BNL Long-term HEP Research Program

HEP Energy Frontier

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Outline

- Guidance from theory
- Energy frontier colliders after the LHC
- Experimental challenges
- Physics searches and measurements
- Communication with relevant stakeholders
  - Interdepartmental efforts

Guidance from Theory

✓ **We've had remarkable success in the predictions and verifications of SM processes**

- **Firm experimental/observational evidence for physics beyond SM (BSM) *but* our understanding is still rudimentary**
  - i. **Neutrino oscillations**
  - ii. **Dark Matter**
  - iii. **Cosmic Baryon Asymmetry**
  - iv. **Dark Energy**
  - v. **Inflation**

➢ **On-going progress; however, ideas for addressing the above are not necessarily accessible to experiments (could be very weakly coupled to SM or from very high energy scales)**

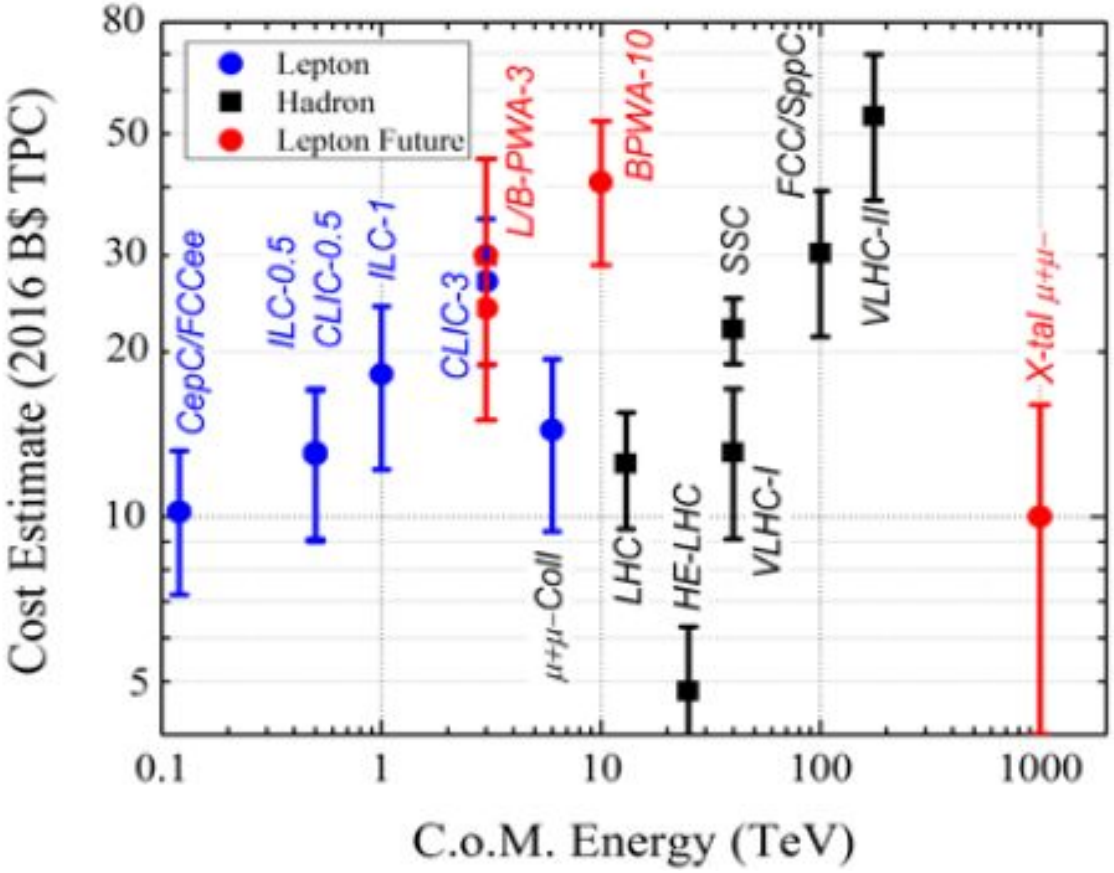
✧ **Also: the entire theory community worldwide is still going through a long drought of successful predictions for BSM phenomena**

➢ **No particular theoretical direction can be rigorously advocated**

➢ **Various energy frontier colliders**

Energy frontier colliders after the LHC

1705.02011



- **HE-LHC financially feasible: < 10B$**
- **CEPC has non-zero probability to go ahead**
- Several machines potentially within the financial reach if undertaken as global projects
- Questionable/prohibitive? FCC, SppC, …

Experimental Challenges

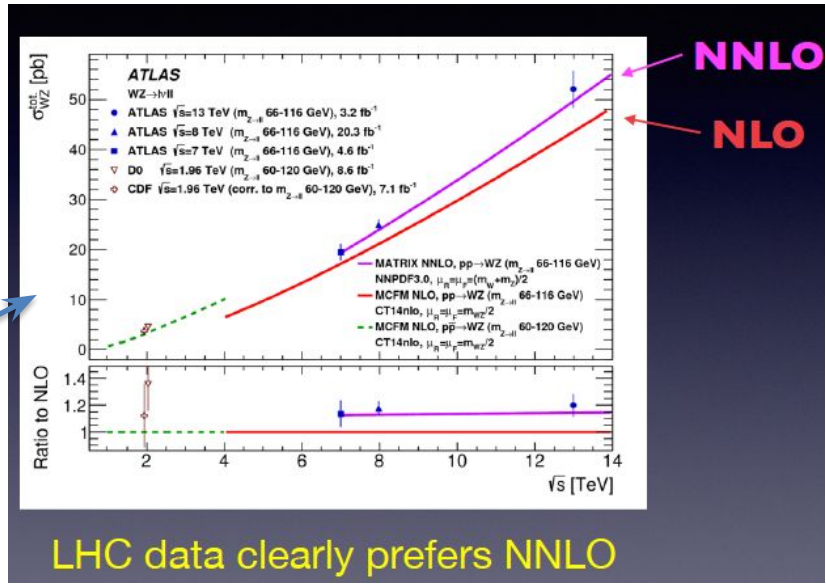
- **Radiation damage**
- **Magnet technology on industrial scale**
- **Computing requirements and data processing**
- **Electronics and triggers**
- **Detector technologies**
- **A sense of scale**
  - **Embedded readout electronics at 1mW/channel → 1.5 MW of power**
  - **Timing on a system scale of millions of channels at ~50ps**
  - **Pile-up reaching 1000 events**

	CMS	ATLAS	CMS HGCal	FCC/SPPC
Diameter (m)	15	25		~27m
Length (m)	28.7	46		~70m
B-Field (T)	3.8	2/4		6
EM Cal channels	~80,000	~110,000	4.3M	70M ($2\times2cm^2$)
Had Cal channels	~7,000	~10,000	1.8M	80M ($5\times5cm^2$)

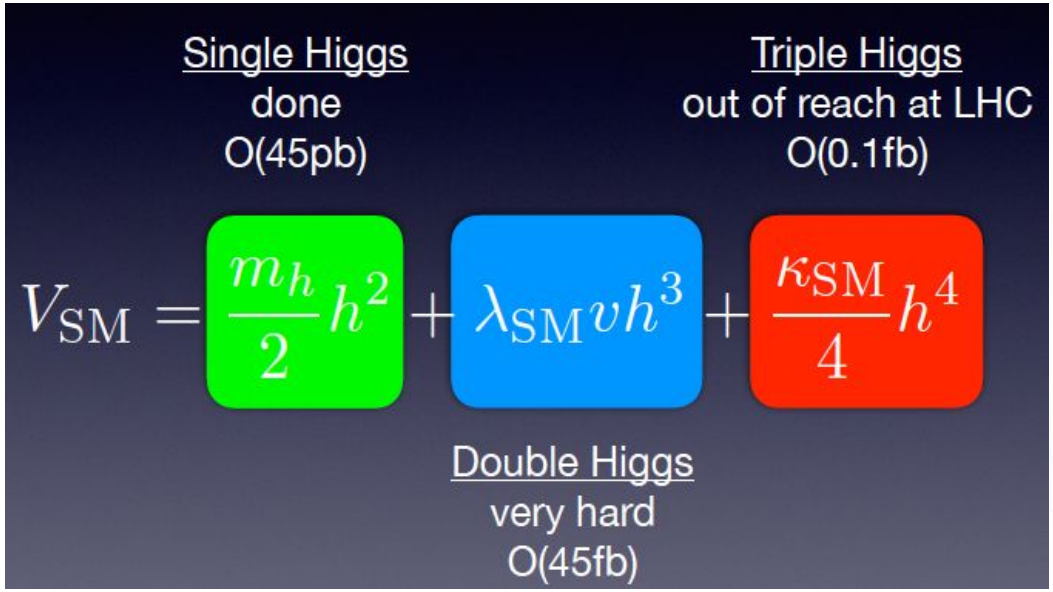
Simply scaling CMS High-Grained calorimeter will require > 5,000 m^2 of silicon

Physics Searches and Measurements

- ✓ **Dark Matter**
- ✓ Vector Boson Scattering
- ✓ **Higgs self-coupling**
- ✓ Flavor anomalies
- ✓ Precision theory calculations at higher orders
- ✓ **We are well situated for the future**
  - ➢ **The challenging area is instrumentation**



Pinning down the Higgs potential



Future bounds on λ from di-Higgs production

LHC Run I, 20.3 fb^{-1} → $\frac{\lambda}{\lambda_{SM}} \in [-14.5, 19.1]$

2γ2b, 1406.5053;
4b, 1506.00285;
2b2τ, 2γ2W, 1509.04670

LHC Run II, 13.3 fb^{-1} → $\frac{\lambda}{\lambda_{SM}} \in [-8.4, 13.4]$

4b, ATLAS-CONF-2016-049

HL-LHC, 3 ab^{-1} → $\frac{\lambda}{\lambda_{SM}} \in [-0.8, 7.7]$

2γ2b, ATL-PHYS-PUB-2017-001

Communication with Relevant Stakeholders

- More focus on cross-department efforts
- Theory-experiment exchange of ideas
  - Promising ideas and their prospects, technical requirements for substantial advance and discovery, feasibility considerations
  - Maybe a brainstorming workshop could be good
- It will take a village
  - Communication with relevant stakeholders & larger NPP community

Conclusions

- **The SM has passed a great variety of tests over decades and currently provides the most precise description of microscopic phenomena**
- **Along the way solid evidence for BSM has appeared: neutrino masses, dark matter,... but our understanding is still preliminary and their underlying dynamics may be hard to access by experiments**
- **Going beyond the LHC**
  - **There is no firm theoretical guidance on the new physics energy scale (*no obvious no-lose theorem, unlike the case for the Higgs*)**
  - **Different energy frontier colliders are proposed but HE-LHC seems the most realistically feasible, technically and financially, with significant reach beyond current energy frontier**
  - **Many experimental challenges are expected in radiation damage, magnet, computing, electronics, trigger and detector designs**
  - **CEPC could offer precision measurement program, potential pp upgrade considered as well**

➢ ***BNL should plan to be a leader in shaping the post-LHC discussion***

However success will require communication and involvement of the larger NPP community