Welcome to the

CEEM

Center for Exploration of Energy and Matter

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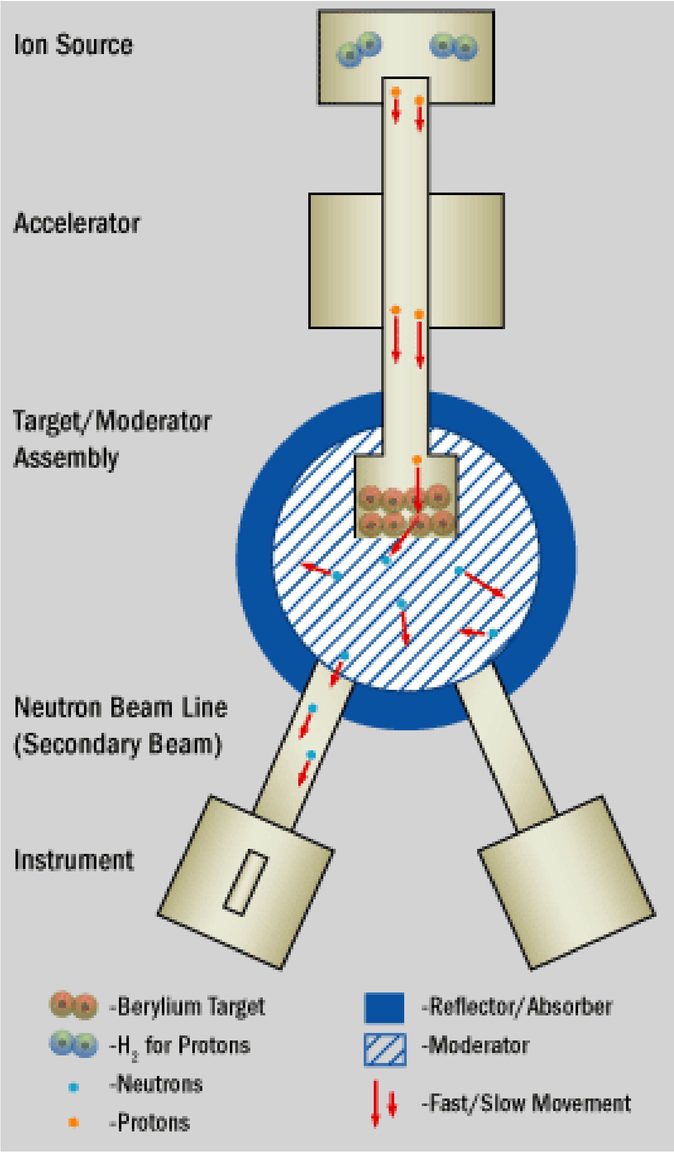
INDIANA UNIVERSITY

What is CEEM?

The **Center for Exploration of Energy and Matter** (CEEM) is a multidisciplinary research facility – the continuation of a tradition of scientific excellence at Indiana University – with 20 faculty, 5 postdocs, 25 graduate students, ~15 undergrad students, and 8 professional / technical and support staff. Key research areas include **theoretical and experimental nuclear physics, and condensed matter (n scattering).**

CEEM resides in the **Multidisciplinary Engineering and Sciences Hall (MESH)**, which also houses IU's **Intelligent Systems Engineering**, our world-renown ***Drosophila* lab,** (Biology) and one of the largest **machine shops** in Indiana.

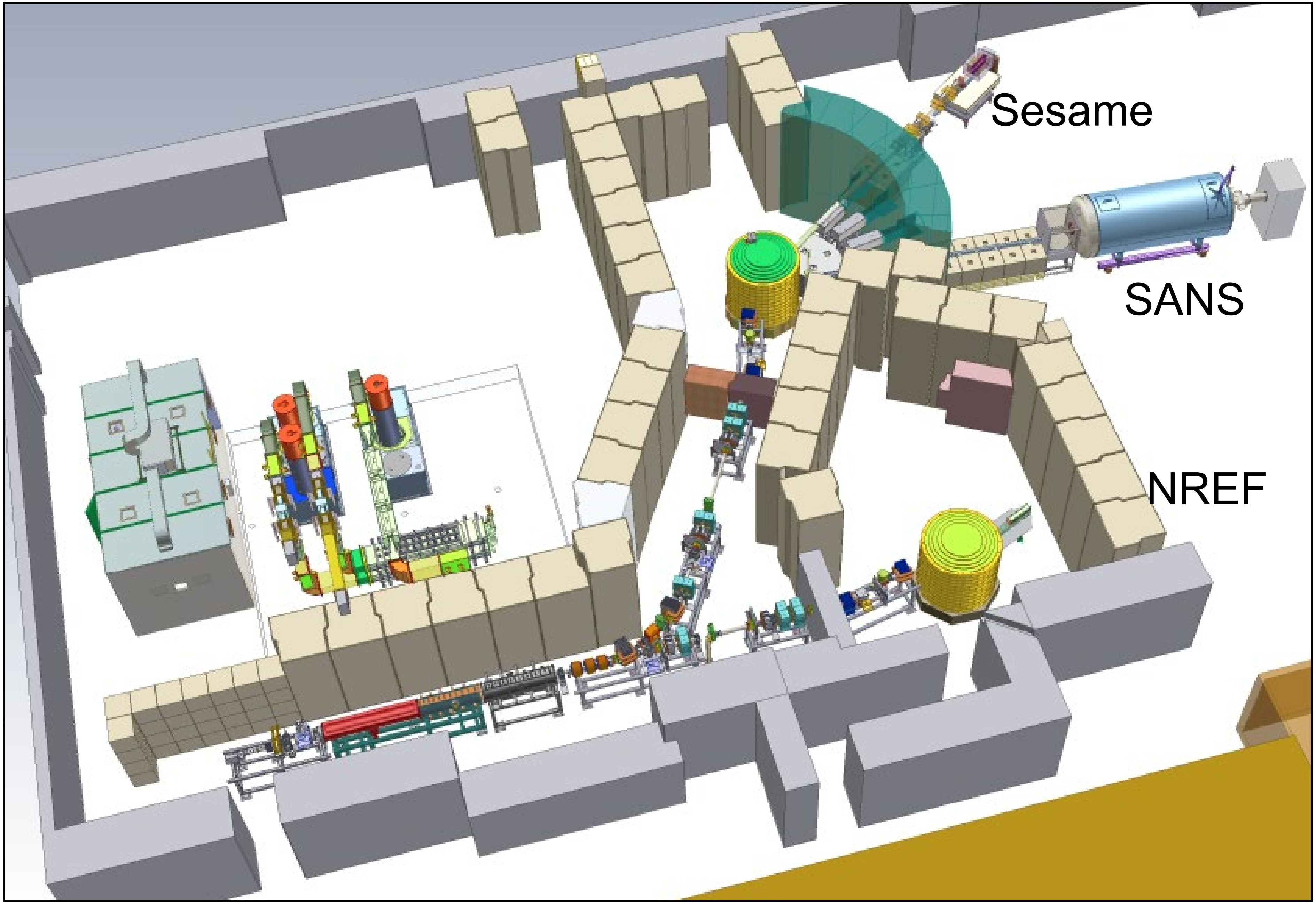
Neutron Science at CEEM – LENS



LENS: a **L**ow **E**nergy **N**eutron **S**ource

Unique facility for carrying out studies in materials science and neutron radiation effects

And: excellent environment for developing new instruments for neutron scattering and detection, new methods for producing and controlling properties of neutron beams, and providing a facility for nREF studies for commercial and defense applications.


Sesame
SANS
NREF

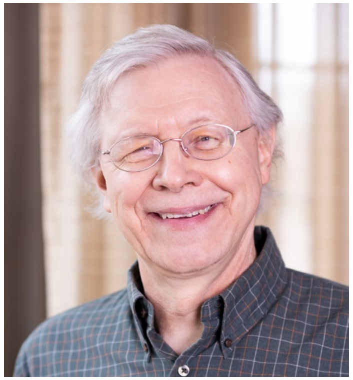
Experimental Nuclear Physics at Indiana

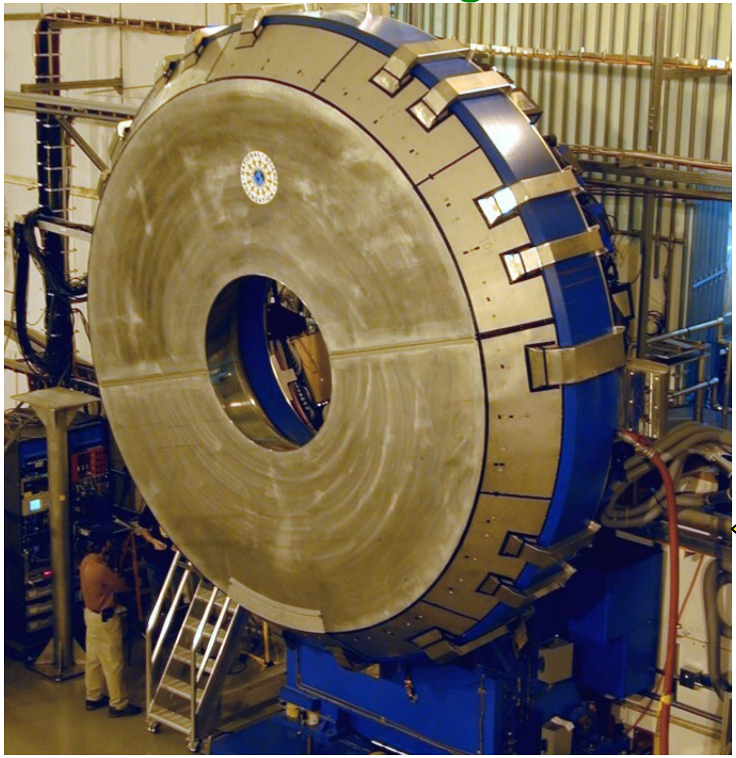
- **Large group**: 7 teaching faculty, 4 research faculty, 4 post-docs, ~20 grads, many undergrads, support staff, …
- ***IU Nuclear Physics graduate program (expt + theory) ranked #6 in US, strongly supported by NSF, DOE, other agencies***
- Play **leading roles** in high-priority exp'ts at many national labs (RHIC@BNL, FNAL, LANL, NIST, SNS@ORNL, FRIB@MSU, GlueX@JLAB) and internationally (Belle-II@KEK, GANIL)
- Use excellent resources / infrastructure / professional support of MESH and CEEM to develop and build cutting-edge equipment for particle detectors, cryogenic devices, front-end electronics
- ***Strong track record among Ph.D.'s: ~40 graduates now in faculty/staff positions at major research universities and national labs, many more in industry, medical physics***

Nucleon structure: using QCD to probe protons

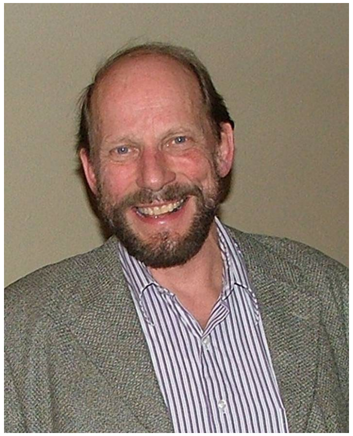
Use high-energy, polarized proton collisions to learn:

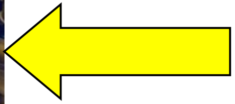
- How do the *gluons, the* virtual field quanta that bind quarks together inside a proton contribute to the *spin* of the proton?
- What role is played by *sea anti-quarks*? Do up and down anti-quarks contribute with opposite sign to the total spin?
- Is *transverse motion* of the partons within a proton correlated with orbital angular momentum, and hence the proton's spin?





How can we *use* QCD to understand how proton properties 'emerge' from this system of strongly interacting partons?





The 30 ton, 20-foot diameter *Endcap Electromagnetic Calorimeter (EEMC),* designed and built at CEEM, is part of the STAR detector system at RHIC

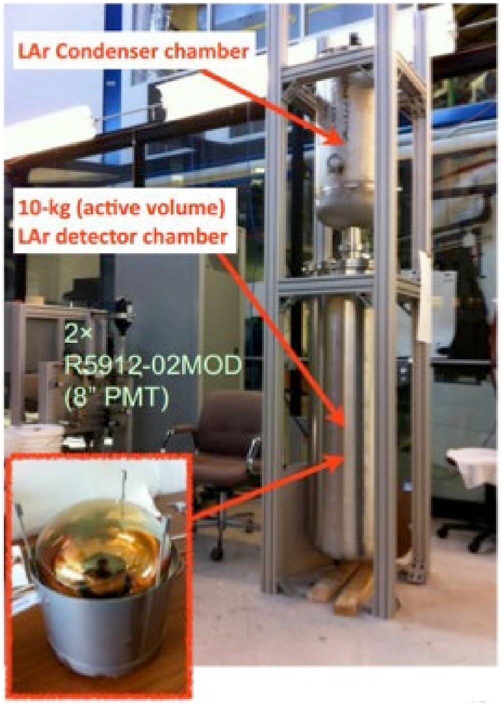
Neutrinos: their properties and behavior

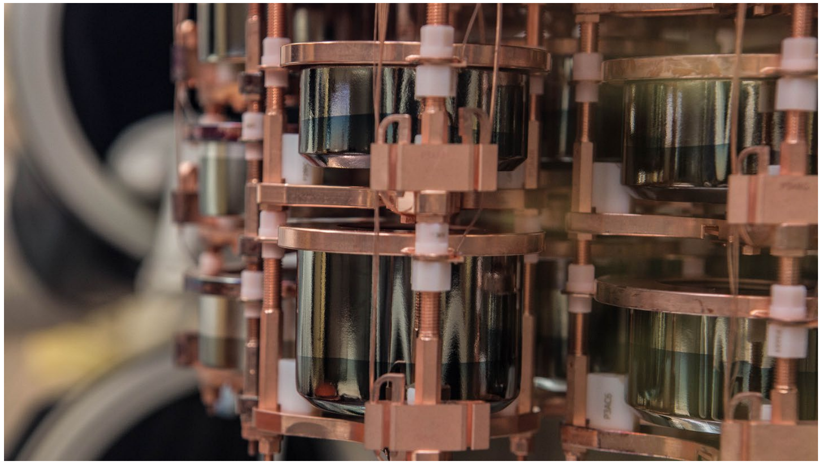
Leaders in COHERENT Collaboration → first observation of ν's scattering "coherently" from entire nucleus, as predicted. Cover of *Science* and others

Plan to lead improved measurements of CEvNS *in Ar, determine absolute neutrino flux using D_2O detector,*

Develop 1-ton Ar detector for CEvNS,

DUNE supernova detector calibration, accelerator-based dark matter search

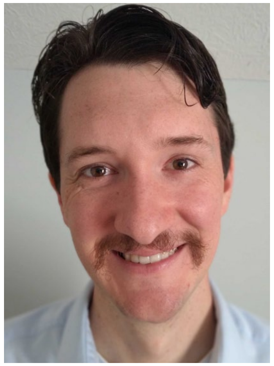




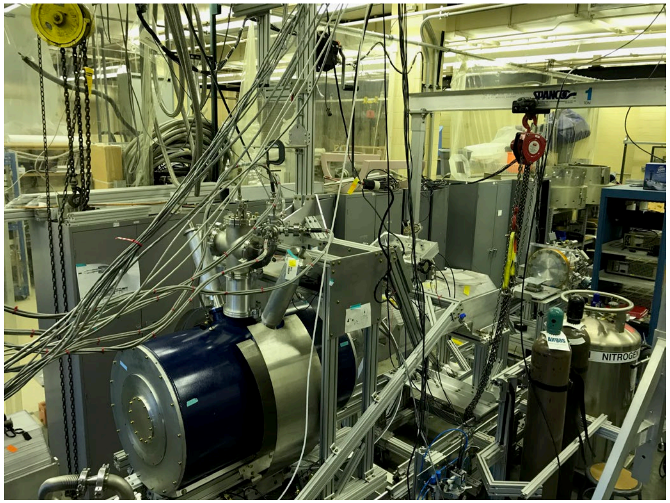
LEGEND: ^{76}Ge neutrinoless double beta decay experiment, → determine if $\nu = \overline{\nu}$

Start commissioning 200-kg exp't experiment in Italy now

Project 8: precise measurement of tritium decay endpoint → directly determine neutrino mass

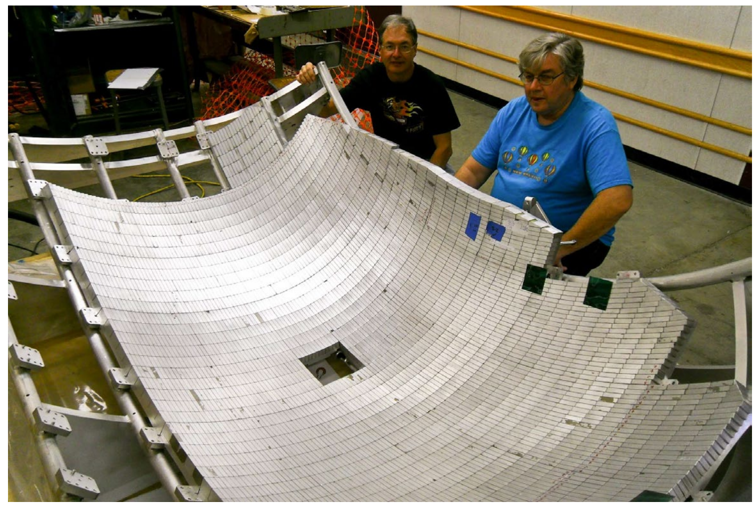


Neutron properties and precision measurements

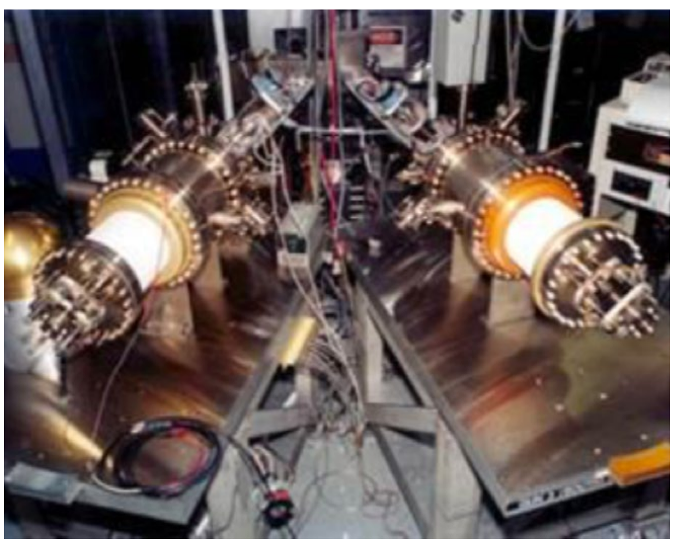


Search for parity-violating “spin rotation” of n in ^{4}He → evidence for exotic spin force

NOPTREX: search for time-reversal violation in *n*+*A* resonance spectroscopy



Use UCNτ apparatus, designed and built at CEEM, to measure n lifetime to accuracy of 0.1% (world best)



Use precision PV *e*-scattering as a tool to:

Measure thickness of ‘neutron skin’ in heavy n-rich nuclei → properties of neutron stars

MOLLER: ultra-precise study of polarized e-e scattering → search for BSM physics

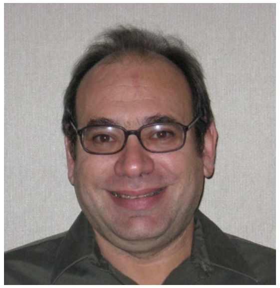
Addressing critical questions in Nuclear Theory

Coulomb gauge Quantum Chromodynamics: a new formalism to describe hadron structure and quark confinement

Partial Wave Analysis: analyze scattering experiments to uncover new, possibly "exotic" hadrons and their properties

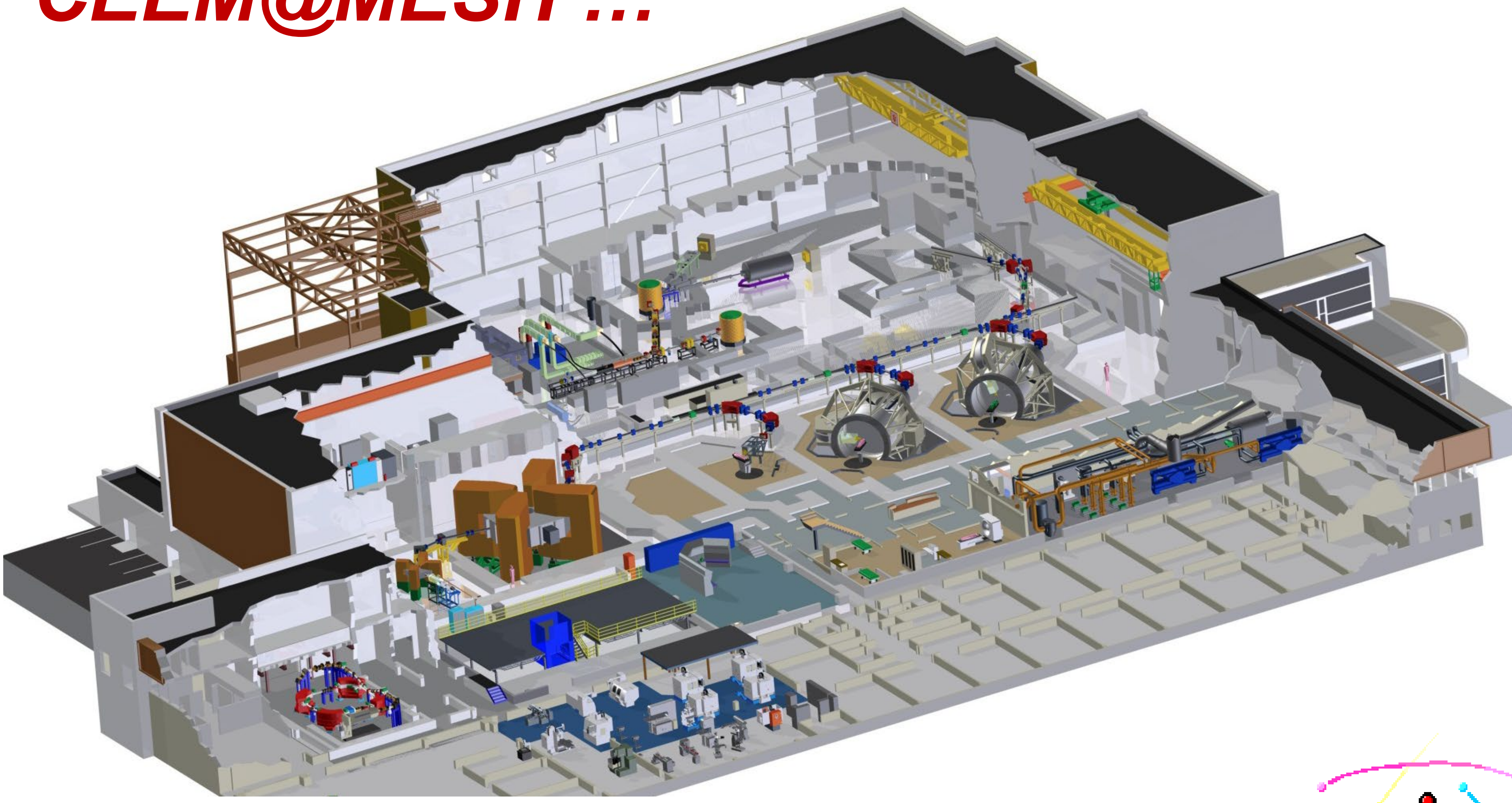
Precise predictions for strongly-interacting elementary particles in nonperturbative QCD. Using Chiral Perturbation Theory and Dispersive methods to extract fundamental parameters of nature and test the Standard Model and its extensions.

Theory of hot nuclear matter and phenomenology of high-energy heavy ion collisions, leading to formation of quark-gluon plasma. Investigate the unusual properties of the QGP and novel quantum phenomena that emerge in this matter created at RHIC and LHC



Large-scale virial and relativistic mean field calculations of the pressure of dense nuclear matter as a function of density and temperature – results relevant in astrophysical simulations of supernovae, neutron star mergers, and black hole formation.

CEEM@MESH …



Enjoy the tour! We’re glad you’re here!