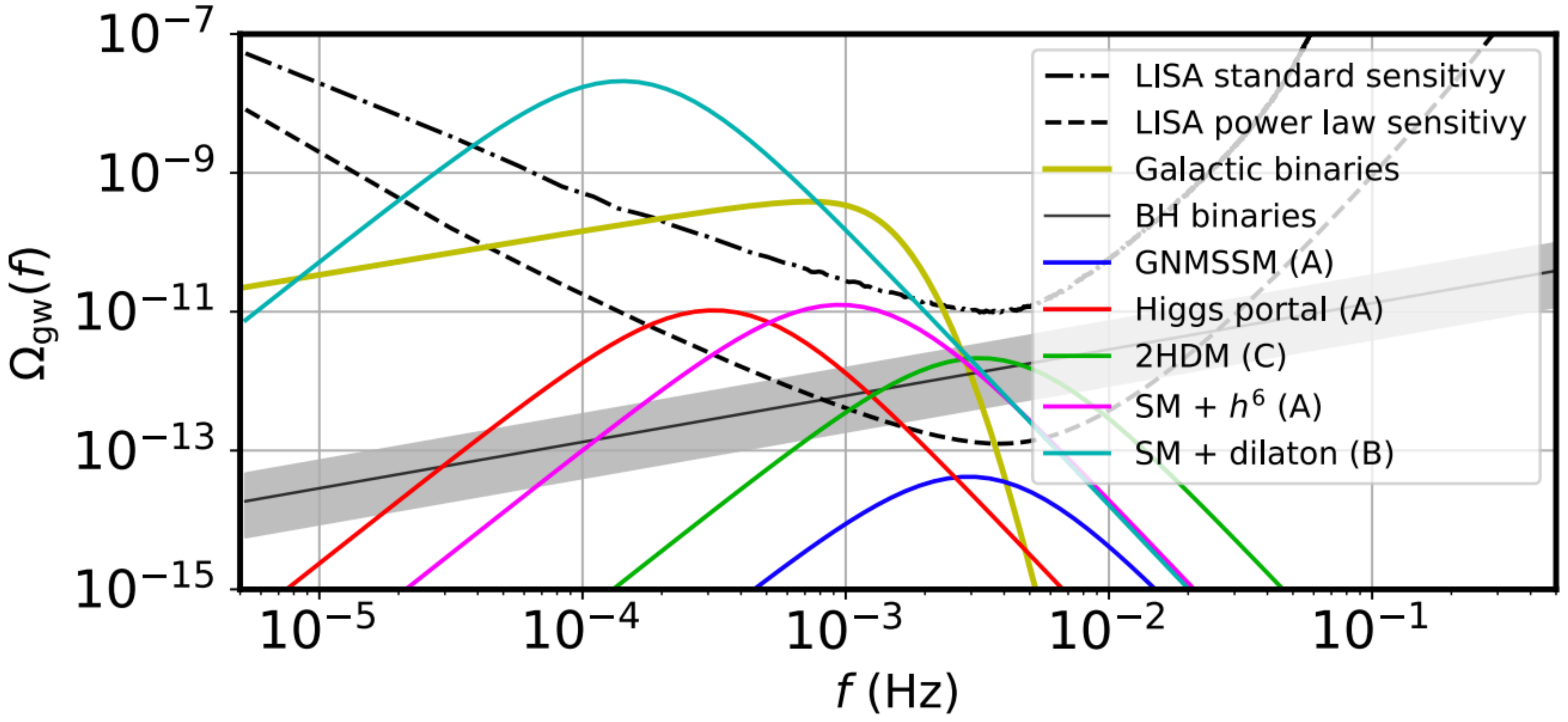
Peccei-Quinn phase transition:

- minimal scenarios predict a second-order phase transition
- possible first order phase transitions with large supercooling in (axion, scalar) and (axion, dilaton) systems
- detectable gravitational waves at ground-based interferometers

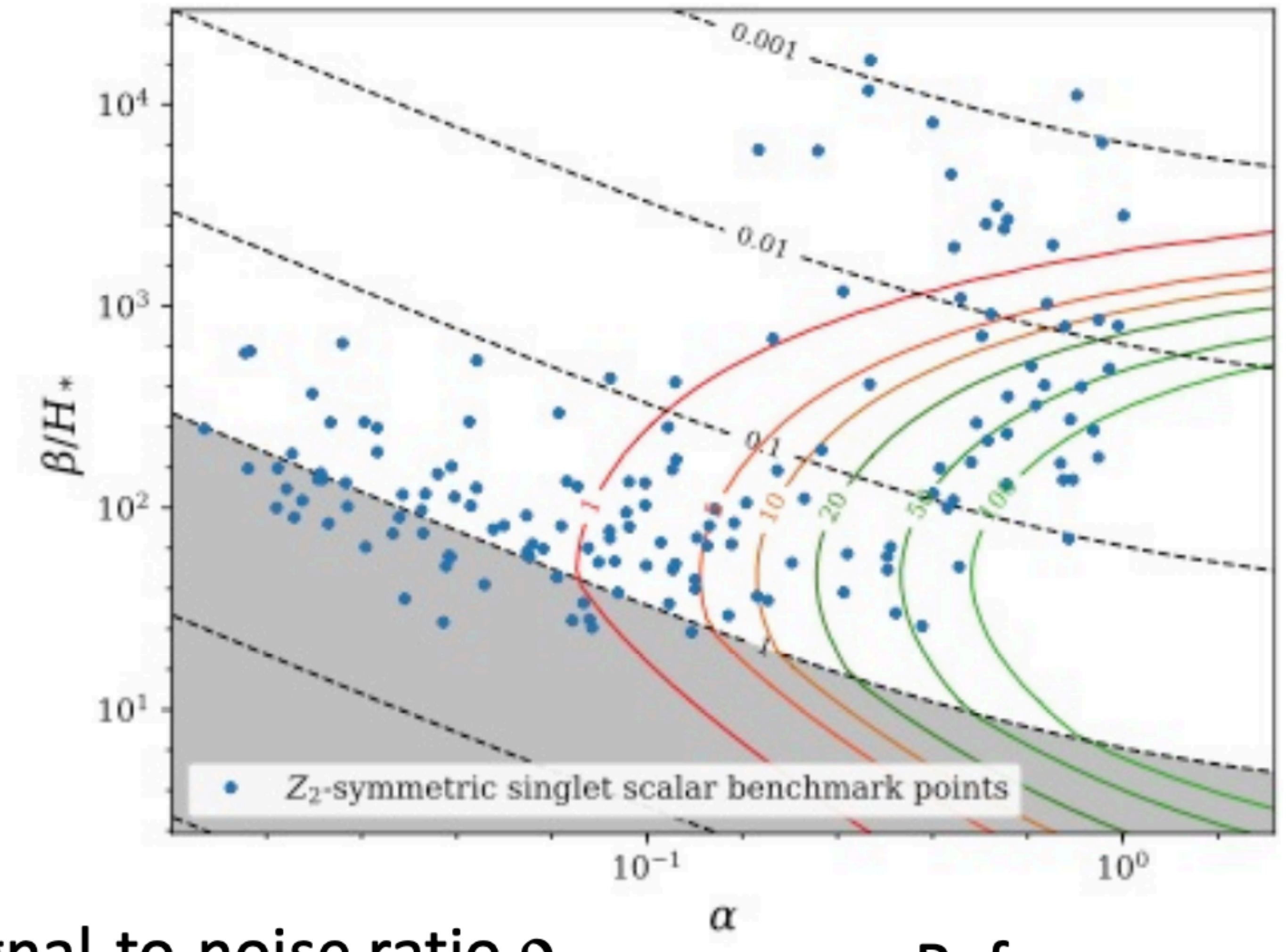


Gravitational wave EW PT: Prof. Mark Hindmarsh's talk

Benchmark models and foregrounds



Estimated LISA prospects



LISA Cosmology Working Group 2019

- White Dwarf binaries
  - Anisotropic, annual variation
- LIGO BHB precursors
  - Below noise, will be well-determined

- Benchmark particle physics models
  - Higgs portal = SM Higgs + scalar
  - 2HDM = 2 Higgs doublet model
  - GNMSSM = general next-to-minimal supersymmetric standard model

- Estimate signal-to-noise ratio ρ

$$\rho^2 = T_{\rm obs} \int df \left(\frac{\Omega_{\rm gw}(f)}{\Omega_{\rm noise}(f)} \right)^2$$

  - Observation time 4 years
  - No foregrounds

- Reference wall speed:
  - $V_w = 0.95$
- NB $\alpha > 0.1$ highly uncertain
  Cutting, Hindmarsh, Weir
  - But important region for LISA
    Ellis, Lewicki, No (2018)

- **Ajit Srivastava et al:** Pulsar measurements extremely accurate, can detect tiny changes in pulsar structure, either due to internal dynamics, or due to GWs
- Pulsars very far away can act as remotely stationed Weber detectors of gravitational waves.
- Pulsers could be sensitive to the mergers of light primordial black holes

Flavour Physics: Dr. Sunanda Patra's talk

Observables		Measurement
$\mathcal{R}_D$ [6]	4-obs. data-set	0.340(27)(13)
$\mathcal{R}_{D^*}$ [6]	4-obs. data-set	0.295(11)(8)
$P_\tau(D^*)$ [40]	4-obs. data-set	$-0.38(51)(^{+0.21}_{-0.16})$
$F_L^{D^*}$ [35]	4-obs. data-set; *New Lattice: arXiv:2007.06956*	0.60(8)(4)
$\mathcal{R}_{J/\psi}$ [12]	SM: 0.2601 ±0.0036	0.71(17)(18)

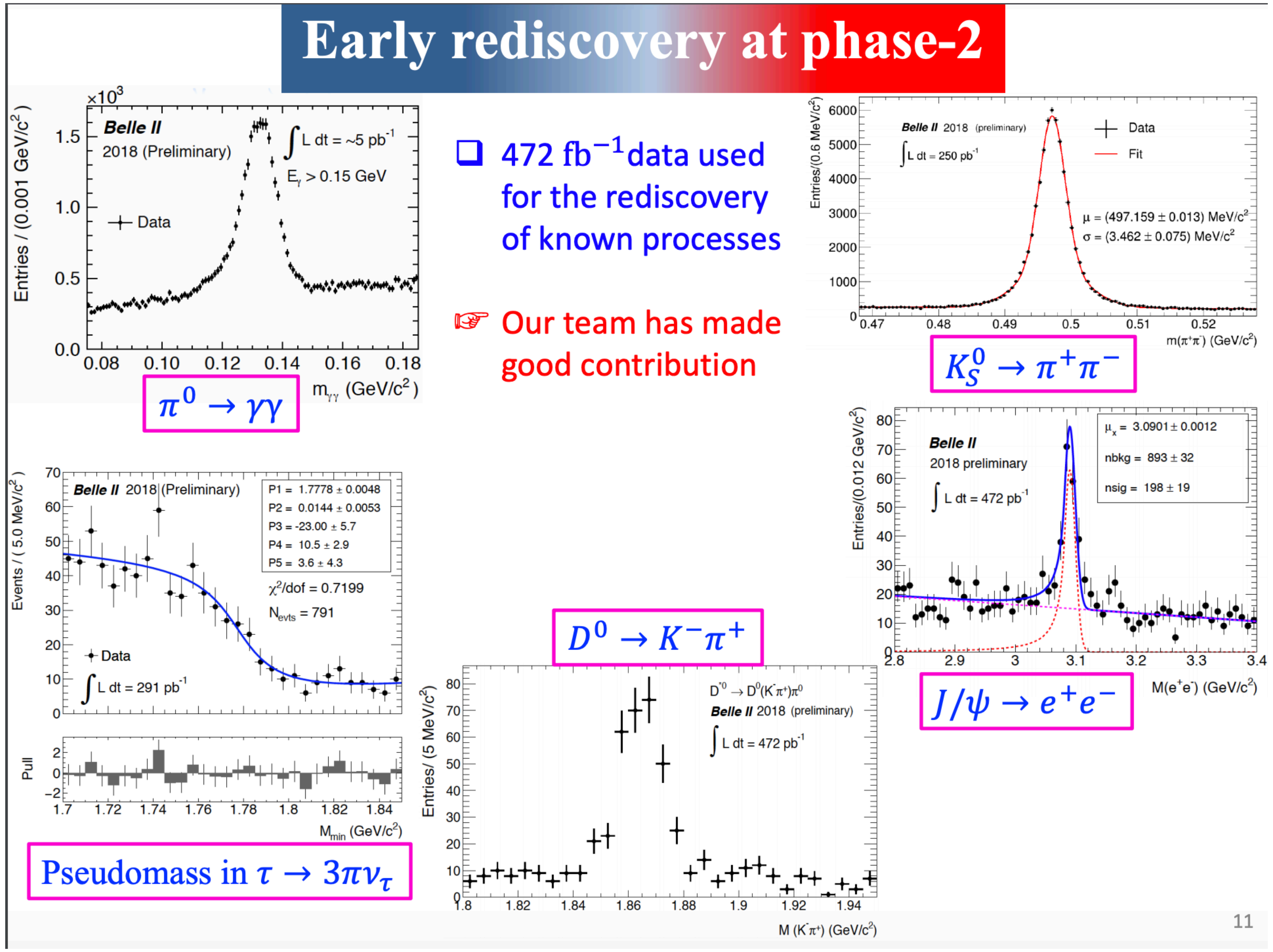
- b-> c tau nu: Compartive studies among various new physics contributions have been studied and preferred scenarios are predicted

Classification Results

Data-Set	Models (SNN-Aggregate)	Parameters	Aggregate Prob. (%)	D_{KL} Serial	SNN-Central Serial	$\Delta\mathrm{AIC}_c$ Serial	$w^{\Delta\mathrm{AIC}_c}$ (%)
4-Obs.	→ **12**	$Re(C_{V_2}),\ Re(C_T)$	**38.48**	**2**	**1**	18	0.07
	→ **15**	$Re(C_{S_2}),\ Re(C_T)$	**26.30**	**3**	**5**	**6**	**0.32**
	13	$Re(C_{S_1}),\ Re(C_{S_2})$	11.53	9	7	9	0.29
	→ **14**	$Re(C_{S_1}),\ Re(C_T)$	8.04	**1**	15	17	0.11
	8	$Re(C_{V_1}),\ Re(C_{S_2})$	5.01	18	**3**	**7**	**0.32**
	→ **10**	$Re(C_{V_2}),\ Re(C_{S_1})$	2.80	**6**	**2**	11	0.16
	6	$Re(C_{V_1}),\ Re(C_{V_2})$	2.19	14	9	12	0.12
	→ **11**	$Re(C_{V_2}),\ Re(C_{S_2})$	1.74	**4**	**4**	**8**	**0.32**
	19	C_{S_2}	1.18	17	6	10	0.29
5-Obs.	→ **12**	$Re(C_{V_2}),\ Re(C_T)$	**42.62**	**1**	**2**	17	0.69
	13	$Re(C_{S_1}),\ Re(C_{S_2})$	15.71	19	**6**	**7**	**3.19**
	→ **15**	$Re(C_{S_2}),\ Re(C_T)$	8.56	**4**	10	**4**	**3.37**
	6	$Re(C_{V_1}),\ Re(C_{V_2})$	6.7	16	12	11	1.33
	8	$Re(C_{V_1}),\ Re(C_{S_2})$	6.54	18	**4**	**5**	**3.31**
	→ **14**	$Re(C_{S_1}),\ Re(C_T)$	6.09	**2**	**7**	15	1.14
	7	$Re(C_{V_1}),\ Re(C_{S_1})$	4.63	8	11	12	1.29
	→ **11**	$Re(C_{V_2}),\ Re(C_{S_2})$	3.7	**3**	**3**	**6**	**3.3**
	→ **10**	$Re(C_{V_2}),\ Re(C_{S_1})$	2.66	**6**	**1**	9	1.67
	17	C_{V_2}	1.45	15	9	10	1.33

- b-> s ll: 511 and 1022 dimensional parameters space for real and complex 9 Cw's have been optimised using OpTex. See A. Biswas's talk

Flavour Physics: Prof. Gagan Mohanty's talk



- Belle II also has found B mesons
- Separated charged kaons and pions
- J/psi -> e+ e-, J/psi -> mu+ mu- are distinguished
- D0 life time has been measured
- Studies charmed B decays are performed

- Interesting Lattice results in B- and K- sectors. See Dr. J T Tsang and Dr. C Kelly's talks

- Other theoretical and experimental developments are discussed in the parallel sessions

Flavour physics:

Charged B decay anomalies with light RHN

- Charged current *B*-anomalies can be addressed with BSM operators with light RHN

- $F_L^{D^*}$ data is not easily achievable in NP scenarios

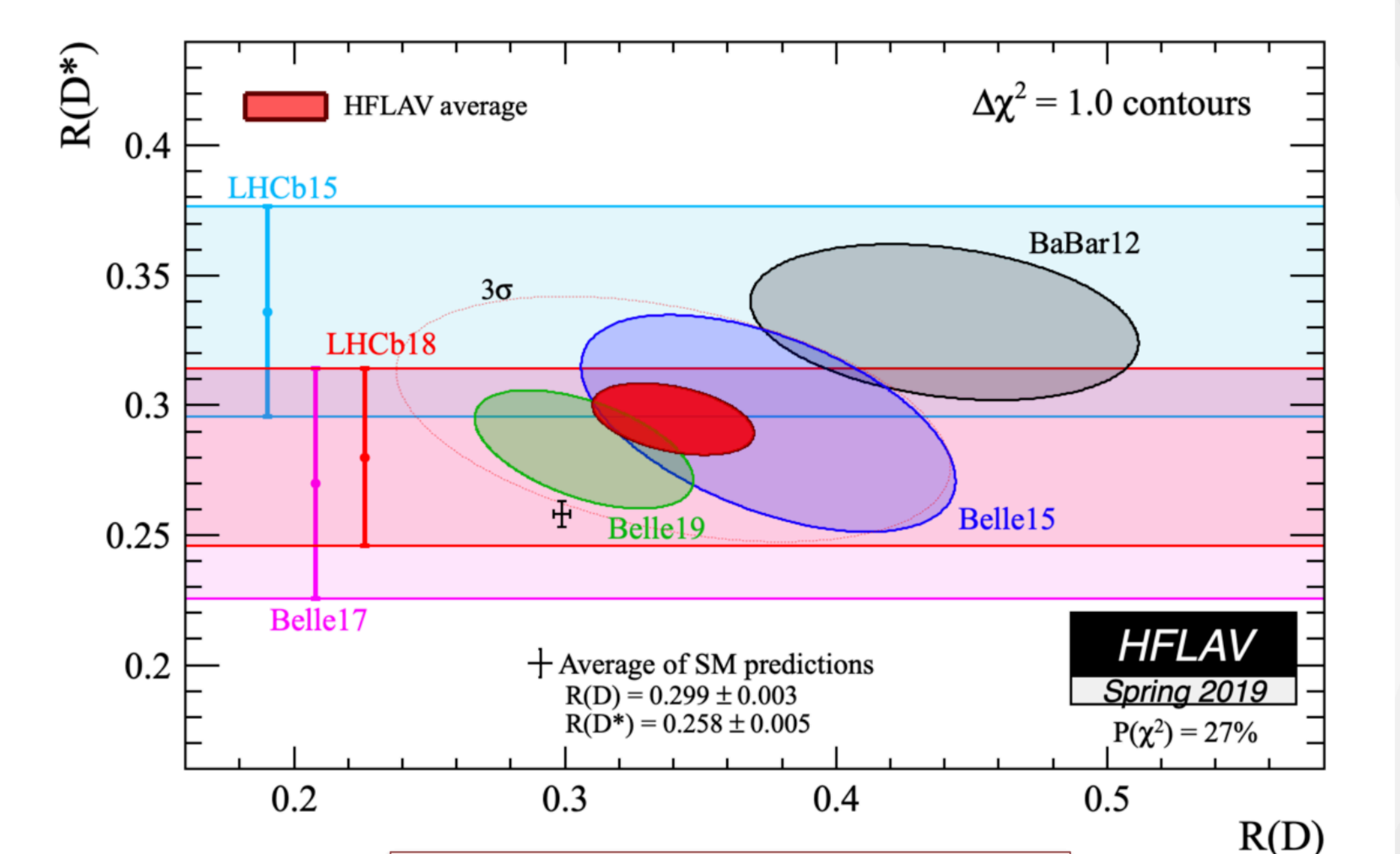
- 4-body angular distribution provides plethora of observables — important to identify the underlying NP dynamics

- Higher spin states provide complimentary information — D^* & D_2^* are easily separable from distributions

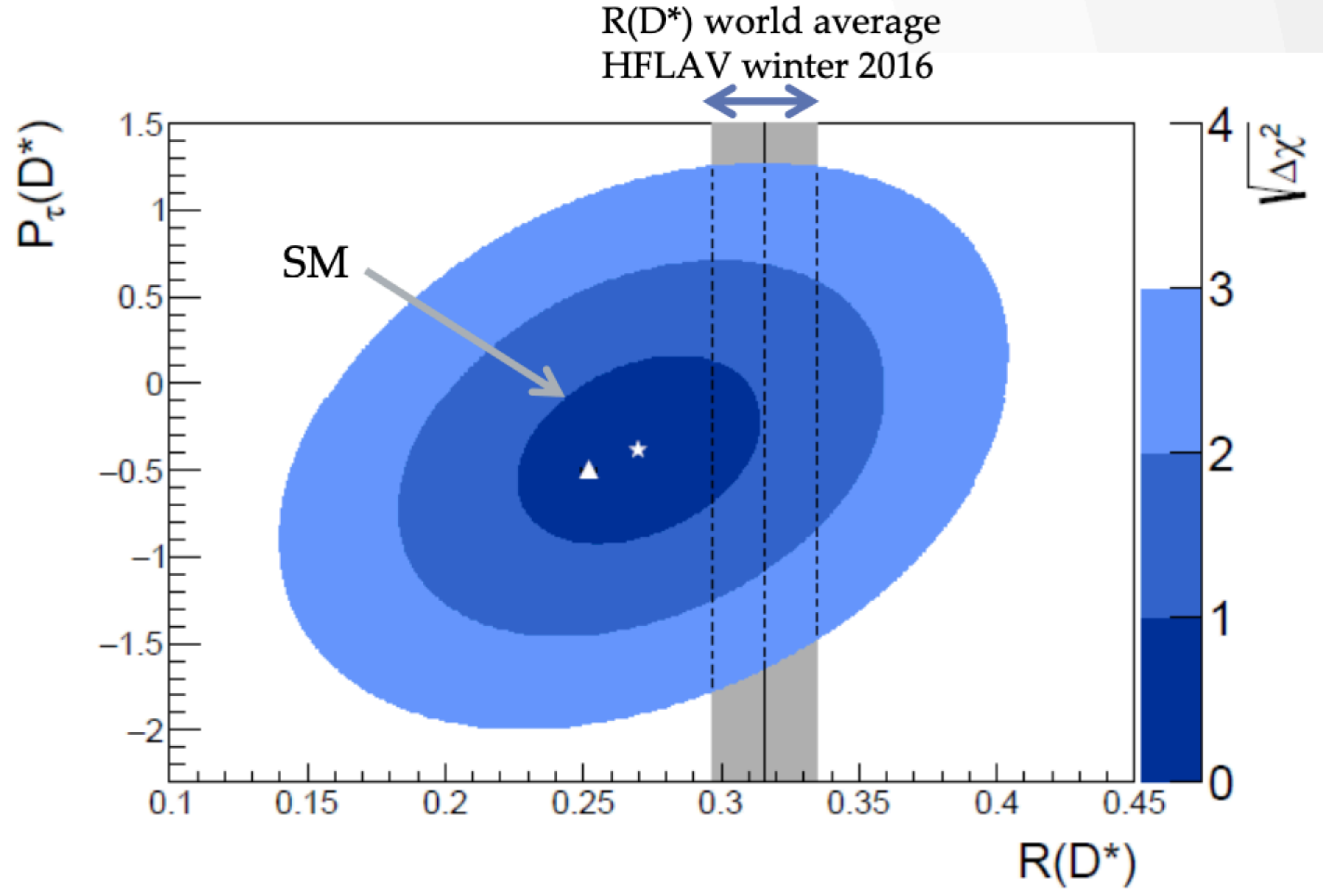
- Caution for modes with τ due to neutrinos in final state
  — experimentally challenging
  — further decay of τ modifies the angular distribution

See Dr. Rusa Mandal's talk

Latest R(D)-R(D*) vs SM



Deviation from SM is 3.1 σ



$$R(D^*) = 0.270 \pm 0.035(\mathrm{stat})^{+0.028}_{-0.025}(\mathrm{syst}),$$
$$P_\tau(D^*) = -0.38 \pm 0.51(\mathrm{stat})^{+0.21}_{-0.16}(\mathrm{syst}),$$

(R(D*) included in the HFLAV avg)

Dr. Koji Hara's talk

Flavour Physics: Dr. Martino Borasto's talk

- Latest BR predictions have precision at 4-5% level:

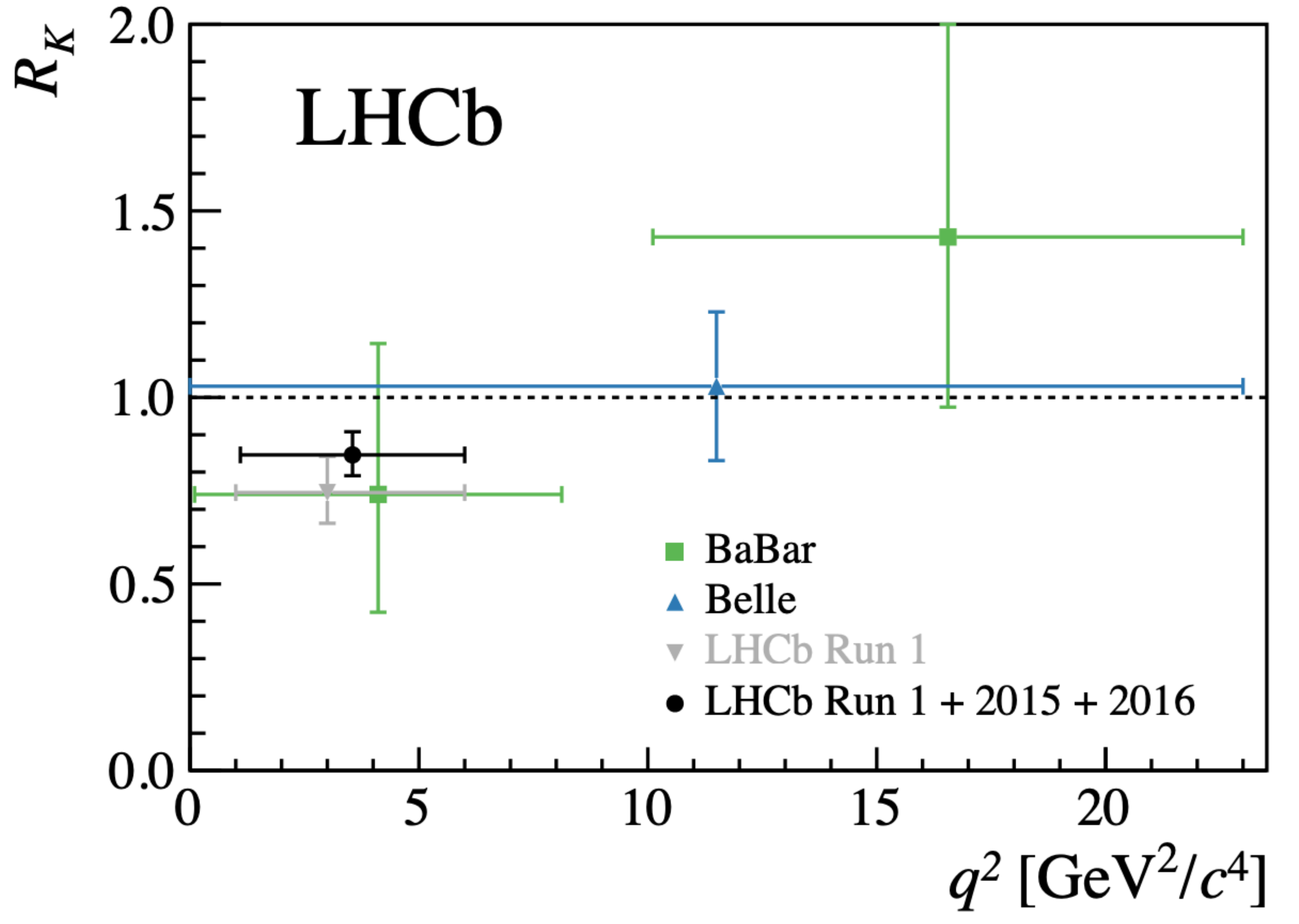
$$\mathcal{B}\left(B_s^0 \to \mu^+\mu^-\right) = \left(3.66 \pm 0.14\right) \times 10^{-9}$$
$$\mathcal{B}\left(B^0 \to \mu^+\mu^-\right) = \left(1.03 \pm 0.05\right) \times 10^{-10}$$

Beneke et al JHEP 10 (2019) 232

- ATLAS+CMS+LHCb combination:

$$\mathcal{B}\left(B_s^0 \to \mu^+\mu^-\right) = \left(2.69^{+0.37}_{-0.35}\right) \times 10^{-9}$$
$$\mathcal{B}\left(B^0 \to \mu^+\mu^-\right) < 1.9 \times 10^{-10} \text{ at } 95\% \text{ CL}$$

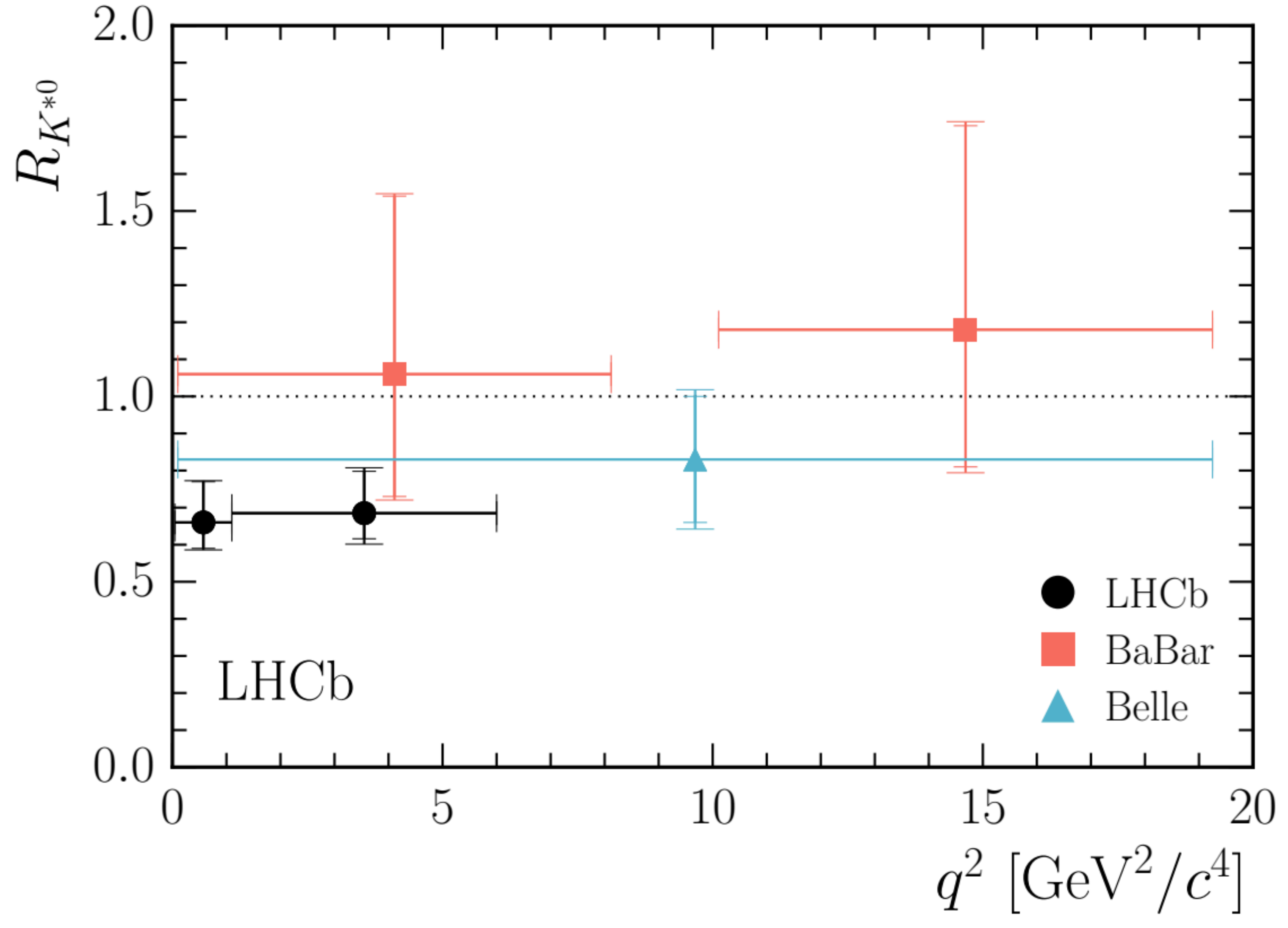
2.1σ deviation compatible with other anomalies



$$R_K = 0.846\,^{+0.060}_{-0.054}\,^{+0.016}_{-0.014}$$

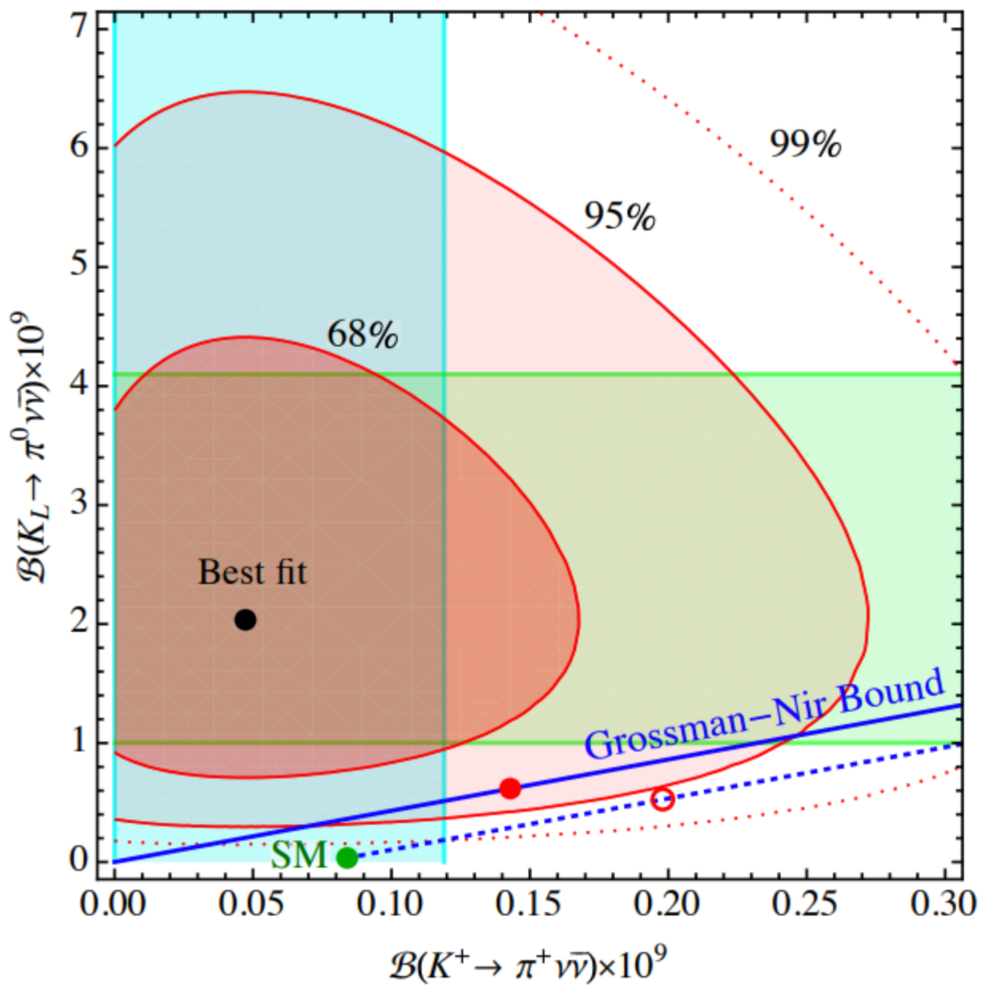
LHCb, JHEP 08 (2017) 055

$$R_{K^{*0}} = \begin{cases} 0.66\,^{+\,0.11}_{-\,0.07}\,(\text{stat}) \pm 0.03\,(\text{syst}) & \text{for } 0.045 < q^2 < 1.1\ \ \text{GeV}^2/c^4 \\ 0.69\,^{+\,0.11}_{-\,0.07}\,(\text{stat}) \pm 0.05\,(\text{syst}) & \text{for } 1.1 \quad < q^2 < 6.0\ \ \text{GeV}^2/c^4 \end{cases}$$

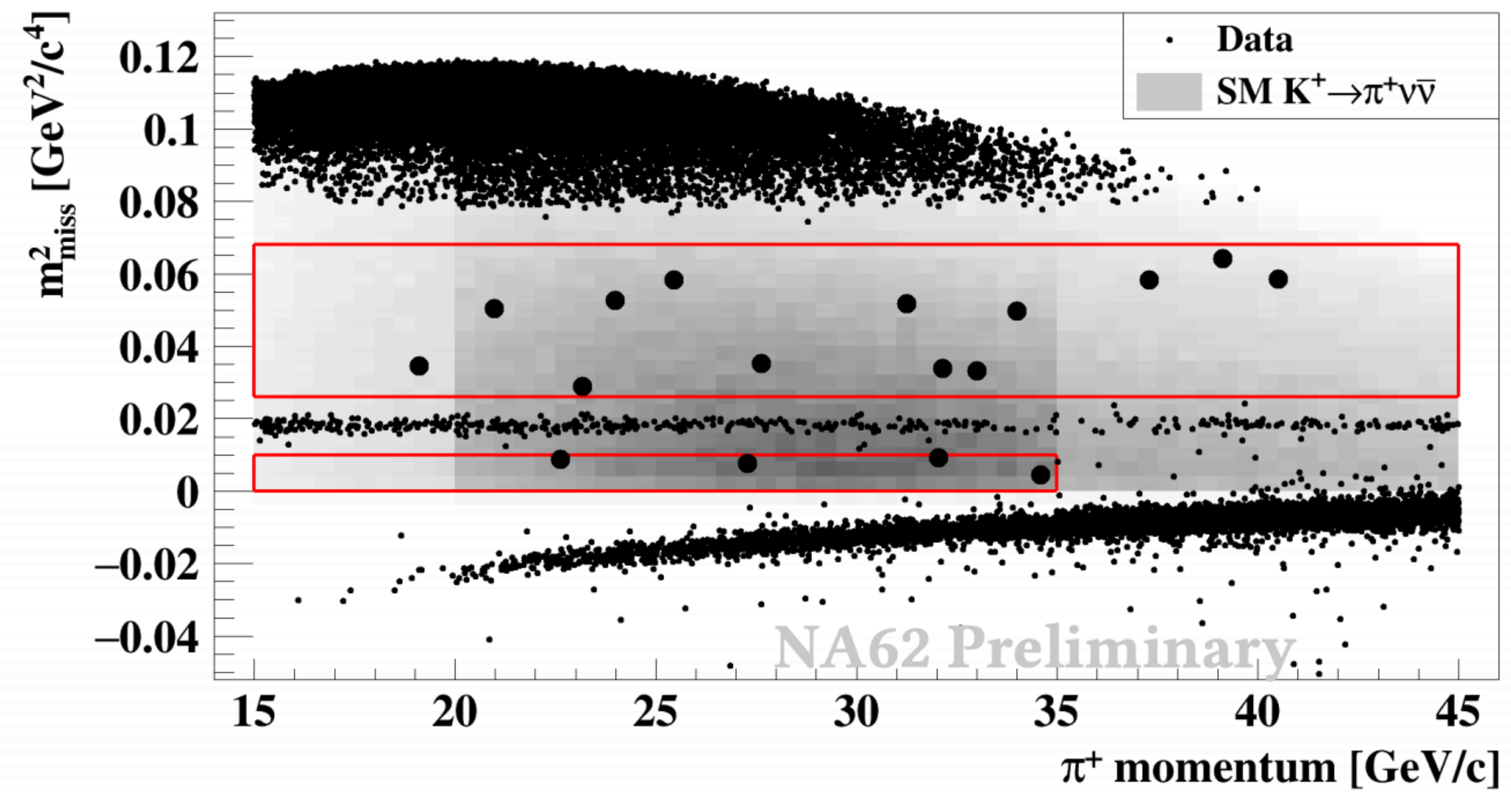


B -> K* mu mu angular analysis

KOTO, NA62 & Rare Kaon decay:



Opening the box in the 2018 data



5.3 background + 7.6 SM signal events expected, 17 events observed

Decay	Γ_{SD}/Γ	Theory err.*	SM BR × 10^{11}	Exp. BR × 10^{11} (Sep 2019)
$K_L \to \mu^+\mu^-$	10%	30%	79 ± 12 (SD)	684 ± 11
$K_L \to \pi^0 e^+ e^-$	40%	10%	3.2 ± 1.0	< 28†
$K_L \to \pi^0 \mu^+\mu^-$	30%	15%	1.5 ± 0.3	< 38†
$K^+ \to \pi^+ \nu\bar{\nu}$	90%	4%	8.4 ± 1.0	< 18.5†
$K_L \to \pi^0 \nu\bar{\nu}$	>99%	2%	3.4 ± 0.6	< 300†

*Approx. error on LD-subtracted rate excluding parametric contributions †90% CL

SM: 3+σ
GN tension: 2.1σ

Dr. Kohsaku Tobioka

Specific models for effects of NP on $K \to \pi\nu\nu$ BRs are constrained by other kaon measurements, esp. Re ε'/ε, ΔM_K

Lattice results for Re ε'/ε × 10^4:

RBC/UKQCD, PRL115 (2015)
$1.38 \pm 5.15_{st} \pm 4.59_{sy}$

Measurements: Re ε'/ε × 10^4

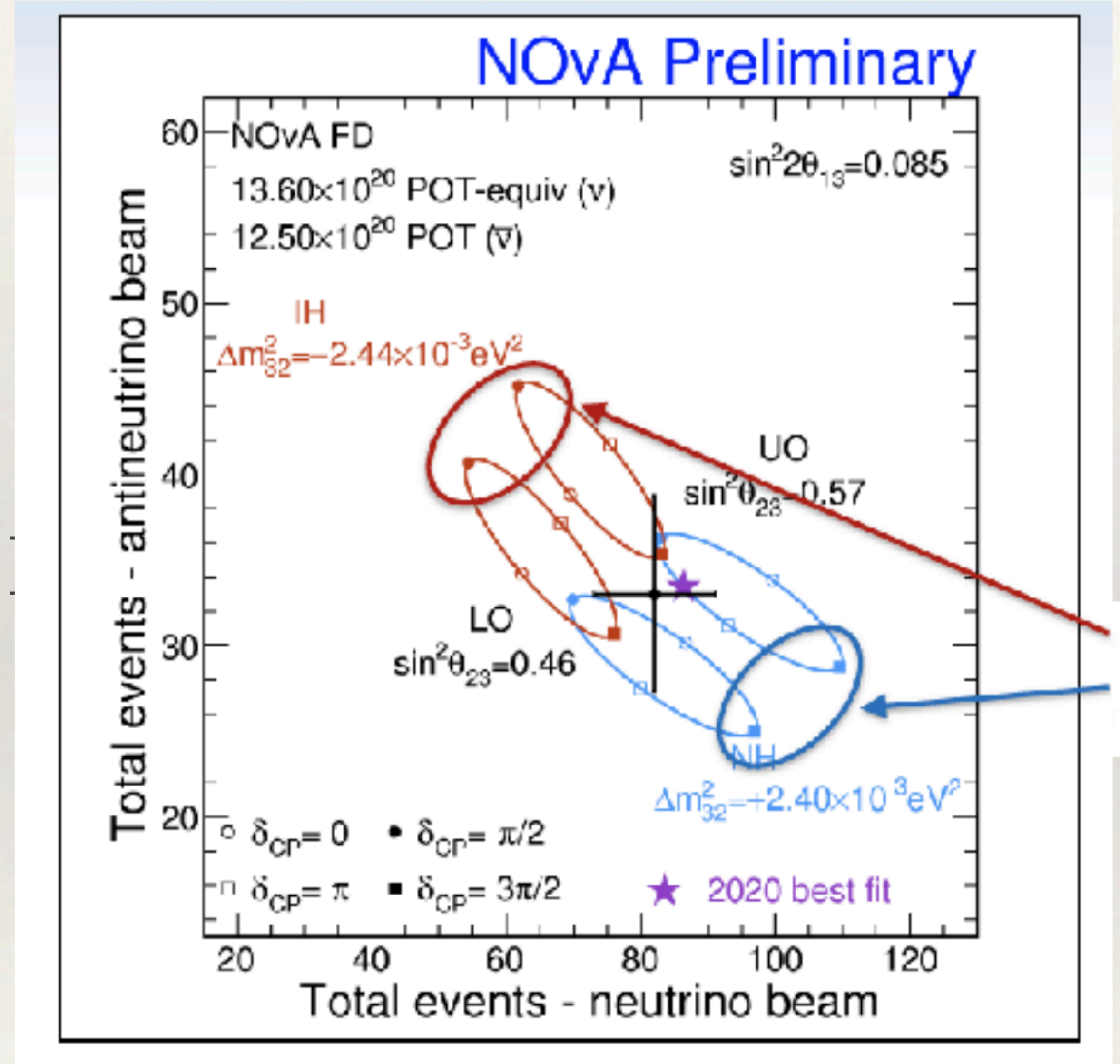
KTeV	19.2 ± 1.1 ± 1.8
NA48	14.7 ± 1.7 ± 1.5
PDG fit	**16.6 ± 2.3 (S = 1.6)**

RBC/UKQCD, arXiv 2004.09440
$21.7 \pm 2.6_{st} \pm 6.2_{sy} \pm 5.0_{IB}$

NA62 performs well but KOTO excess could be a background

Dr. Matthew Moulson

Nutrino data and Updates: Prof. Srubabati Goswami's talk



Joint analysis of disappearance and Appearance data in both neutrino and antineutrino channel

Δm^2_{32} = (2.41 ± 0.07) x 10^{-3} eV^2
$\sin^2(\theta_{23})$ = 0.57 $^{+0.04}_{-0.03}$ (49°)

B.F. for δ_{CP} = 0.83π

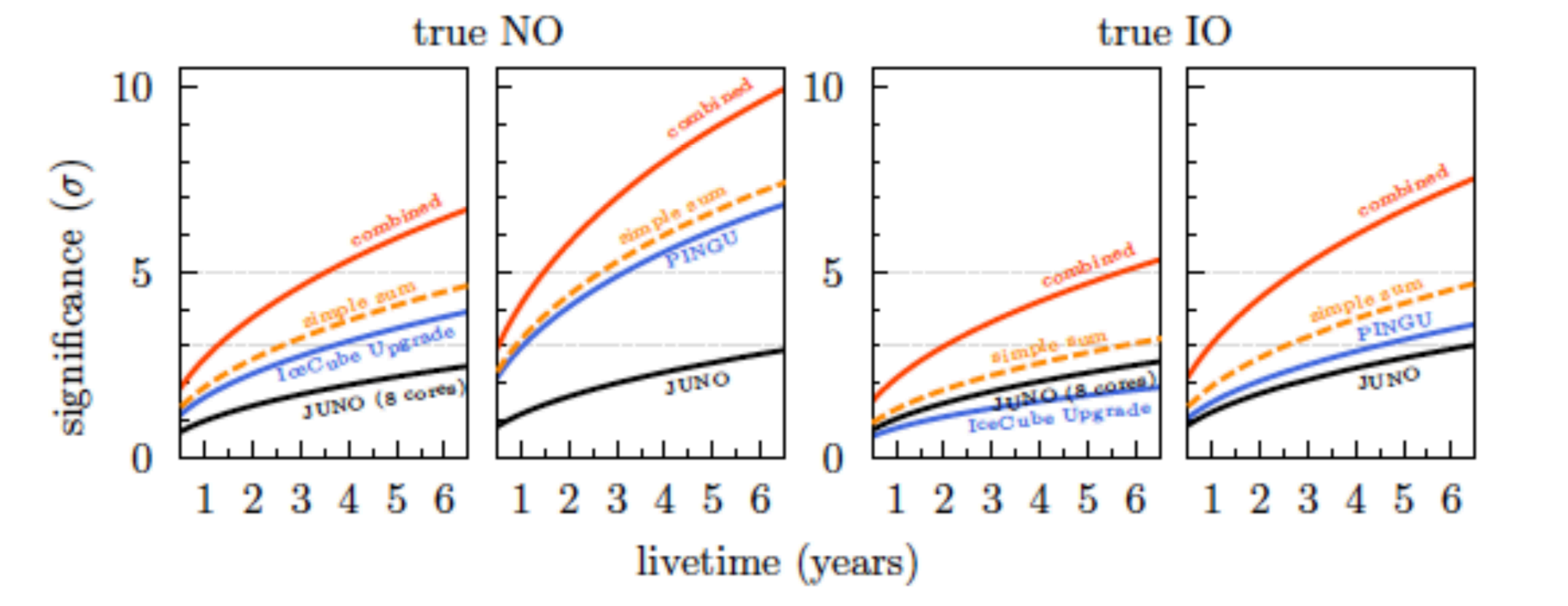
Exclude IH $\delta_{CP} = \pi/2$ at > 3 σ
Disfavor NH $\delta_{CP} = 3\pi/2$ at ~2 σ

Preference for

Normal Hierarchy at	1.0 σ
Upper Octant at	1.2 σ

Measurements of CP phase along with preference for NH

8 core JUNO + IceCube upgrade/PINGU / (better efficiency for lower energy neutrinos)



5σ sensitivity in 4(6) years NO (IO)

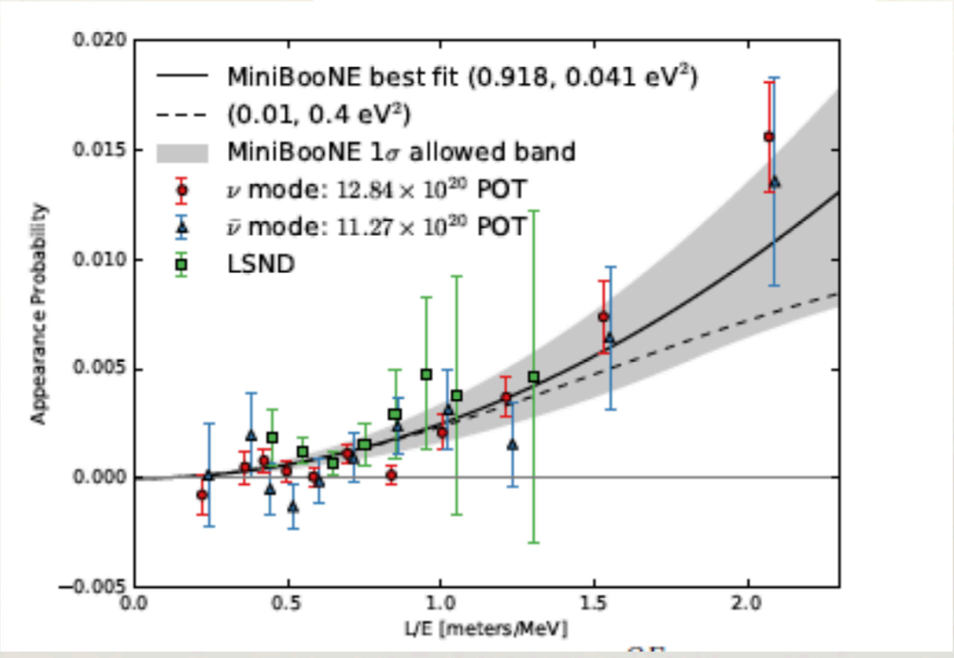
IceCube : earth matter effect of atmospheric neutrinos
JUNO: interference effect in vacuum oscillation } **Synergy**

hep-ex 1911.06745

Sensitivity on Hierarchy by combined Experiments

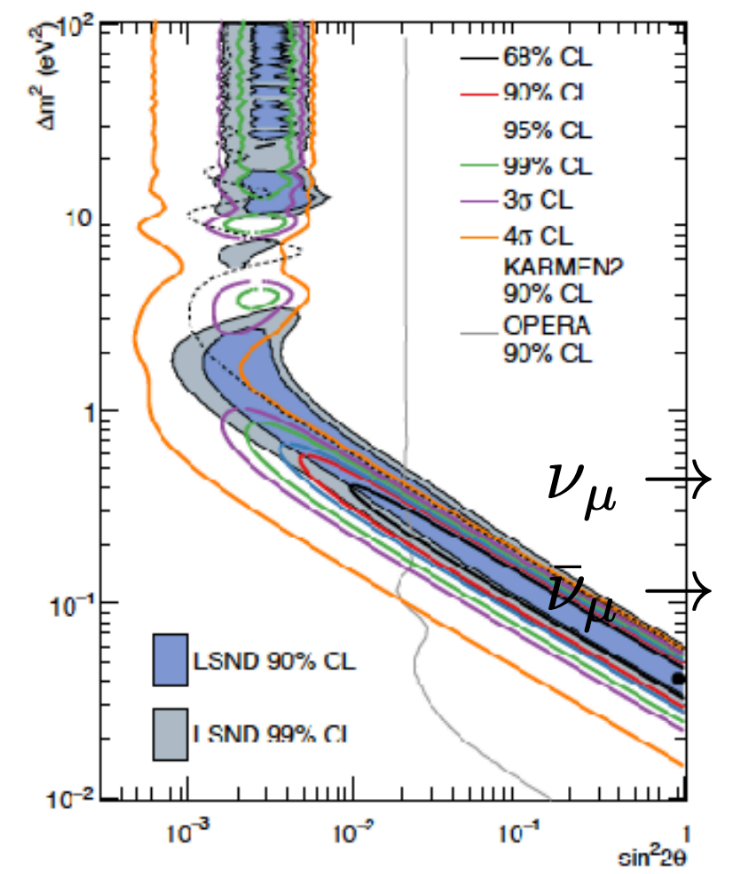
LSND and MiniBoone

$200 < E_\nu^{QE} < 3000$ MeV



Combined significance ~ 6σ

A.A. Aguilar Arevalo, PRL 121, 221801, 2018.



Two neutrino fit

MiniBoone : neutrino + antineutrino

Tension between Miniboone and LSND

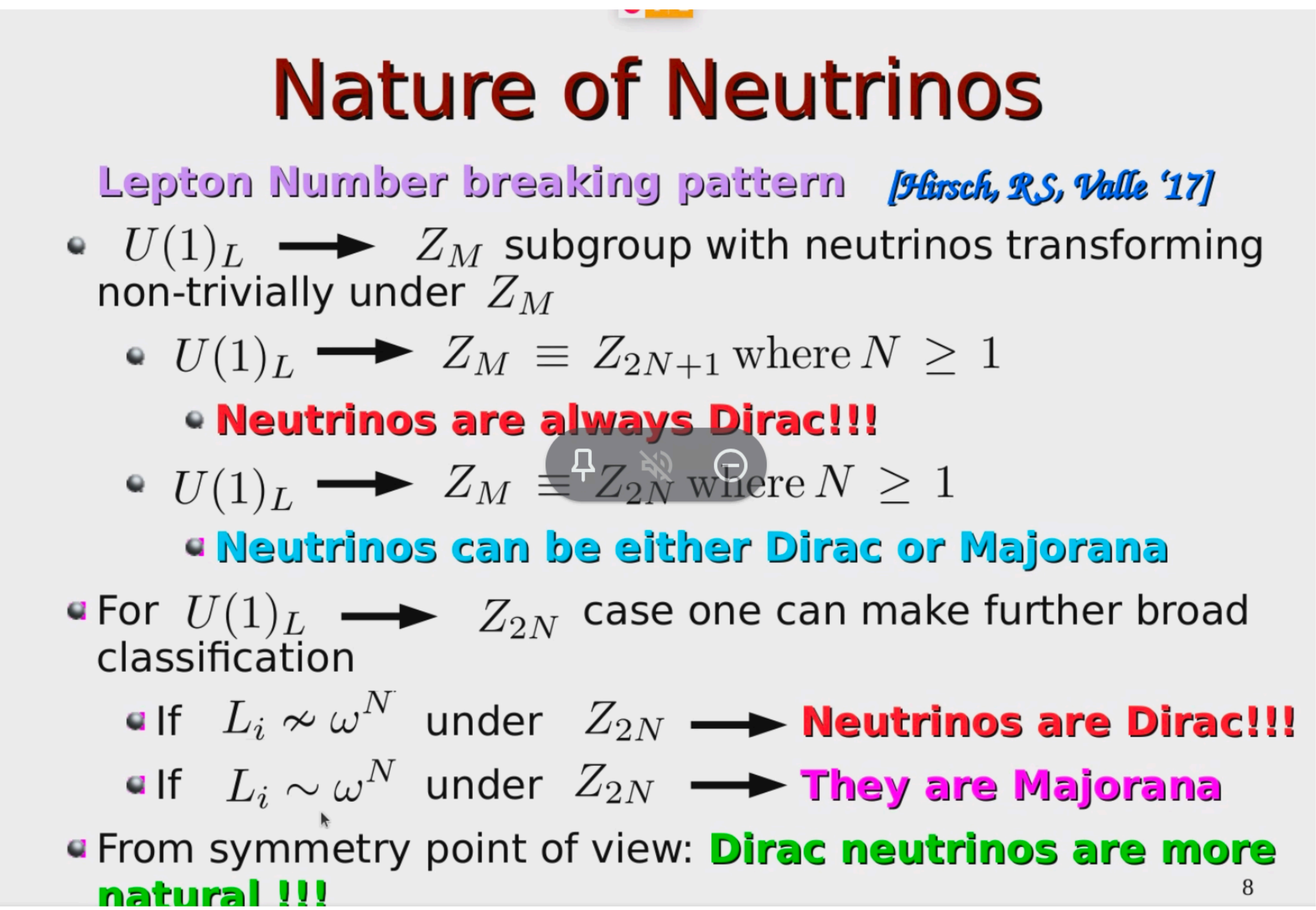
- Many other experiments like NEOS, DANSS, ANITA, T2K, etc updates are given in the talk.

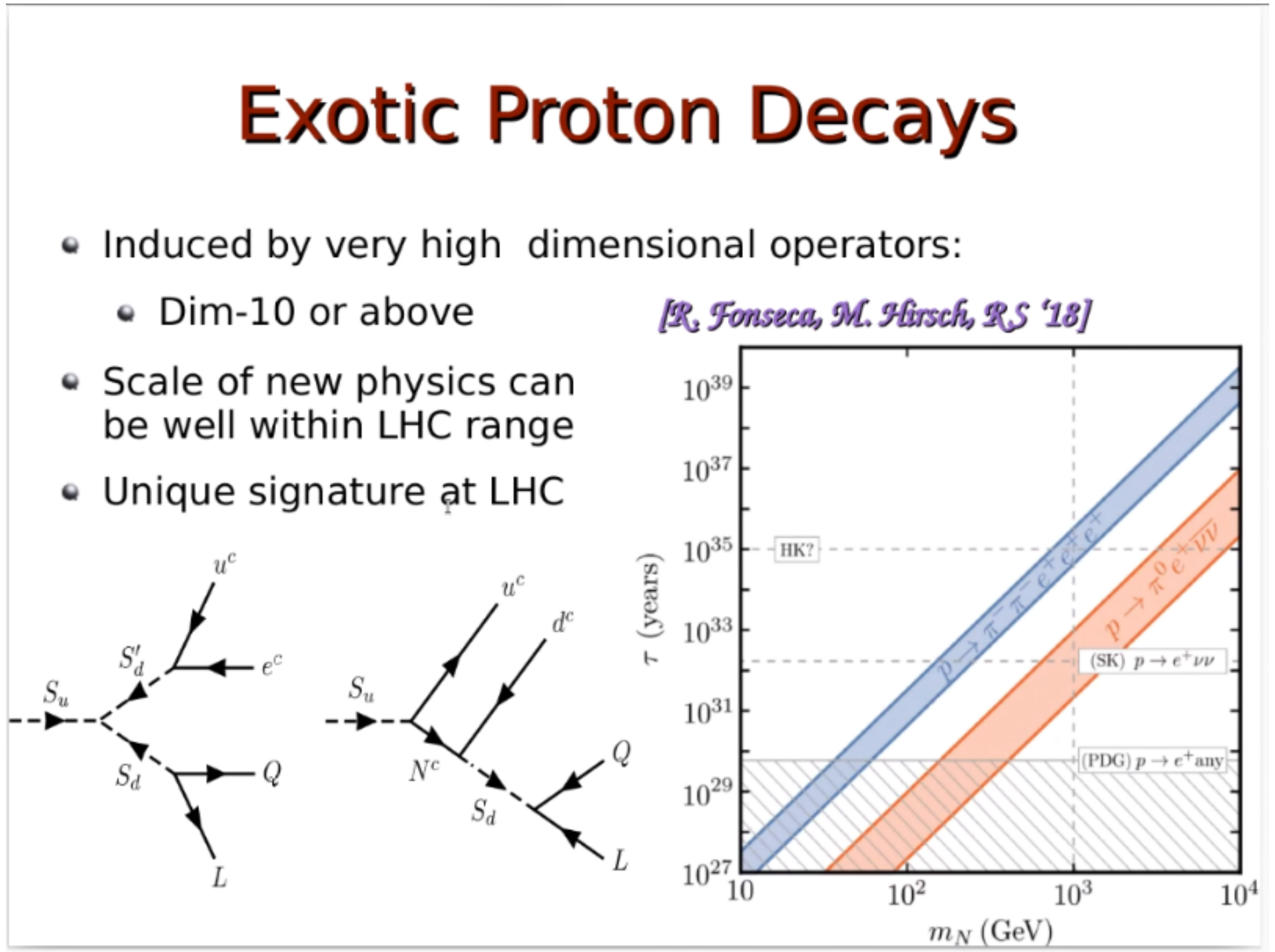
- A model independent study of the non-oscillatory explanations of the MiniBooNE excess was performed

New physics scenarios allow to directly connect the observed MiniBooNE excess of events to expected excesses in other experiments (T2K ND280, MINERνA, PS-191, NOνA)

See Dr. Vedran Brdar's talk

Neutrino Physics:Dr. Rahul Srivastava’s talk





- Different breaking mechanism of B-L symmetry and the choices of discrete symmetries lead to Dirac or Majorana fermions
- Exotic Leptoquark decays are predicted

Neutrino Physics: Dr. Manimala Mitra's Talk

J. Chakrabortty, H. Zeen Devi, S. Goswami, *JHEP* 08 (2012) 008
P. S. Bhupal Dev, S. Goswami, M. Mitra and W. Rodejohann, Phys. Rev. D 88, 091301 (2013)
R.Awasthi, A. Dasgupta and M. Mitra, arXiv: 1607.03504)

Collider signatures → lepton channels

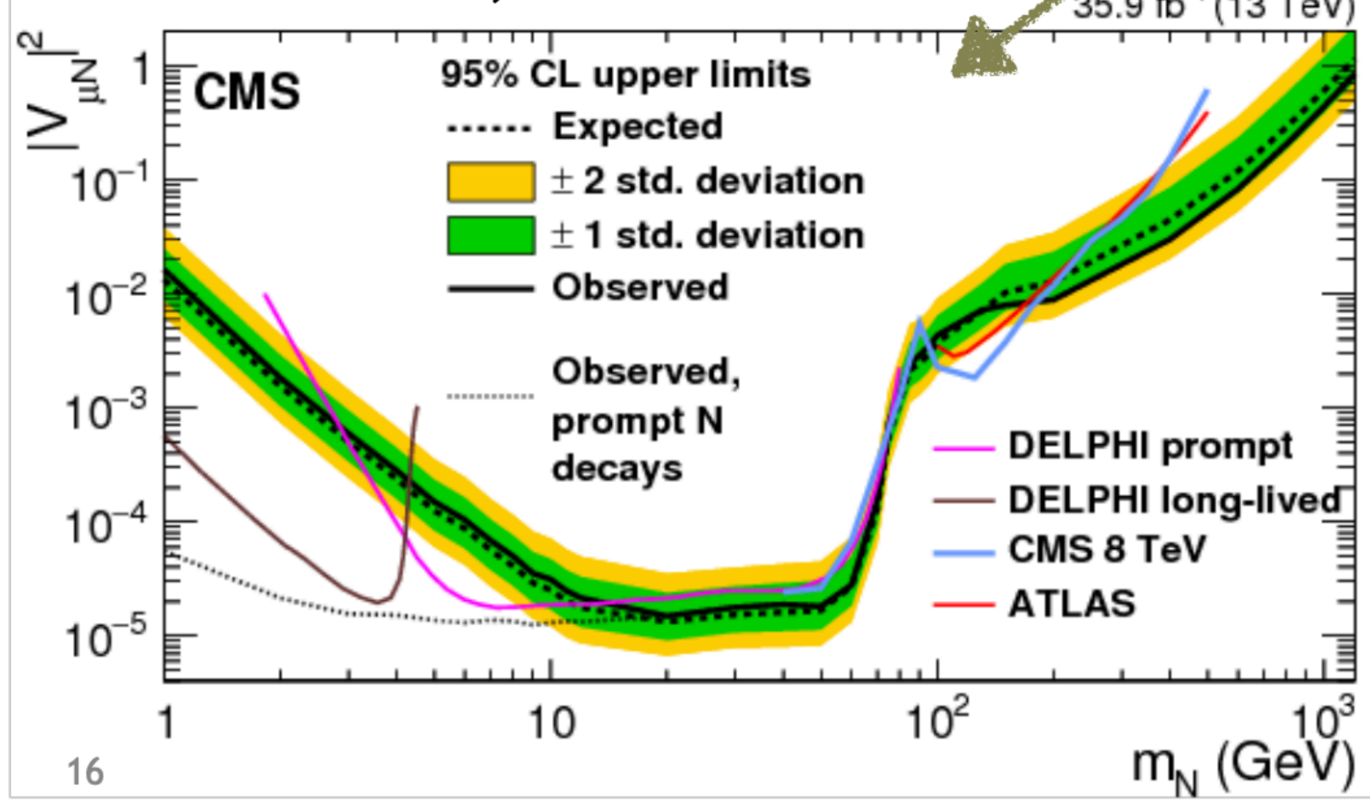
- Like sign/ different flavor dileptons $l^\pm l^\pm / l^\pm l'^\mp + 2j$
- Trilepton channels $l^\pm l^\mp l^\pm$ → For Dirac neutrinos N_R
- Lepton number violating $l^\pm l^\pm$ → Proof of heavy Majorana neutrinos N_R

Atre et al., JHEP **0905**, 030 (2009); Aguila et al., NPB **813**, 2009; Aguila et al., 2007; Aguila et al., PLB **672**, 2009; Arhib et al., 2010, ...

3l+X search

Poor sensitivity in low and high mass regime

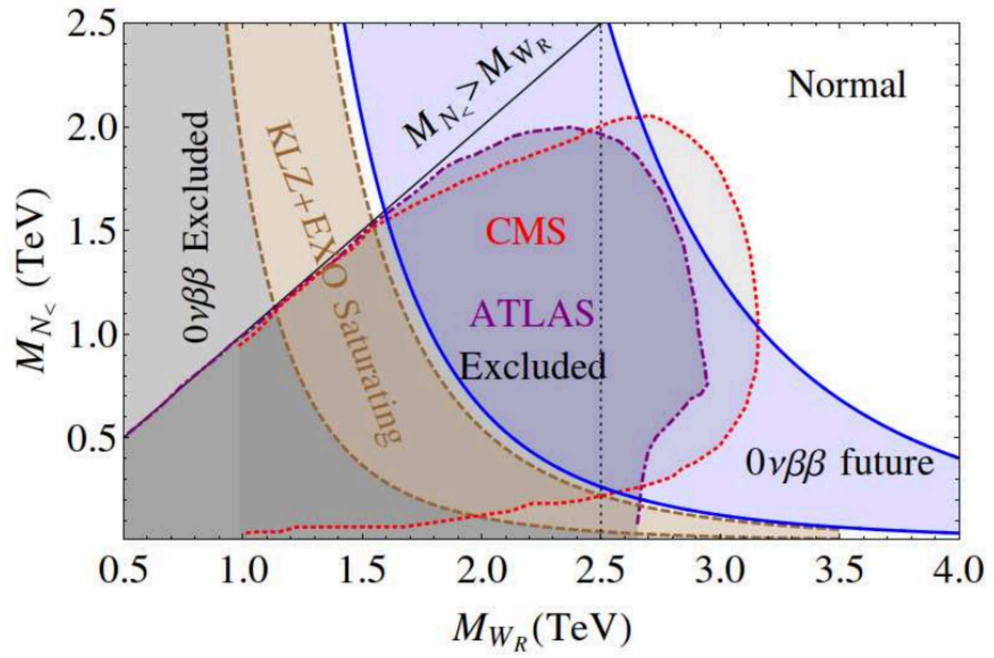
CMS collaboration, arXiv 1802.02965



$l^\pm l^\pm + jj$

Similar constraints

CMS collaboration, 1603.02248
CMS collaboration, arXiv 1806.10905



The contour is $M_{N_<} = \frac{p^2}{M^4_{W_R}} \frac{\Phi(\text{oscillation parameters})}{\sqrt{m^\nu_{exp} - m^\nu_{ee}}}$

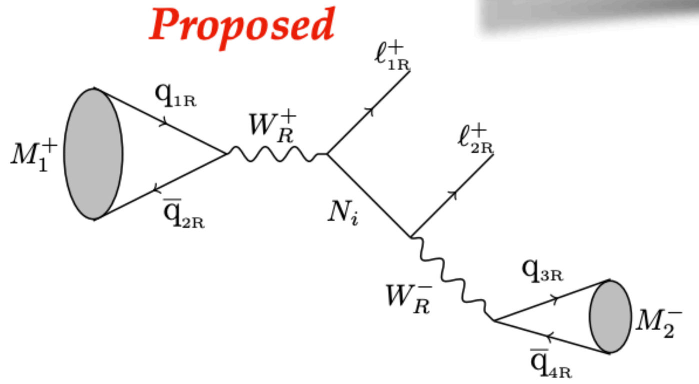
- Future $0\nu\beta\beta \to m^N_{ee} = 0.1 - 0.01$ eV.

$0\nu\beta\beta$ → **Complementary to LHC**

However, LHC puts stringent bound in the TeV range

Lepton Number Violating Meson Decays

Proposed

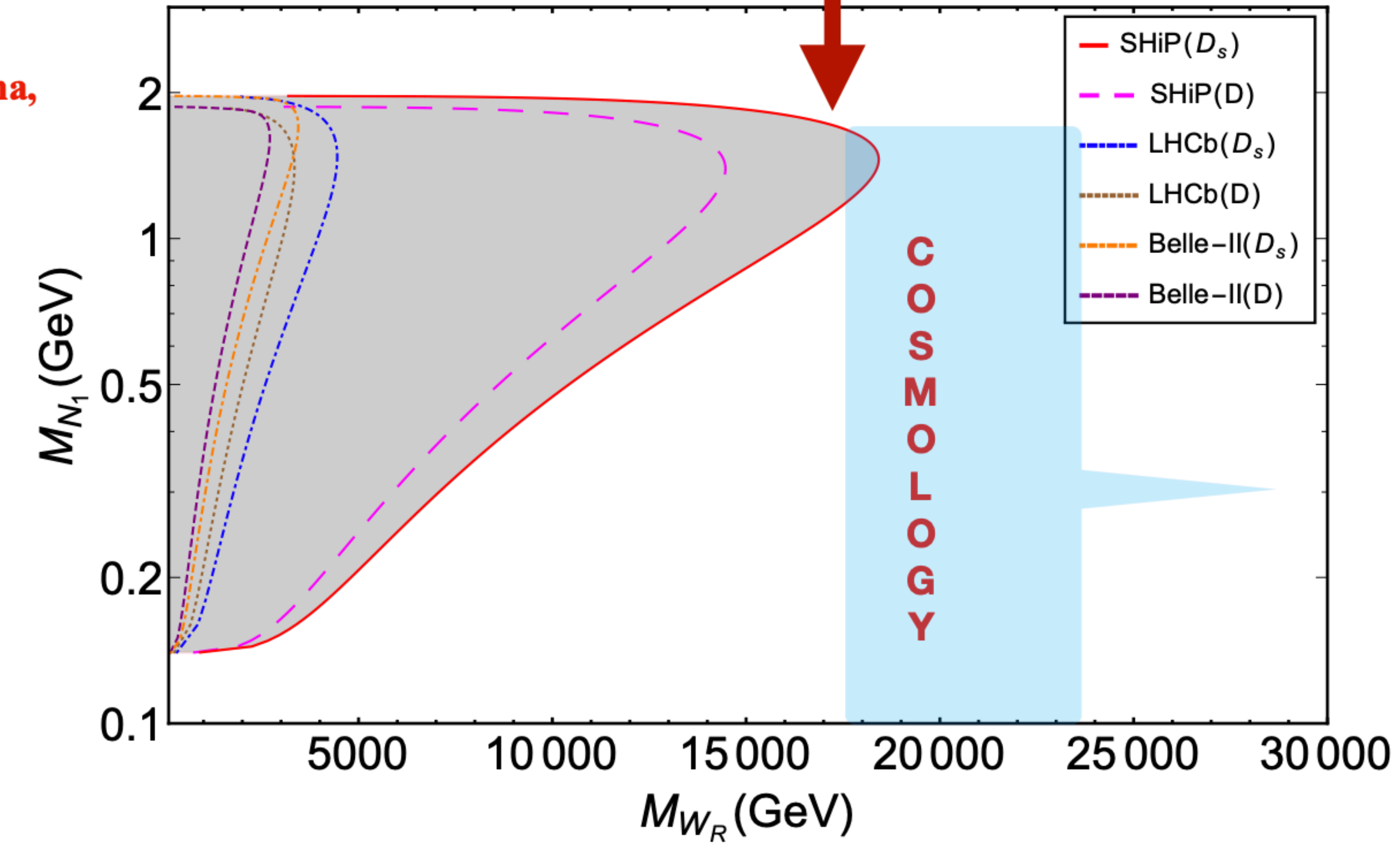


$M^+ \to e^+ e^+ \pi^-$

Sensitive to Sub-GeV Neutrino

Sensitive to a very high mass WR

S. Mandal, M. Mitra, N. Sinha, PRD 96 (2017) 3, 035023



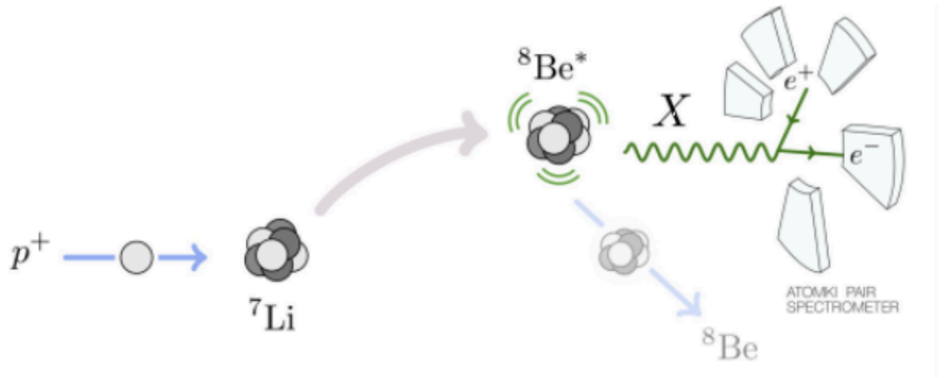
LHC search and LNV meson decays are complimentary probes

- Neutrino mass models: Different modes and their collider searches are discussed along with meson decays
- Displaced vertex signature in U(1)' extended model and TypeIII scenarios are discussed. See Dr. Arindam's talk

Be and (g-2) anomalies: Dr. Chandan Hati's talk

Anomalies in nuclear transitions of: ^{8}Be and ^{4}He

- Create excited ^{8}Be* from a p-beam on ^{7}Li
- Nucleus de-excites emitting a γ
- Measure angular distribution of e^+e^- form internal pair creation



In 2016, the ATOMKI collaboration reported to have seen a "6.8σ" excess in ^{8}Be* → ^{8}Be γ (→ e+e−) transition, compatible with a resonance **Krasznahorkay et al PRL 2016** 2019 reinvestigation @ " 5σ "

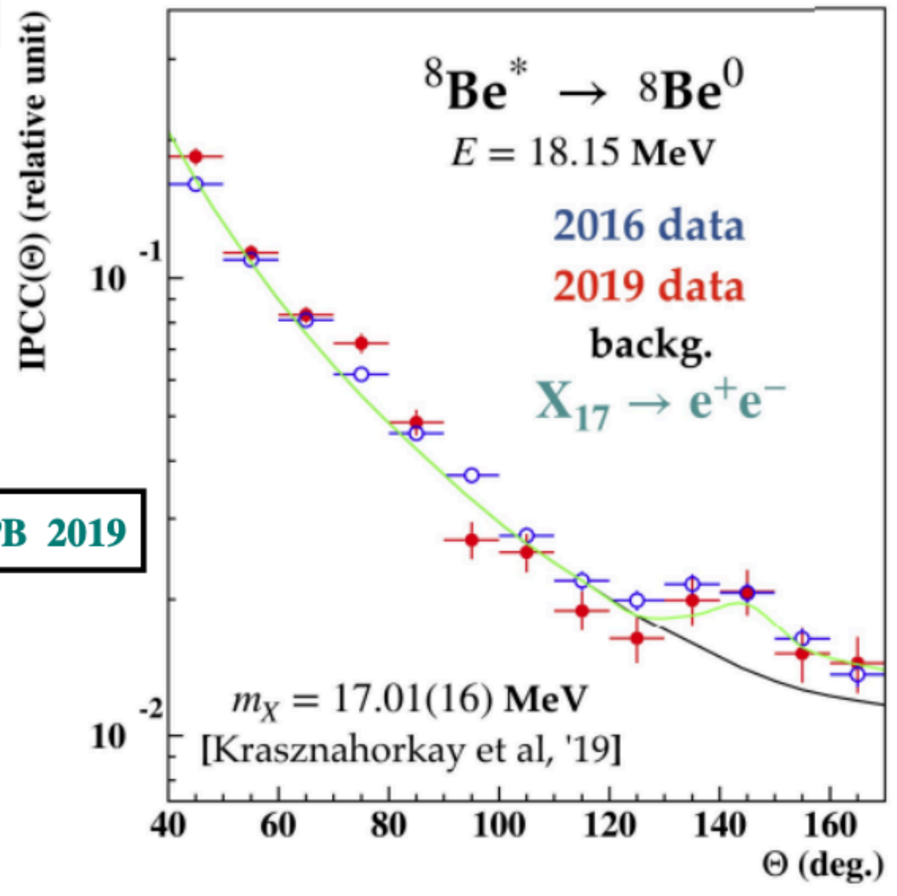
$$^8\mathrm{Be}^{*\prime}(j^\pi = 1^+, T = 1^*) \to {}^8\mathrm{Be}^0(j^\pi = 0^+, T = 0), \quad E = 17.64\ \mathrm{MeV}$$
$$^8\mathrm{Be}^{*}\ (j^\pi = 1^+, T = 0^*) \to {}^8\mathrm{Be}^0(j^\pi = 0^+, T = 0), \quad E = 18.15\ \mathrm{MeV}$$

Resonance observed in isospin conserving transition
but absent in isospin violating one!

Best fit for the isospin conserving transition: **Krasznahorkay et al APPB 2019**

$$m_X = 17.01(16)\,\mathrm{MeV} \qquad \Gamma_X/\Gamma_\gamma = 6(1) \times 10^{-6}$$

***Isospin mixing can affect these fit values



Similar anomaly in e^+e^- angular correlation of ^{4}He ($0^- \to 0^+$, 21.01 MeV decay) @ 7.2 σ

U(1)B-L with MeV order Z_(B-L) along with vector like isodoublet, isosinglet leptons extension can explain these anomalies

JHEP 07 (2020) 235

Neutrino Physics with NSI: Prof. Yasaman Farzan's talk

Neutrino scattering experiments

$q^2 \gg m_{Z'}^2$

~~$\mathcal{L}_{NSI} = -2\sqrt{2} G_F \epsilon_{\alpha\beta}^{fP} (\bar{\nu}_\alpha \gamma^\mu L \nu_\beta)(\bar{f}\gamma_\mu P\, f)$~~

$10 \text{ MeV} \lesssim m_{Z'} \ll 1 \text{ GeV}$

Relaxing bounds from scattering experiments, NuTeV and CHARM

Light mediator, Small coupling, large NSI

Bounds on Z' mass and couplings

Flavor structure of NSI

$a_\psi L_\psi + B \xrightarrow{\kappa_\alpha, \kappa_\beta} \epsilon^f_{\alpha\beta}\epsilon^f_{\beta\alpha} = \epsilon^f_{\alpha\alpha}\epsilon^f_{\beta\beta}.$

More than one ψ $\rightarrow$ $\left|\epsilon^f_{\alpha\beta}\right|^2 < |\epsilon^f_{\alpha\alpha}\epsilon^f_{\beta\beta}|$

Y.F. and J. Heeck, "Neutrinophilic Nonstandard interactions," PRD 94 (2016) 053010

How can we obtain the opposite relation?

$$|\epsilon^f_{\alpha\beta}| > |\epsilon^f_{\alpha\alpha}\epsilon^f_{\beta\beta}|^{1/2}$$

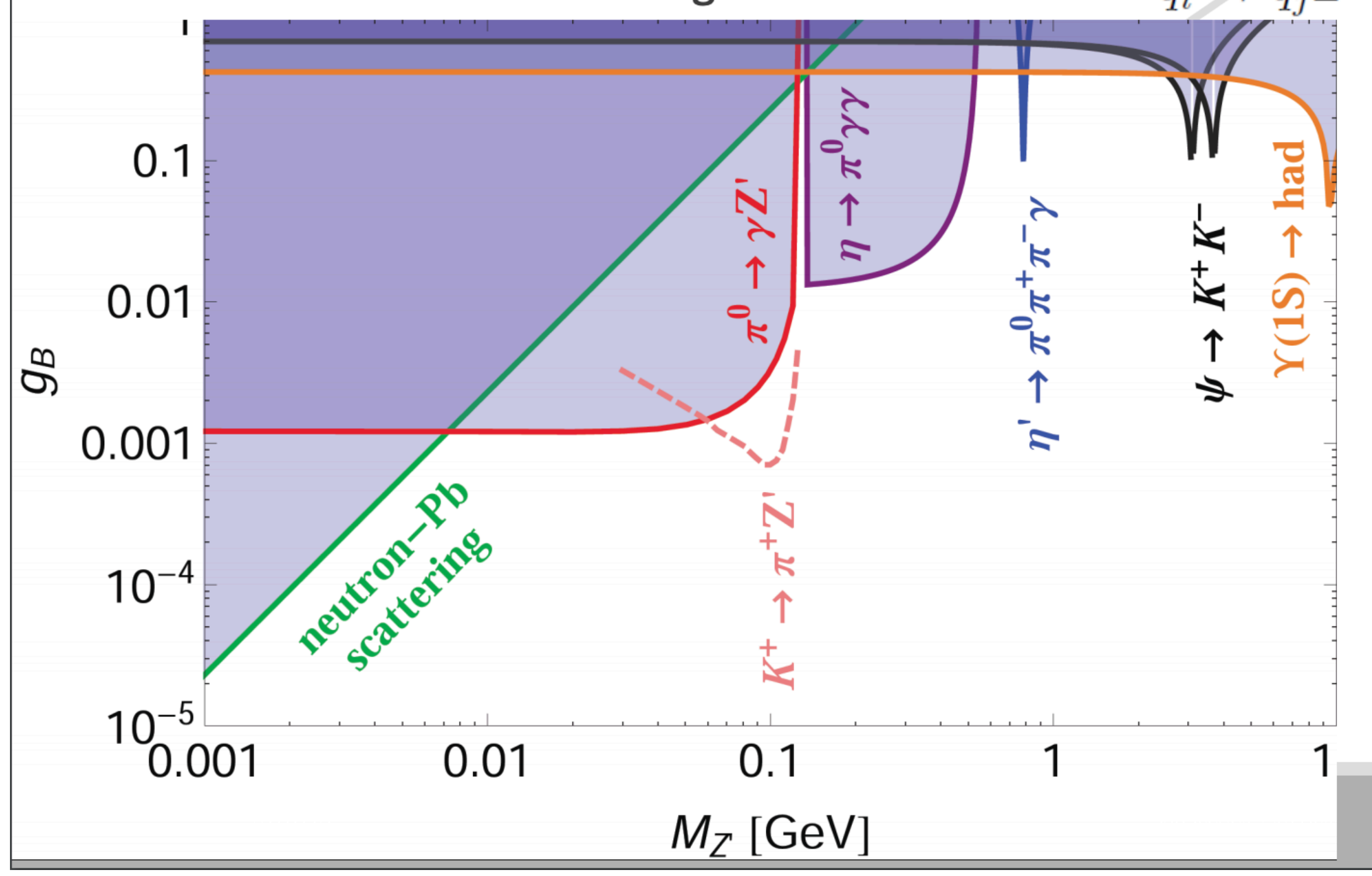
Y.F., "A model for lepton flavor violating Non-standard neutrino interactions," PLB (2020) 135349

Models with arbitrary flavour structure

Coupling to quarks

Non-chiral couplings: No impact on total measurement at SNO

Flavor universal: Going to mass basis



Y.F. and Heeck, *Phys.Rev.D* 94 (2016) 5, 053010

Feeble Neutrino-portal Dark Matter at Neutrino Detectors: Prof. EJC's talk

- Neutrino-portal: $\lambda N\phi\chi$ with a decaying ϕ and a stable χ DM.
- Characteristic channels of freeze-in production:

  i) $hh \to \phi\phi,\ \phi\phi \to \chi\chi,\ \phi \to \chi N/\nu,$
  ii) $\nu h \to N^{(*)} \to \phi\chi,\ \phi \to \chi\nu$
  iii) $\nu h \to N,\ NN \to \phi\phi/\chi\chi,\ \phi \to \chi\nu$

- The decay $\phi \to \chi\nu$, involving $y_\nu \lambda$, can be very late to provide an additional source of energetic neutrinos.
- They contribute to dark radiation or exotic signals at neutrino detectors.

- There are various other neutrino and nuetrino-DM scenarios discussed in the parallel sessions addressing XENON1T excess along with other anomalies.


THANK
YOU!