Warm, Dense Plasmas using the Proton Beam from PSR

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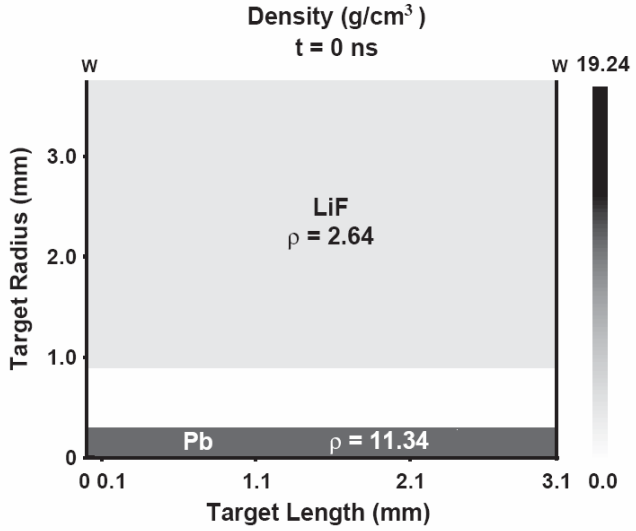
Heavy ion-induced high-energy density states in matter at the GSI Darmstadt SIS-18*

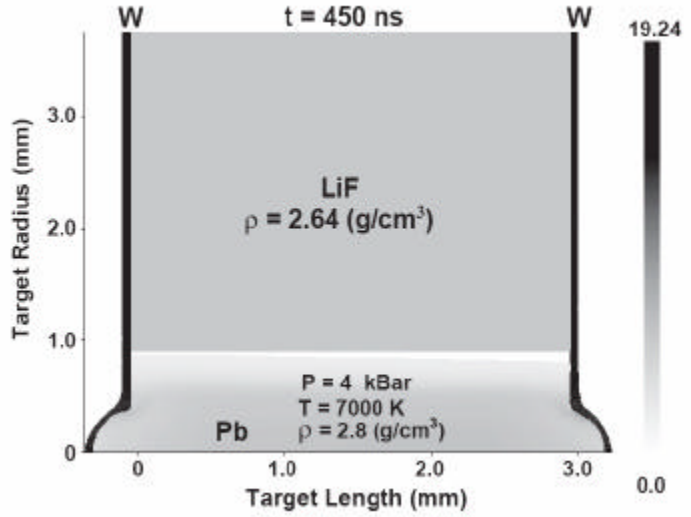
A cylindrical target is irradiated with a uranium beam of 0.5 GeV/u, an intensity of $1x10^{10}$, and a pulse duration of 300 ns. The beam power deposition profile along the radial direction is a 1.0 mm FWHM Gaussian. Calculations for 0.3 mm radius and 3 mm long Pb target surrounded by a LiF cylinder with an inner radius of 0.9 mm gives:

– 1.7kJ/gr beam deposition

– at 300 ns, the beam deposits 1.7 kJ/gr leading to a temperature of 9500 K, ~20 kbar

– at 450 ns, an outer shock front has almost filled the inside of the LiF cylinder with material at 7000 K, 4 kbar, and 2.8 gr/cm^3





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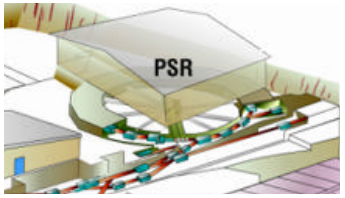
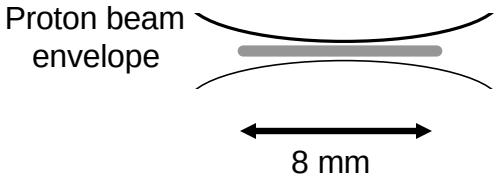
*Tahir N. A. et al, Nucl. Inst. Meth. in Phys. Rev. A 544 (2005) 16–26

The PSR pulse can be used to generate HEHD states comparable to the proposed SIS-18 experiment

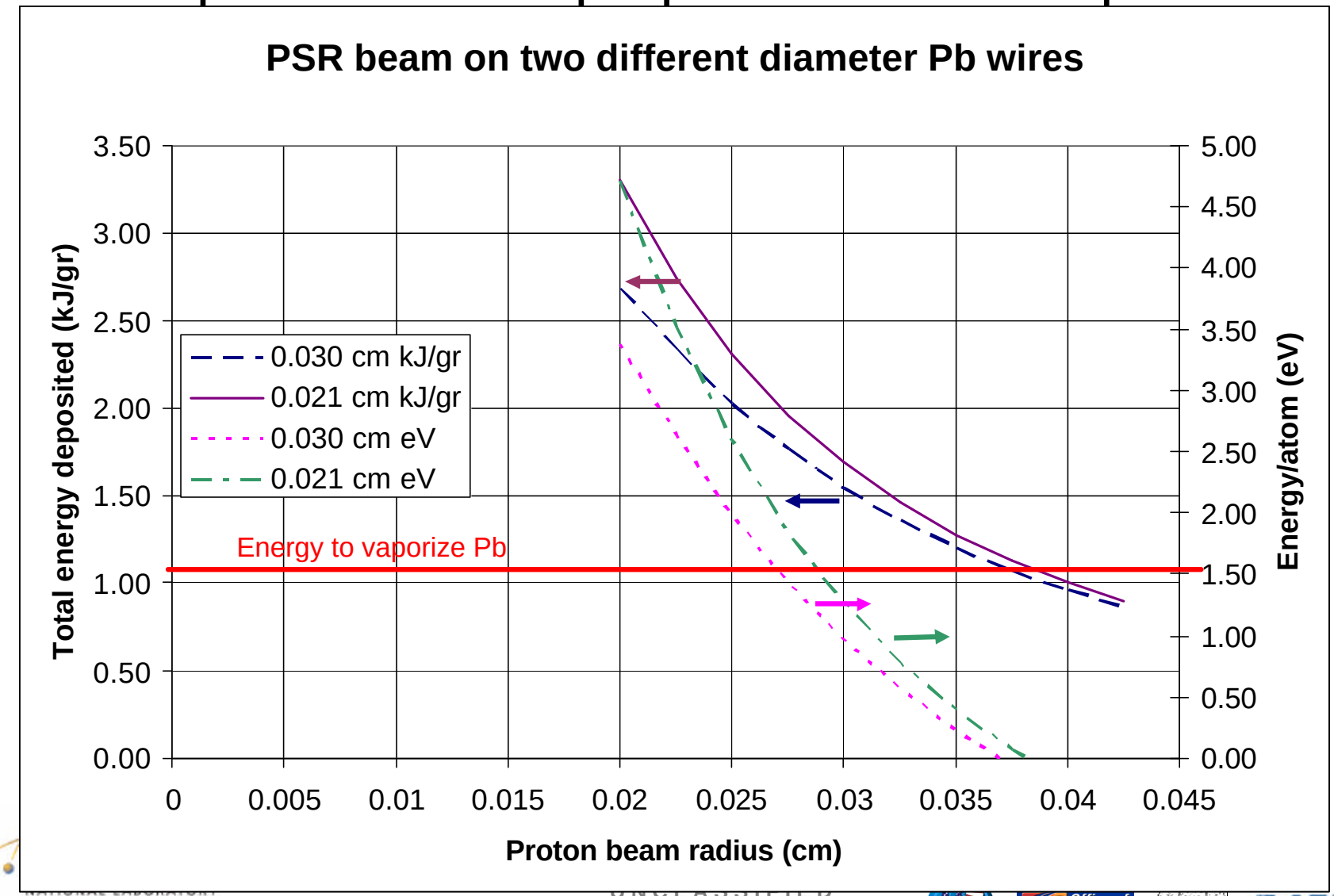
- The PSR beam has the following demonstrated performance: 8μC/pulse, 330 ns pulse length, ε_h = 6.3 π mm-mrad, ε_v = 10.3 π mm-mrad, 800 MeV.
- Target: Pb wire 0.22 mm radius and 8 mm long
- Beam at target: minimum 0.3 mm radius that expands to 0.33 mm at wire end and deposits 11 MeV in the Pb.





- Energy partitioning
  - Heating and vaporizing wire: 1.1kJ/gr
  - Residual energy for plasma excitation: 2.8 kJ/gr.
- For comparison, proposed SIS-18 experiment has
  - 0.3 mm radius and 3 mm long Pb target
  - Heating and vaporizing wire: 1.1kJ/gr
  - Residual energy for plasma excitation: 3.2 kJ/gr.

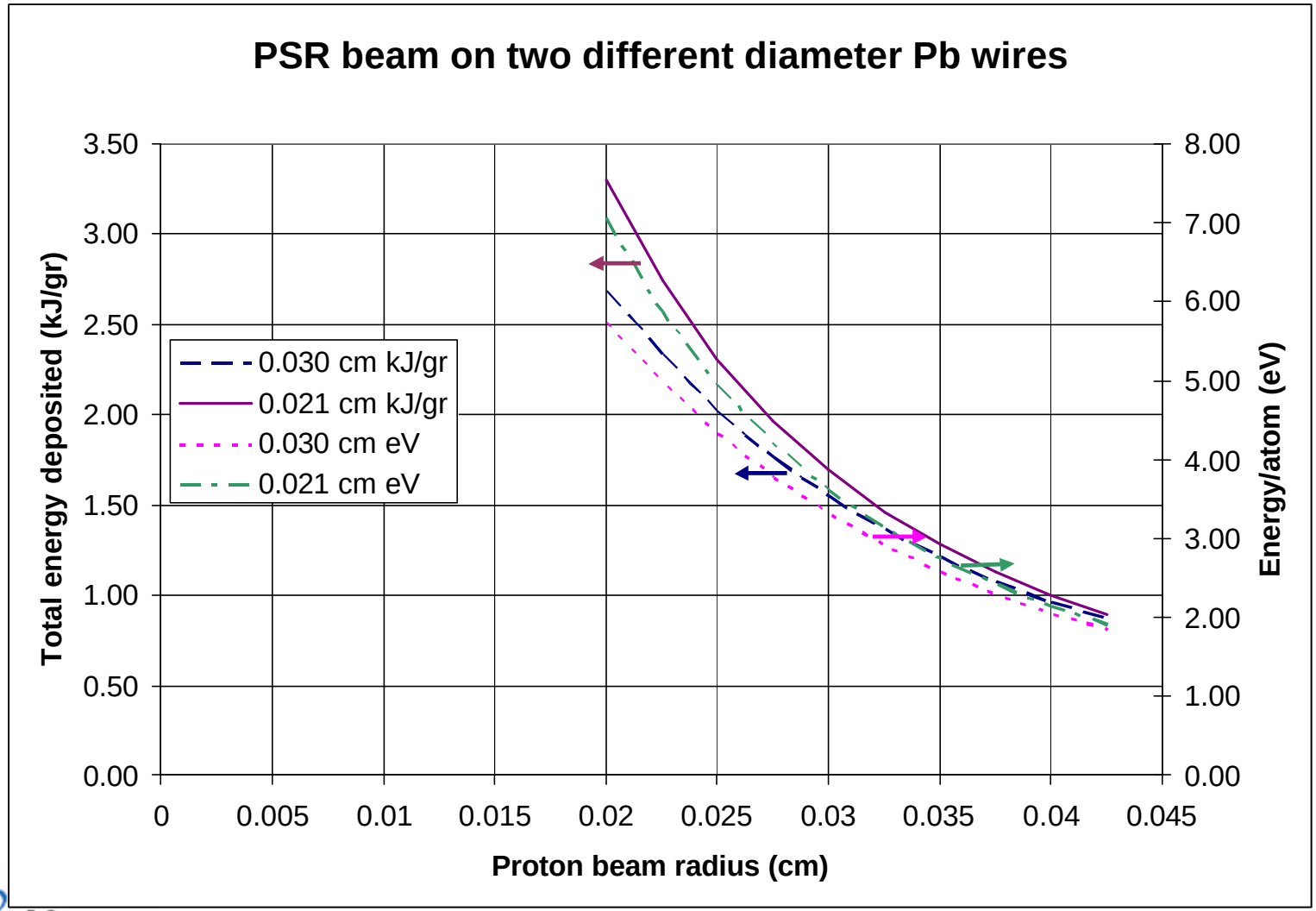
The PSR pulse can be used to generate HEHD states comparable to the proposed SIS-18 experiment



Wire pre-heating provides more energy that goes into heating the plasma and allows for other target materials

- For Pb, 1.1 kJ/gr goes into vaporizing the wire. Preheating allows either:
  - increasing the deposited energy density by 50% to 4 kJ/gr compared to 2.8 kJ/gr
  - doubling the wire diameter to 0.45 mm and deposit the same energy density.
  - Using shorter PSR pulses (proportionally less energy)

Wire pre-heating provides more energy that goes into heating the plasma and allows for other target materials



Wire pre-heating provides more energy that goes into heating the plasma and allows for other target materials

Other targets can be considered:

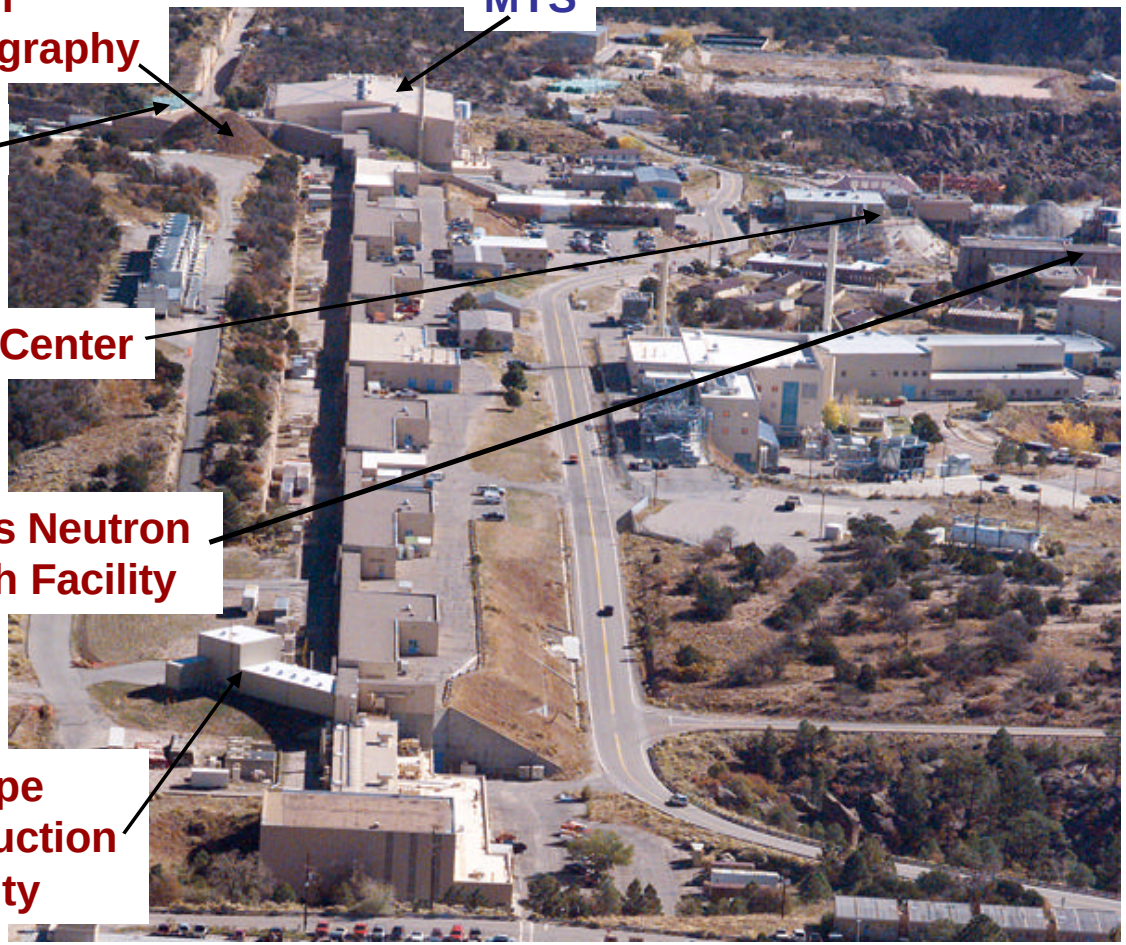
- Targets such as Au, W, Ir, Pt, Re, or U are 80% denser and results in denser plasmas, thus increasing the plasma pressures (~x2 effect).
- Other materials have a higher material density to vaporization energy ratio, giving higher final temperatures (~10% effect).

Wire pre-heating is well within state-of-art

- Density measurements have been made on exploding wire-initiated plasmas using tungsten wires*
  - Tests were on 7.5 to 40 μm W wires carrying 15–120 kA per wire for 30–70 ns.
  - The rapidly expanding ~few mm/μs coronal plasmas surrounding the slowly expanding <1 mm/μs residual wire cores have areal densities up to about $2 \times 10^{18}/cm^2$
  - Coronal plasma W number densities were estimated to be up to a few times $10^{18}/cm^3$, while core W densities as low as a few times $10^{20}/cm^3$ were observed.

*Pikuz, S. A. et al, Phys. Plasmas, **6** 11 (1999) 4272

Unlike any other user facility worldwide, LANSCE operates four major areas for basic and applied science

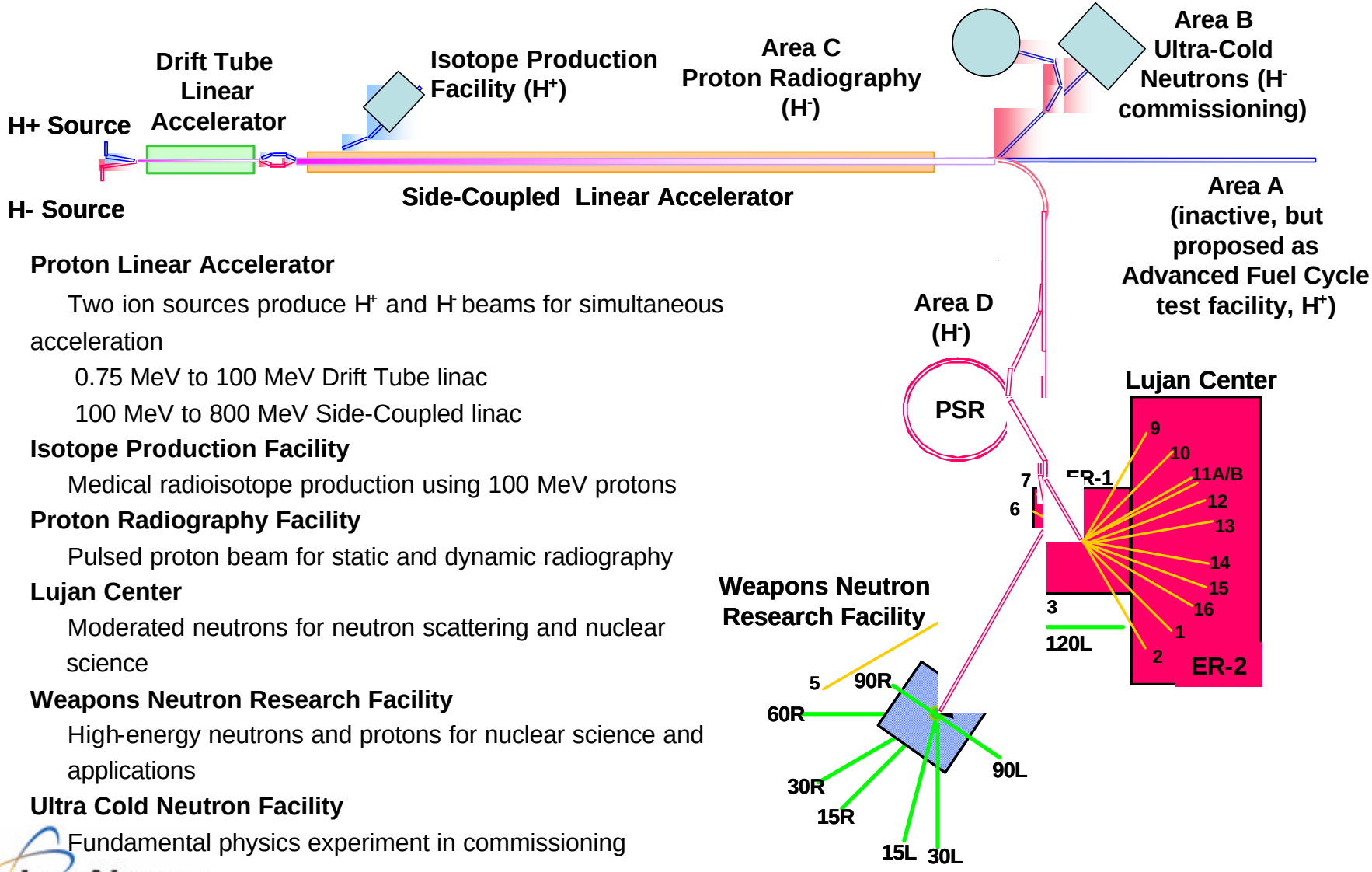


- Three consecutive highly successful operating cycles as a national user facility
- The LANSCE user program is now as large as was the program at LAMPF
- A lifetime extension project is needed to keep LANSCE vital and to provide the foundation for the future

Each of the three user facilities at LANSCE are equal to the best now existing in the world in capability and usage

- Proton Radiography Facility (unique)
  - Scheduled operation in 2005 for > 4000 hours
  - Power - as required for experiment
  - User Program - 15 dynamic shots approved by PAC
- Lujan Center - neutron scattering and nuclear science
  - Scheduled operation in 2005 for >4000 hours
  - Power - 110 kW
  - User Program >500 user visits, >150 experiments (1/3 for weapons program)
- Weapons Neutron Research Facility - nuclear science, radiation effects, and shock physics
  - Scheduled operation in 2005 for > 4000 hours
  - Power - 4 kW
  - User Program >500 user visits, >75 experiments (1/4 for weapons program)

The LANSCE user facility operates for 6-8 months per year in 24/7 mode with unmatched versatility worldwide



Proton Linear Accelerator

Two ion sources produce H^+ and H^- beams for simultaneous acceleration

0.75 MeV to 100 MeV Drift Tube linac

100 MeV to 800 MeV Side-Coupled linac

Isotope Production Facility

Medical radioisotope production using 100 MeV protons

Proton Radiography Facility

Pulsed proton beam for static and dynamic radiography

Lujan Center

Moderated neutrons for neutron scattering and nuclear science

Weapons Neutron Research Facility

High-energy neutrons and protons for nuclear science and applications

Ultra Cold Neutron Facility

Fundamental physics experiment in commissioning