HEPAP FACILITIES SUBPANEL
Cosmic Frontier Facilities

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HEPAP Meeting

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Main Science Goals of Cosmic Frontier

- Discover (or set limits on) non-baryonic **Dark Matter** particles that comprise ~20% of the Universe
- Determine the physical origin of the accelerated expansion of the Universe and probe the nature of the **Dark Energy** that comprises ~75% of the Universe
- Probe the **high-energy Universe** through particle astrophysics experiments in cosmic and gamma rays
- Probe the **physics of the early Universe** and **neutrinos** through Cosmic Microwave Background and other experiments
- Complements Energy and Intensity Frontiers in probing physics beyond the Standard Model
- U.S. has established world leadership in CF research

Dark Matter Searches: Strategic Triad

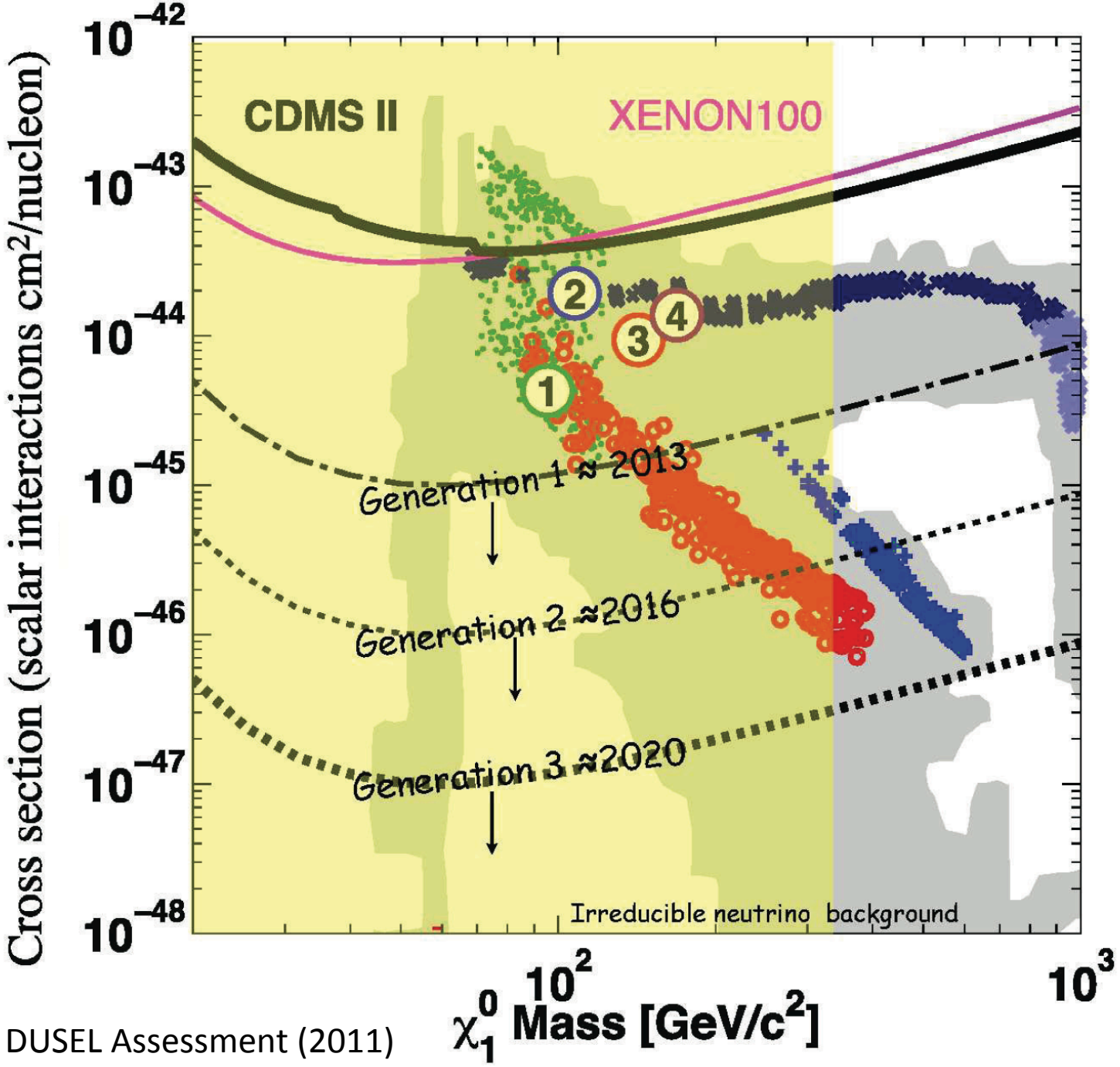
- Direct Detection Experiments searching for WIMPs and axions
- Production of WIMP Dark Matter particles at colliders (LHC)
- Indirect detection of DM particles via annihilation products in our Galaxy
  - cosmic & gamma rays & neutrinos, e.g., FERMI, AMS, IceCube, VERITAS,…

Direct Dark Matter Detection

- First-generation experiments now operating or commissioning
  - variety of technologies: ADMX, COUPP, DarkSide, LUX, SuperCDMS, XENON, PICASSO, CoGENT, DRIFT, miniCLEAN, DMTPC, DM-Ice,…
- 2nd Generation DM experiments
  - XENON1t, DEAP3600, XMASS1t under construction
  - R&D funding results for further G2 expts announced soon
  - Downselect expected FY14
  - Results expected 2017-2020

3rd Generation Dark Matter Detection Experiments

- Factor of ~10 increase in sensitivity to WIMP nuclear recoils over G2
- G3 technology choice will be informed by G2 results
  - if detection by G2 or LHC or indirect expts or not
  - Large statistics/mass/cross-section vs. increased sensitivity
  - ability to reach ultralow background rates
- At least two G3 detectors required
  - Different nuclear targets and/or technologies
  - Ready for construction early 2020's



From NRC DUSEL Assessment (2011)

3rd Generation DM Assessment

- "The direct detection dark matter experiment is of paramount scientific importance and will address a crucial question upon whose answer the tenets of our understanding of the Universe depend."

  —2011 NRC DUSEL assessment

- The question of the composition of the matter in the Universe makes the science addressed by these detectors *absolutely central*.
- 3rd generation detectors will build on G2 technology & results; require *significant scientific/engineering challenges to resolve before initiating construction*.

Dark Energy and Cosmic Acceleration

- 2011 Nobel Prize for Discovery of Accelerated Expansion of the Universe
- Is acceleration due to Dark Energy or a modification of General Relativity?
- If it's Dark Energy, what is its nature? Vacuum energy (cosmological constant) or some other physics?
- Cosmic Surveys address these questions by probing expansion history and growth of large-scale structure
  - supernovae, weak & strong lensing, galaxy clustering (Baryon Acoustic Oscillations), clusters
- US (HEP) program for Dark Energy research
  - BOSS, DES (operating)→MS-DESI (2018+)→ LSST (2020's)
  - follows Dark Energy Task Force (Stage III→IV) and "Rocky III"

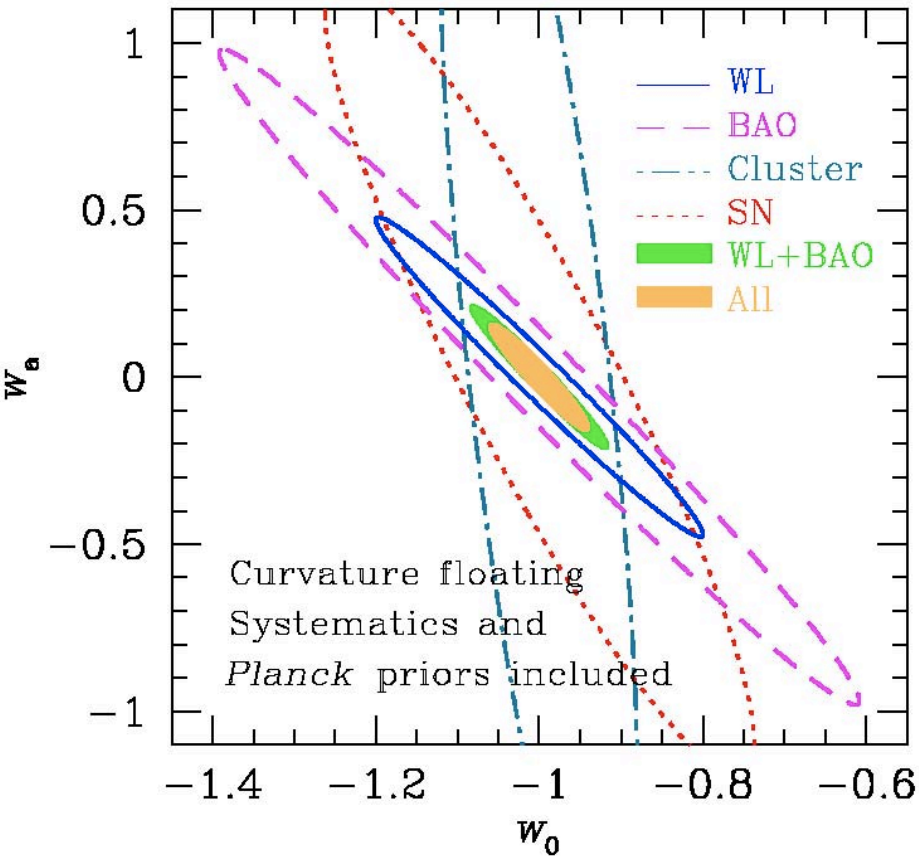
Large Synoptic Survey Telescope

- Highest-ranked large, ground-based project in Astro2010
- 8.4-meter telescope with 3-gigapixel, wide FOV camera at Cerro Pachon, Chile
- Wide, fast, deep surveys of the southern sky over 10 yrs
  - survey 3 billion galaxies over ~18,000 sq. deg. + tens of thousands of supernovae
- Central next-generation (Stage IV) facility for OHEP Dark Energy program
  - Factor 5-10 in Dark Energy reach
  - Dark Energy Science Collaboration recently formed
- Central facility for the NSF US Optical/Near-infrared Astronomy System in the next decade (solar system to galaxies): broad user community
- Project timeline enables “First Light” 2019, survey operations 2022-

LSST

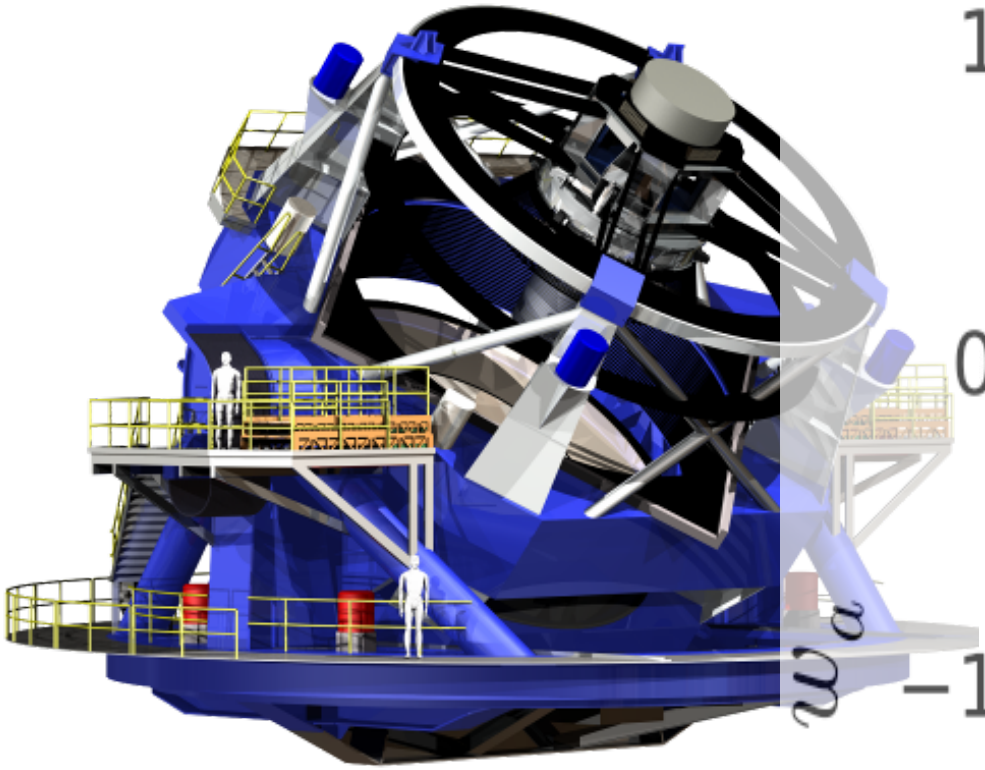
$$w(a) = w_0 + w_a(1-a)$$

8.4-meter Telescope



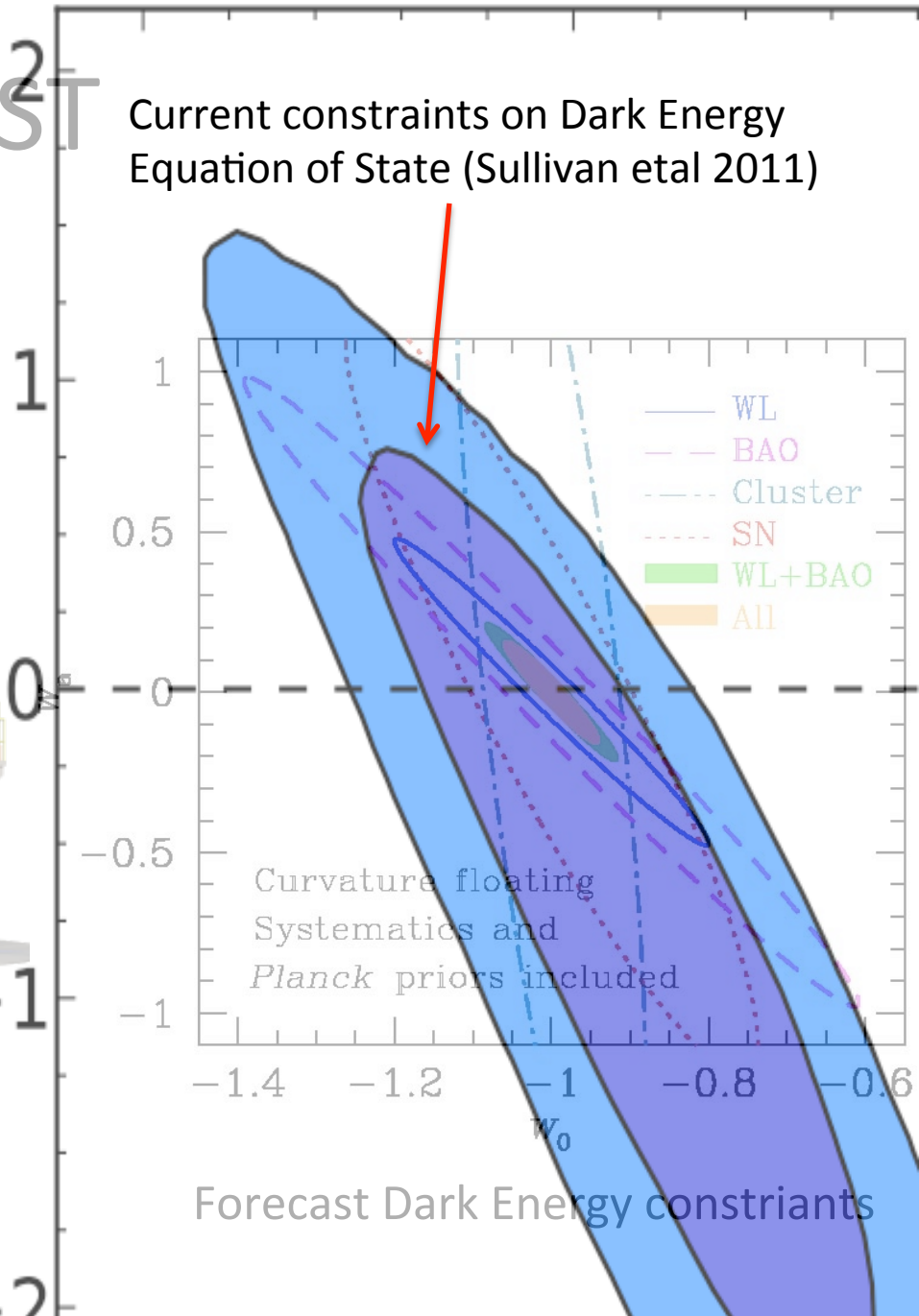
Forecast Dark Energy constriants

LSST



8.4-meter Telescope

Current constraints on Dark Energy Equation of State (Sullivan etal 2011)



Forecast Dark Energy constriants

LSST Assessment

- Determining whether gravity or dark energy is the origin of cosmic acceleration and probing nature of Dark Energy (75% of the energy density of the Universe) are fundamental.
- LSST is a uniquely powerful facility for cosmic surveys through its combination of large aperture, wide field of view, and sensitive, large-format camera combined in a dedicated facility.
- In addressing these questions, LSST will be *absolutely central* to a world-leading particle physics program**.**
- NSB has authorized NSF Director to request MREFC construction funding. LSST camera has been awarded CD-1 approval by DOE and is *ready to initiate construction*.

Next Generation Dark Energy Experiment

- Stage III: BOSS (spectroscopy), DES (imaging)
- Stage IV: MS-DESI (spectroscopy), LSST (imaging)
- Full resolution of the physical origin of accelerated expansion and the nature of Dark Energy expected to require a complementary experiment to LSST.
- Results from Stage III will help inform future directions. Exploratory discussions at Snowmass.
- Discussions will be coupled with astronomy community
- Variety of concepts under discussion, e.g.,
  - Space-based DE experiment (WFIRST NRO)
  - Large optical telescope (LSST spectroscopy)
  - 21cm BAO surveys (radio telescope)
  - SN measurements (Cf. Rocky III)

Next Generation DE Assessment

- Full resolution of the physical origin of accelerated expansion and the nature of Dark Energy expected to require a complementary experiment to LSST.
- Given fundamental importance of these questions, such a facility would be *absolutely central*.
- Readiness will depend on which concept(s) are pursued; *mission and technical requirements are not yet fully defined*.

Cosmic Frontier Conclusions

- Roadmap of progressive experiments in direct dark matter detection: G1→G2→G3
- Program of progressive experiments in probing dark energy and cosmic acceleration: Stage III→ Stage IV (LSST)
- Fully resolving nature of dark energy expected to require next generation DE experiment complementary to LSST.
- Given fundamental importance of these questions, these dark matter & dark energy facilities *absolutely central* to progress in high-energy physics.
- Other areas of Cosmic Frontier research evolving (e.g., CMB) and could lead to future opportunities.