Irradiation Facilities for HEP Detectors

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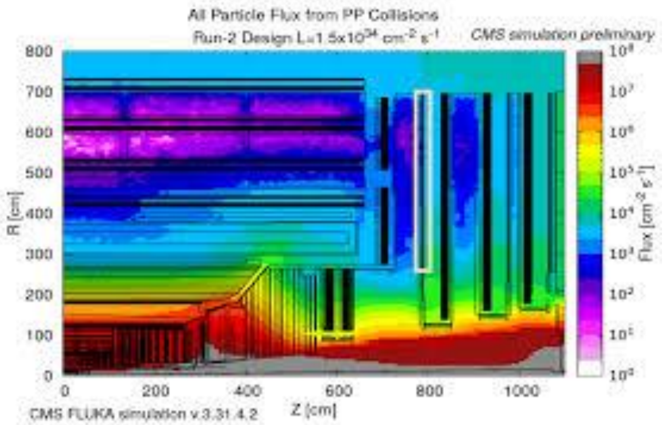
Outline

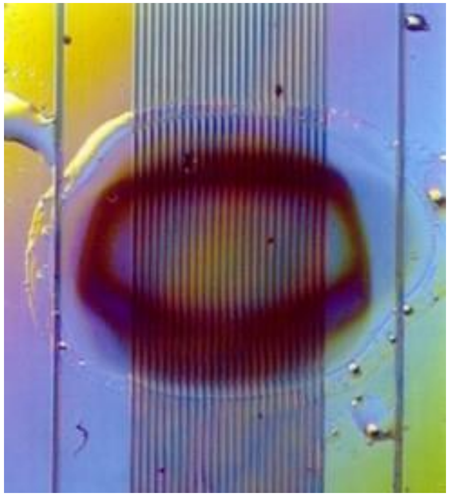
- Applications for irradiation facilities for HEP detectors
- Overview of worldwide facilities for HEP detectors
  - N.B.: LANL's facility covered in separate talk
- Synergies with other fields
- Future needs

Snowmass White Paper: "Test Beam and Irradiation Facilities"
https://arxiv.org/abs/2203.09944

Applications for irradiation facilities

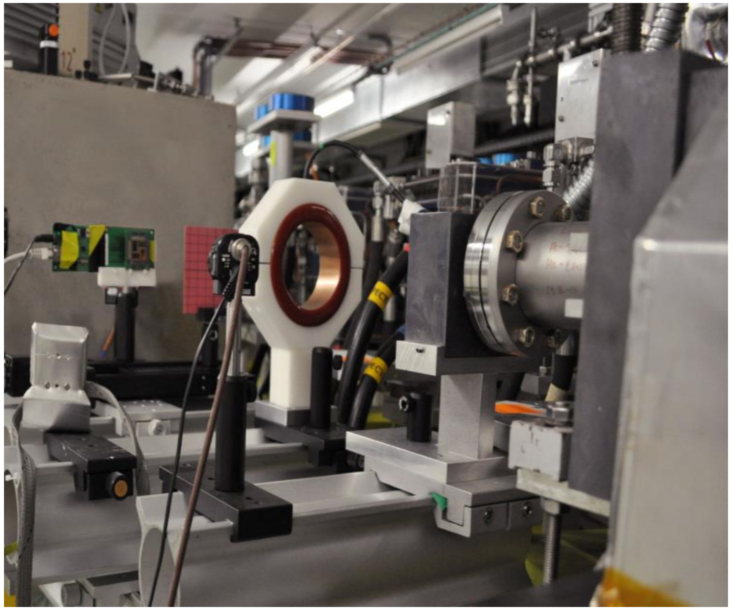


- Allow HEP community to test the lifetime and performance of their detectors (sensors, electronics, materials) under realistic radiation conditions
  - for every new experiment we push technological boundaries, need to verify radiation hardness with every new design
- Crucial especially for collider detectors and some space-based astro-particle physics experiments
- Custom detector components often need to be developed to sustain intense radiation fields
  - off-the-shelf parts usually not radiation hard



Applications for irradiation facilities

- Current main applications (HEP and NP):
  - silicon sensors (bulk and surface damage)
  - crystal and plastic scintillators
  - ASICs and other readout electronics (including live Single Event Effect [SEE] testing)
  - auxiliary components: e.g. DCDC converters
  - materials: e.g. glues, support structures, packaging, novel sensing materials
- Synergies with material development for accelerators and targets exist, though they typically need much higher doses
- Need realistic particle content, energies, fluence/dose
  - typically use protons or neutrons for bulk damage and SEE testing
  - high-rate electrons or photons useful for surface damage and SEE studies



Current requirements

- Irradiation areas around the world are in high demand, often difficult to obtain beamtime
- Present HL-LHC use case: measure total integrated dose on the order of 10^{16} - 10^{17} 1 MeV n_{eq}/cm^2 on a reasonable timescale (days/weeks)
  - Future collider needs would go up to 10^{18} n_{eq}/cm^2
- At the same time there is significant electronics component testing for a variety of applications that need much lower beam rates on the order 10^6 – 10^{10} particles/second which requires either dedicated facilities or a beam with significant range

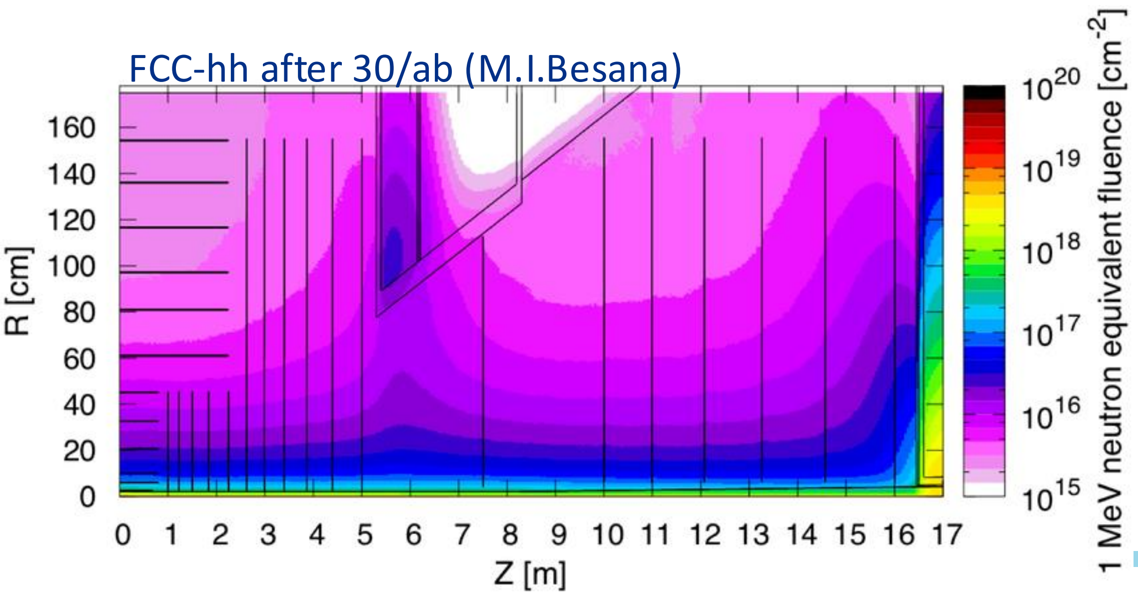
Some of the current facilities

main workhorse e.g. for HL-LHC

Facility	Particles	Energy Range	SEE Testing
BASE (LBNL, US)	p, n, heavy ions	1-55 MeV	yes
CERN (Geneva, CH)	p	24 GeV	yes
CNL (UC Davis, US)	p, n	1-67.5 MeV	yes
CYCLONE (Louvain, BE)	p, heavy ions	14.4-65 MeV	yes?
FACET-II (SLAC, US)	e^-	10 GeV	n/a
GIF (Sandia, US)	n/gamma, heavy ions	1.17-1.33 MeV	yes
HFIR (ORNL, US)	gamma	-	yes
ITA (FNAL, US)	p	400 MeV	yes
KAZ (Karlsruhe, GE)	p	23 MeV	yes?
LANSCE (LANL, US)	p	800 MeV	no
NSRL (BNL, US)	p, heavy ions	50-2500 MeV	yes
PIF (TRIUMF, CA)	p	5-500 MeV	no
RINSC (Rhode Island, US)	n	-	no
SEUTF (BNL, US)	heavy ions	1-350 MeV	n/a
TRIGA (Ljubljana, SI)	n	few MeV	no

Future needs

- Future collider-based experiments will experience unprecedented radiation exposures of 10 Giga Gray ionizing dose and fluences of 10^{18} 1 MeV n_{eq}/cm^2 over their lifetimes
- Detectors, support structures, electronics, data transmission components, and on-board data processing units will all need to be evaluated for performance at these dose rates and integrated doses two orders of magnitude greater than systems operating today
- This will require new high-dose-rate environments for accelerated testing so that the anticipated integrated dose can be delivered in days rather than months or years.



Activation of the detector materials will limit facility throughput unless remote material handling techniques are implemented (robotics). Benefit from expertise with accelerator components, targets and windows for neutrino beam lines

Community recommendations

- **Detector BRN:**

  The BRN report highlights very precise test beams (in multiple dimensions: spatial, energy spread, timing, and intensity) as an important area where US-based facilities can play a world-leading role

- **Snowmass:**

  IF09-5 Facilities (mainly at National Labs) are a vital element of detector technology development and should be supported. Present gaps that could be strengthened include: high-quality electron test beams, multi-TeV test beams, user access to low-temperature facilities covering liquid noble elements down to mK temperatures, low-noise - including vibration, RF, radioactive and cosmics - high-dose irradiation, and foundry access for radiation-hard microelectronics, semiconductor detectors, and superconducting devices for both development and production.

- **P5:**

  To enable groundbreaking detector innovation and US leadership in this field, we need to invest in a coherent set of modernized facilities with enhanced capabilities. These include test beam and irradiation facilities with beam properties and intensities appropriate for future experimental demands, low-background and underground facilities, cleanroom space, access to nano-fabrication facilities, and microelectronics foundries.

Synergies

- Test beam and irradiation facilities attract interest from beyond the HEP community. Irradiation facilities in particular, are a scarce commodity in high demand both in the broader scientific community (e.g. radiation hardness testing for NASA missions) and in the private sector (aerospace).
- HEP users benefit from non-HEP facilities, e.g. at hospitals, for their irradiation needs (at cost, very limited availability)
- Many user facilities have a charge model for beam time for private companies that support the facility
  - could envision:
    - HEP users: free of charge
    - non-HEP, DOE-SC: t.b.d.
    - non-DOE-SC: to be charge fair share

Summary

- Irradiation facilities play crucial role when developing next generation detector technologies
- Beamtime at current facilities sparse and beam/facility properties not always optimal

- Detectors at a future 10 TeV pCM collider could experience two orders of magnitude harsher radiation conditions

➔ We need to develop completely new technologies, and we need adequate facilities to test these under realistic conditions