Theory Perspective

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TRIUMF Science Week 2021
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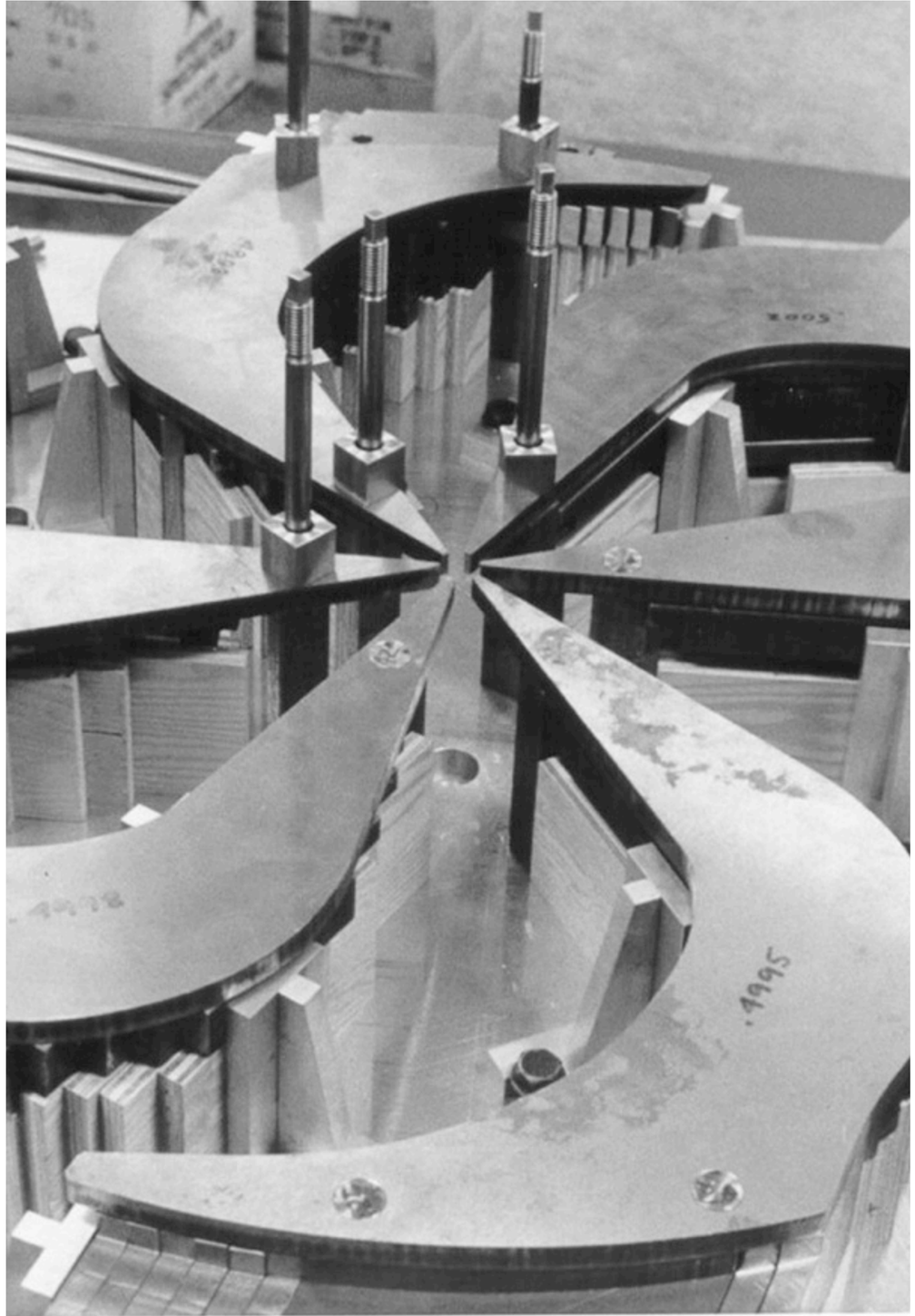


Discovery, accelerated

The Standard Model is Remarkable, But…

- **SM** = best tested, must successful theory in all of science.
  It has been confirmed by experiments over 15 orders of magnitude in energy.
- We are still working to understand many of its aspects: strong coupling, Higgs physics, …
- **But:** (see talk by G. Mohlabeng)
  - **dark matter:** what makes up the missing matter deduced from cosmology?
  - **baryogenesis:** why is there more matter than antimater?
  - **neutrino masses:** what is their origin?
  - **electroweak hierarchy:** why is $G_F \gg G_N$ if the Higgs is a fundamental scalar?
  - **more:** inflation, quantum gravity, strong CP, anomalies, …

Particle Theory at TRIUMF

- **Phenomena at colliders, intensity, and precision experiments:**
  - Higgs, electroweak, and new physics searches at colliders *(ATLAS, Belle II)*
  - tests of dark matter and dark sectors *(SuperCDMS, DEAP, SBC, DarkLight, NA62, Belle II, ATLAS)*
  - SM deficiencies/anomalies with precision measurements *(UCN, DarkLight, ATLAS, ALPHA)*
  - neutrino oscillations and properties *(HyperK, nEXO, PIENU(Xe), BeEST, HALO)*
  - proposals for new techniques and experiments to study this physics
- **Particle physics in astronomy and cosmology:**
  - tests of the SM and beyond using astro data including CMB, cosmic rays, stars
  - measurements of the very early Universe with gravitational waves
  - implications of these observations for laboratory experiments

Particle Theory at TRIUMF

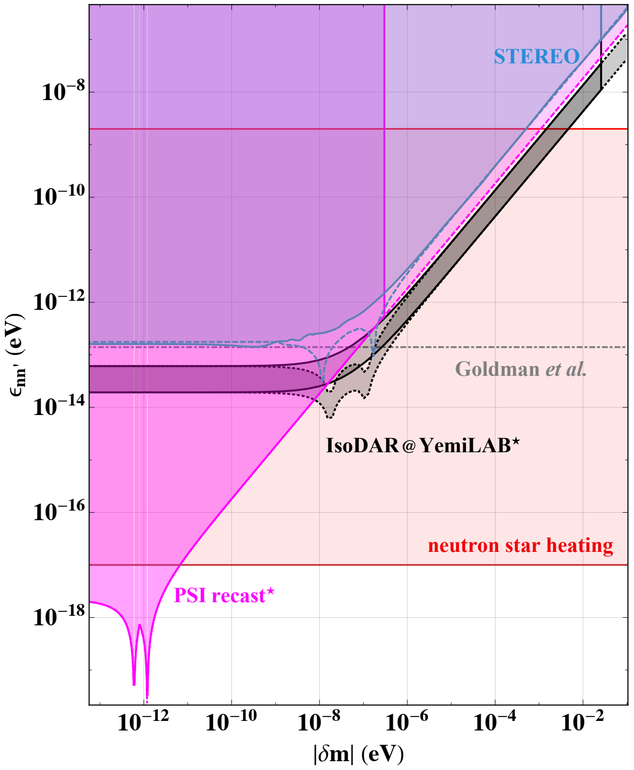
- **Current Roster:**
  - **faculty:** D. McKeen, D. Morrissey (DM has been found at TRIUMF!)
  - **postdocs:** N. McGinnis, N. Raj, M. Shamma
  - **graduate students:** J. Coffey, R. Mizuta, A. Omar, M. Stefanyk
  - **emeritus:** J. Ng, R. Woloshyn

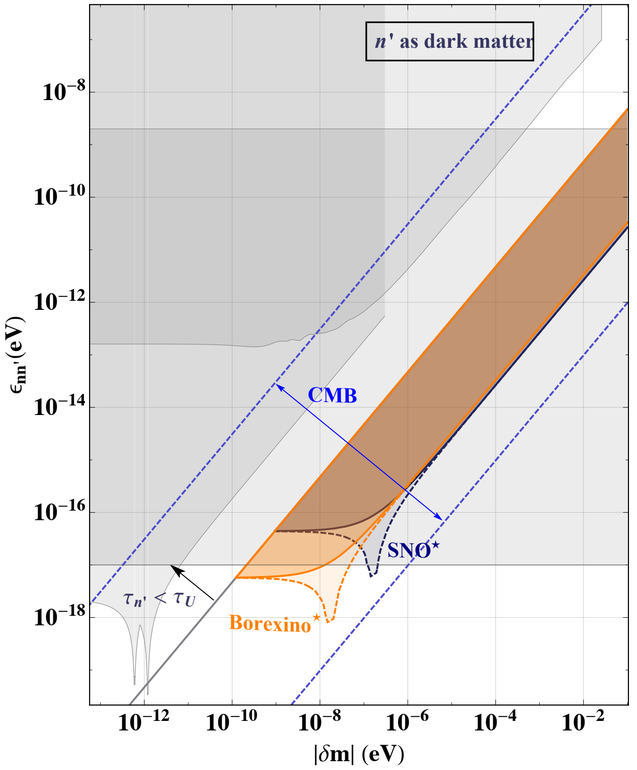
- Strong connections with UBC, UVic, SFU, McDonald Institute, SNOLAB Perimeter Institute, and other groups in Canada and internationally.

- **5YP:** build to three particle faculty with an expanded focus (*e.g.* AMO searches)

Recent Work #1: Tests of Dark Neutrons

- Dark neutrons: $\mathcal{O}_{n'n} = \frac{1}{\Lambda_{n'}^2}(udd)n' \rightarrow \epsilon_{nn'}\, n\, n'$
- They can be DM and explain neutron lifetime anomalies (beam vs. bottle).
- Existing experiments and observations can be used to test their existence.

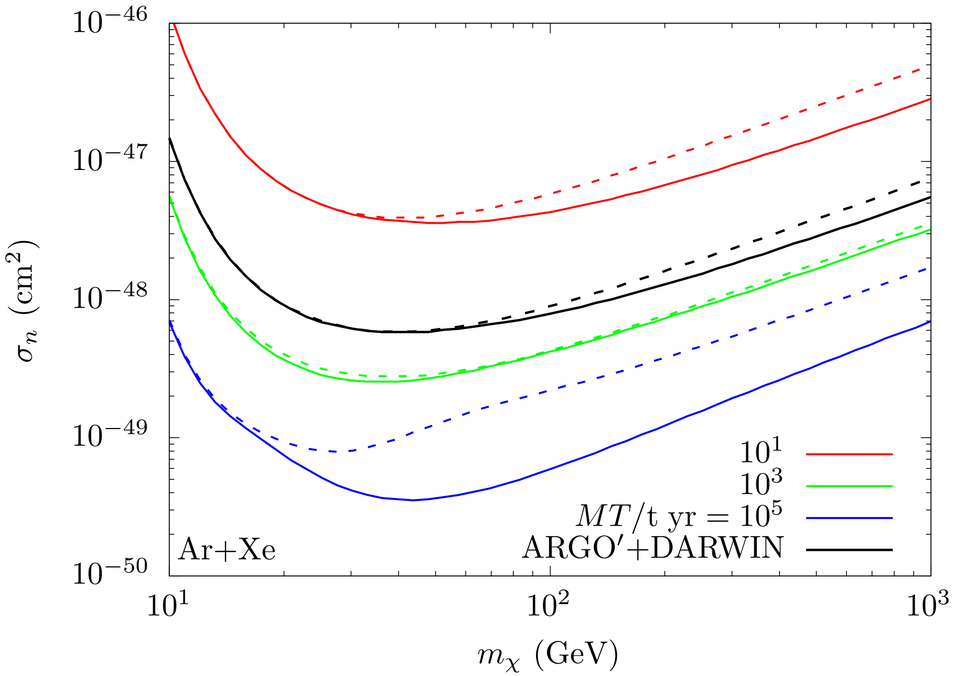


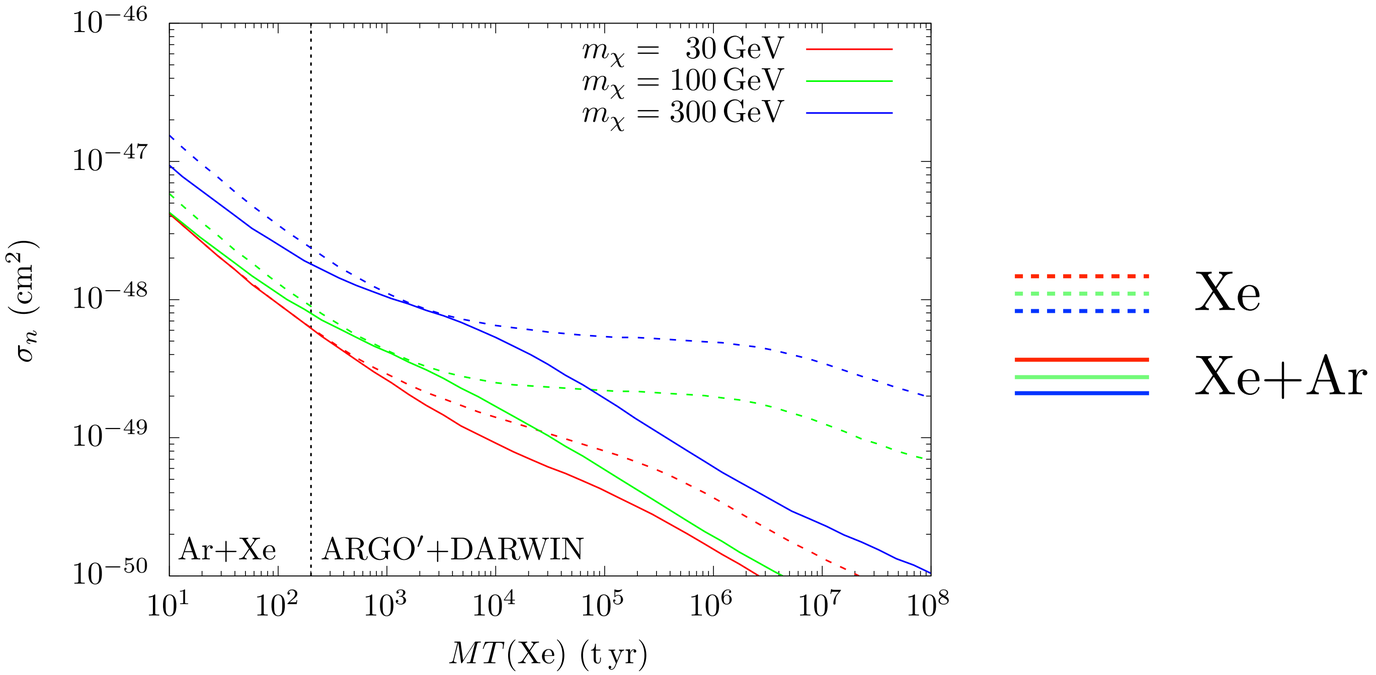


[M. Hostert, D. McKeen, M. Pospelov, N. Raj, hep-ph/2201.02603, under review at Phys.Rev.D]

Recent Work #2: Neutrino Floor for DM

- Large dark matter search experiments are starting to detect neutrinos as backgrounds.
- These will be an obstacle to DM discovery. **[J. Monroe + P. Fisher 2007; Billard et al. 2013]**
- Combining data from xenon (DARWIN) and argon (ARGO) detectors can improve reach.





[A. Gaspert, P. Giampa, D. Morrissey Phys.Rev.D105, 035020]

Activities and Initiatives

- TRIUMF Theory also acts as a resource for particle theory and experiment across the Canadian community.
- **Activities:**
  - TRISEP Summer School in Particle Physics (July 4-15, 2022) [with particle department]
  - LISA Canada Workshop 2022 (Aug. 24-25, 2022) [with LISA Canada collaborators]
  - GUINEAPIG Workshop on Light Dark Matter (Sept. 8-10, 2022) [with SNOLAB, MI, …]
  - ongoing theory seminar, workshop, dark matter forum, and visitor program

- **Future Vision:** a dedicated workshop/visitor/education centre and program for all of TRIUMF.

New initiative - TRIUMF workshop/education/visitor centre

- Model based on very successful centres such as the Institute for Nuclear Theory (INT), Munich Institute for Astro- and Particle Physics (MIAPP) , Aspen Center for Physics (ACP), …
- Would host multiple in-house workshop and collaboration programs year-round.

  Note: my examples are based on theory centres and workshops, but this would cover all lab topics!
- Program proposals would be submitted externally and reviewed by an evaluation committee.

  Dedicated TRIUMF administrative staff would help with housing, logistics, and hosting.
- True workshop format: office space for participants, 2+ week timeline, limited presentations.
- **Infrastructure and administration can be modular:**
  - would also allow extended student and scientist visits from member universities
  - facilitate hosting of summer schools organized by member universities, co-op student programs
  - expand outreach activities for younger students and programs for teachers

TRIUMF

Thank you
Merci

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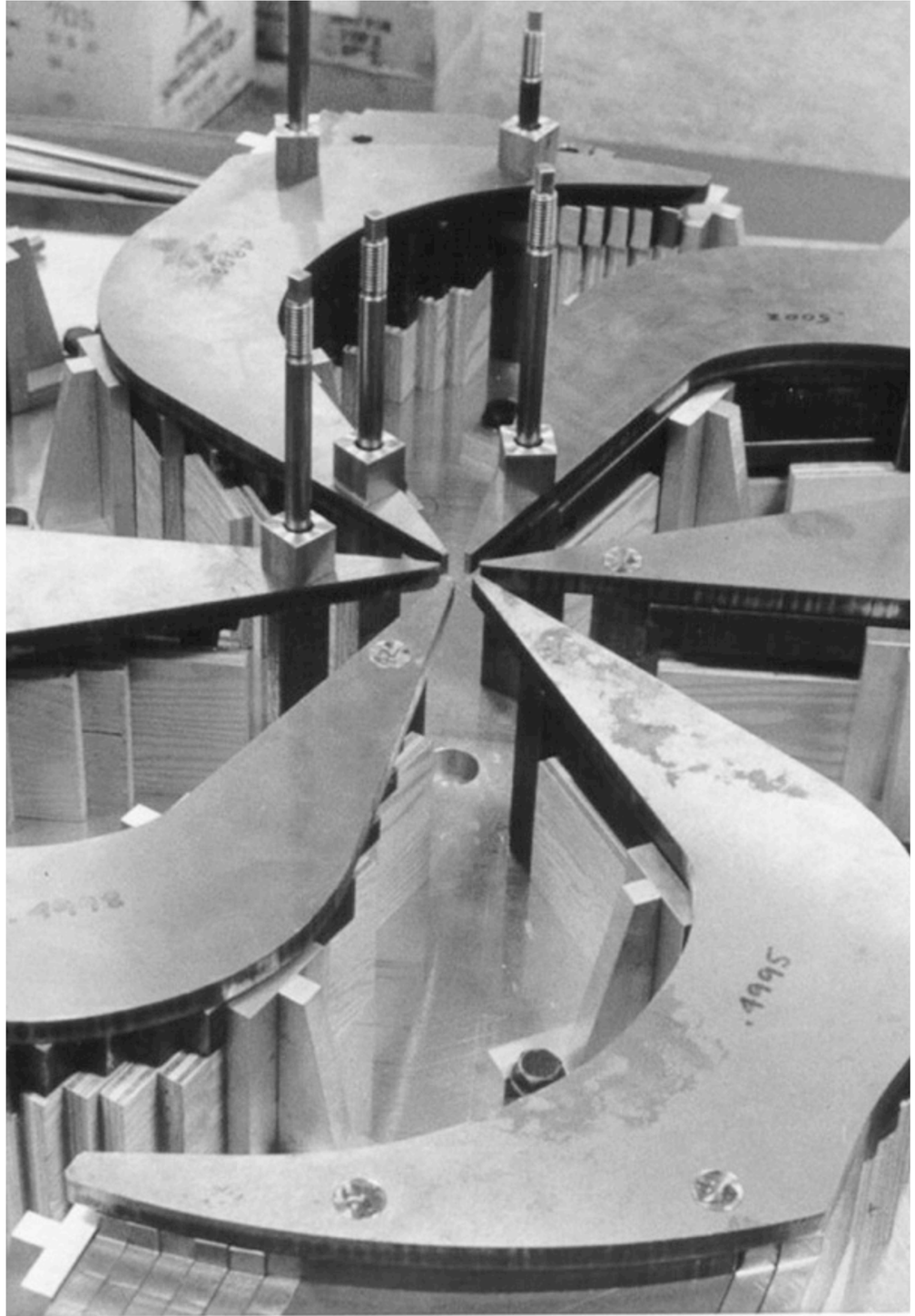
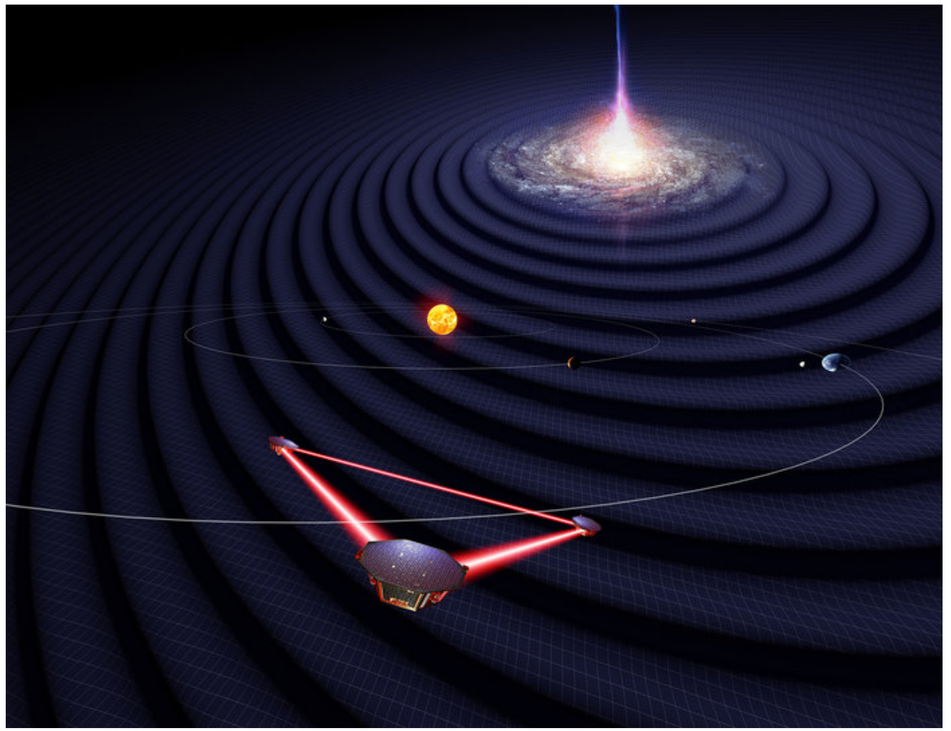


Discovery, accelerated

Extra Slides

LISA Canada Workshop 2022

- LISA = Laser Interferometer Space Antenna
  → space-based detector for gravitational waves to launch in 2030s
- GW science spans astrophysics, particle physics, nuclear physics, and more!
- LISA Canada Workshop 2022 will look for new synergies on this project within the Canadian Community.
- Aug.24-25, remote



GUINEAPIG Workshop on Light Dark Matter

- GUINEAPIG = **G**eV and **U**nder **I**nvisibles with **N**ew **E**xperimental **A**ssays for **P**articles **I**n the **G**round

- Workshop on the nature and experimental detection of lighter (m < GeV) dark matter.

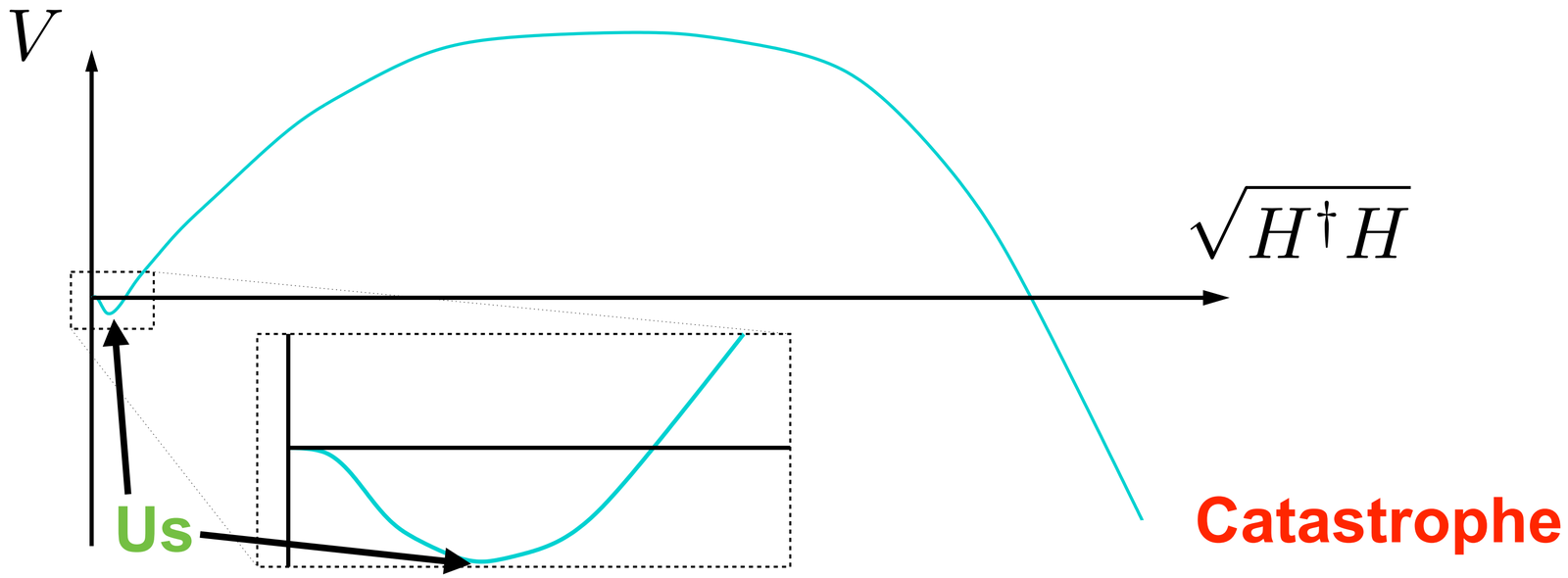
- This is a rapidly growing field with plenty of room for new ideas and experiments!

- Sept. 8-10,TRIUMF and remote

e.g. SM Higgs Potential

- Higgs potential: $V = -\mu^2 H^\dagger H + \lambda (H^\dagger H)^2$

$$\rightarrow V_0 + \frac{1}{2} m_h^2 h^2 + \lambda v\, h^3 + \ldots$$



- We are only metastable against tunnelling to catastrophe!

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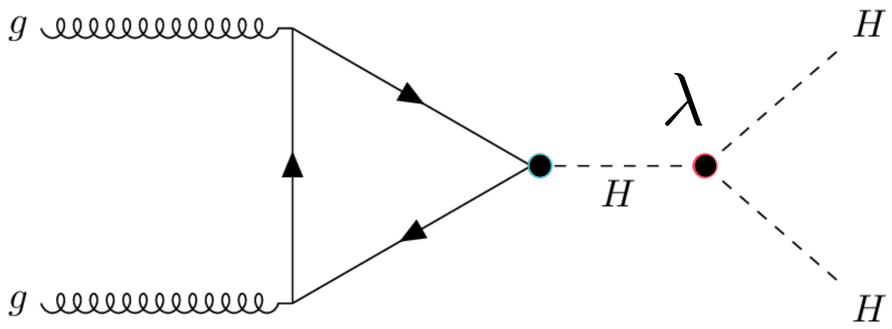
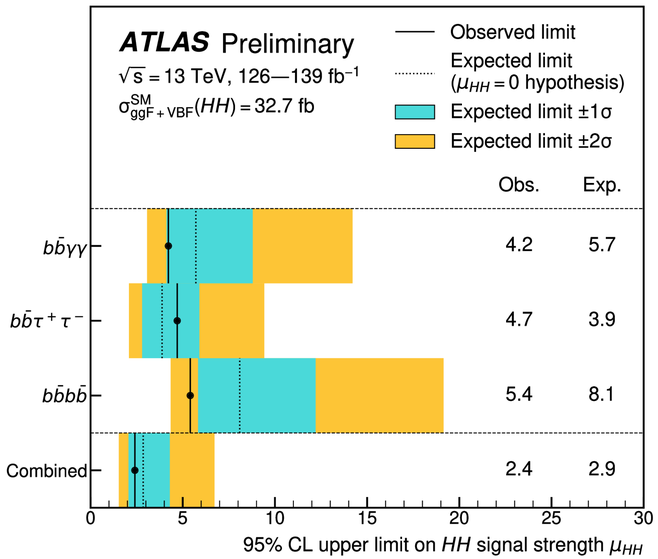
- The key coupling λ implies di-Higgs production ($h \rightarrow h + h$).





- New physics can stabilize the potential and modify di-Higgs production.