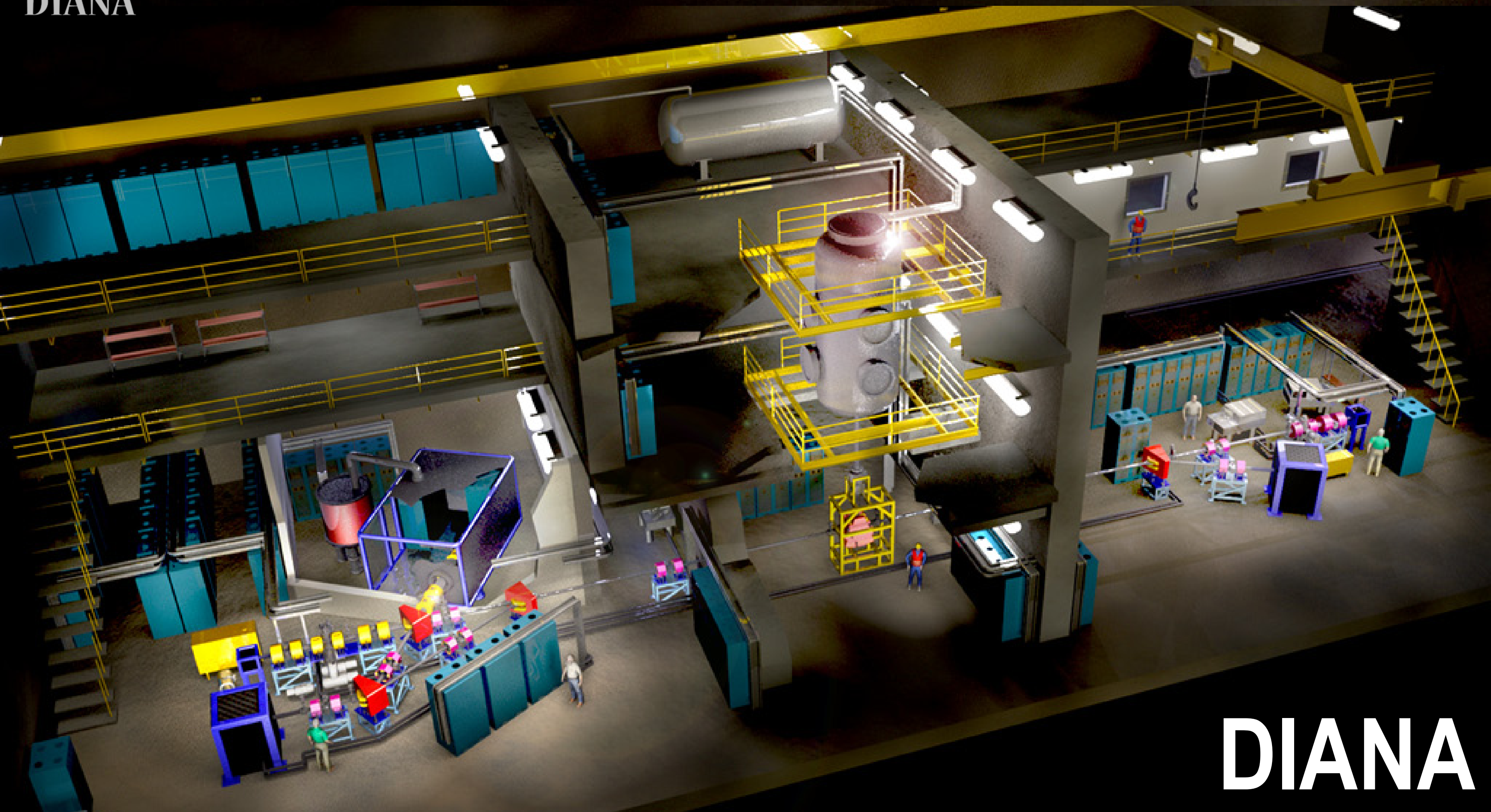


DIANA

A NEXT GENERATION DEEP UNDERGROUND ACCELERATOR FACILITY

D. Leitner for the DIANA collaboration
Michigan State University

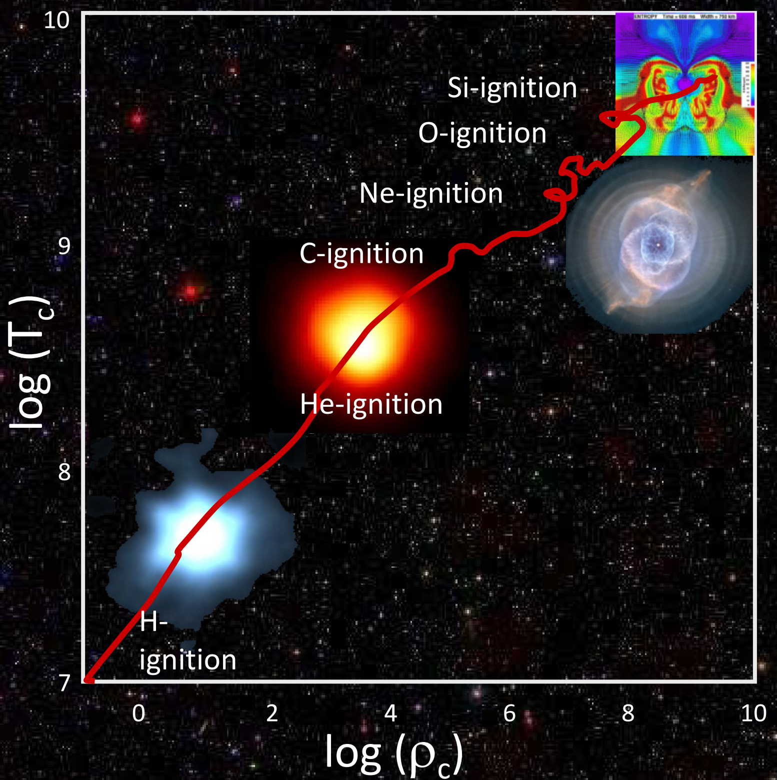
PAC'2011
New York, April 2011

Outline of the Talk

- Why underground ?
- Brief science motivation
- Consequences of the science goals for the design
- Accelerator Design
- Status

Astrophysics Underground Accelerator DIANA

Addresses two key questions identified in the nuclear science long range plan

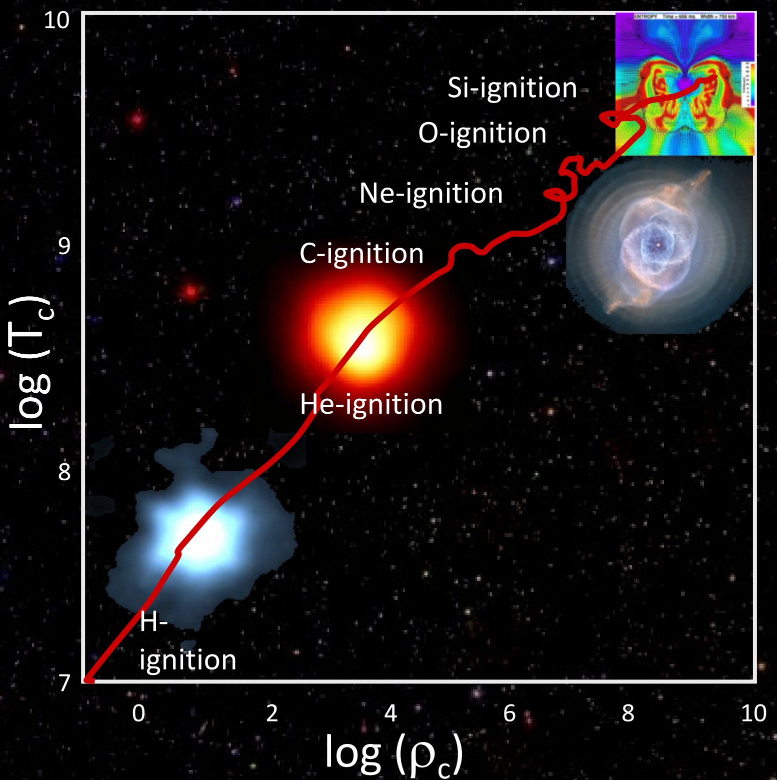


- **What is the origin of the elements in the cosmos?**
- **What are the nuclear reactions that drive stars and stellar explosions?**

NP long range plan identifies a opportunity for a DIANA type facility at DUSEL:

'The **direct measurement of reaction rates on stable nuclei** that **require high-intensity beams**, and are needed to model stars and novae, also presents enormous challenges. The largest handicap is the small cross section coupled with large natural background, which prohibits the detection of the characteristic reaction signals.
The use of **underground based low-energy accelerator facilities**, as demonstrated by LUNA at the European Gran Sasso underground laboratory, **significantly reduces cosmic-ray-induced background by several orders of magnitude**. This approach is complemented by the development of active background-reduction techniques based on event identification or inverse kinematic techniques to reduce the natural radiation and beam induced background. **DUSEL will provide an opportunity for the development of such a facility in the United States.**'

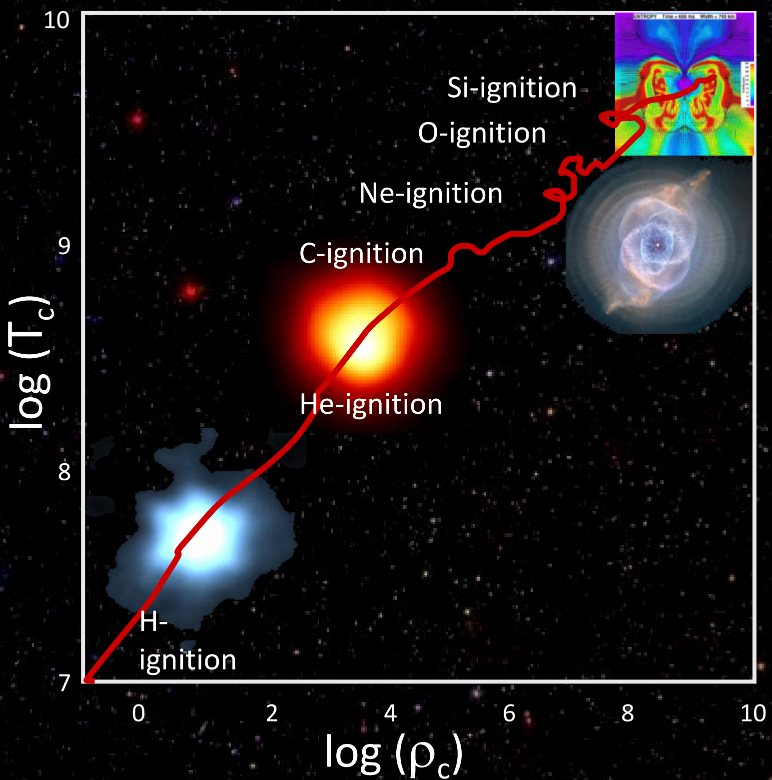
DIANA will address three fundamental scientific questions



- Solar neutrino sources and the metallicity of the sun
- Carbon-based nucleosynthesis
- Neutron sources for the production of trans Fe elements

→ Science program will sustain a facility life time of 30+ years

DIANA will address three fundamental scientific questions



Challenges:

Temperatures of the stars are low

Sun : T= 15.0 10^6 K (CM energy around tens of keV)

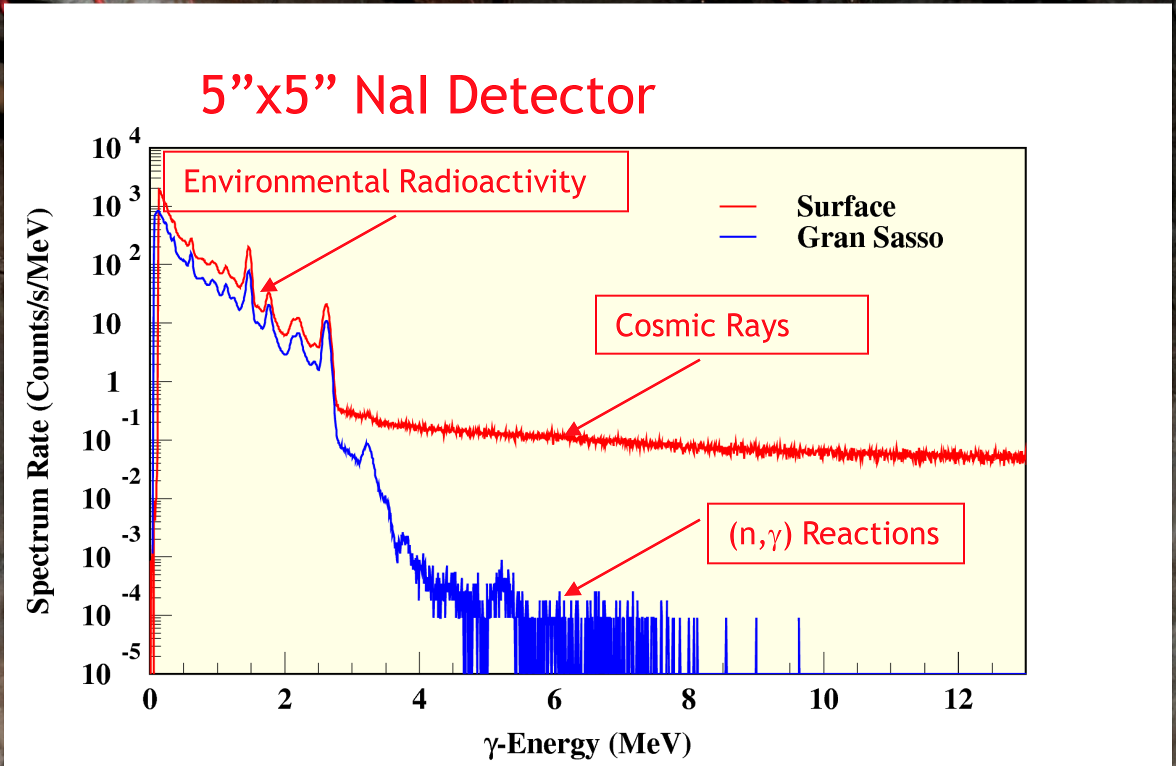
The cross section depends exponentially on temperature : 1 x 10^{-4} picobarn (!) in the region of interest

This is not a problem in the sun: Reaction Rate: 10^{38} s^{-1}

But in the laboratory: counts/months to counts /day and background gets the defining limit of the measurement

Need high intensity beams at low energy

Why Underground ? The background counting rate is reduced by many orders of magnitude



Data from LUNA collaboration, Gran Sasso

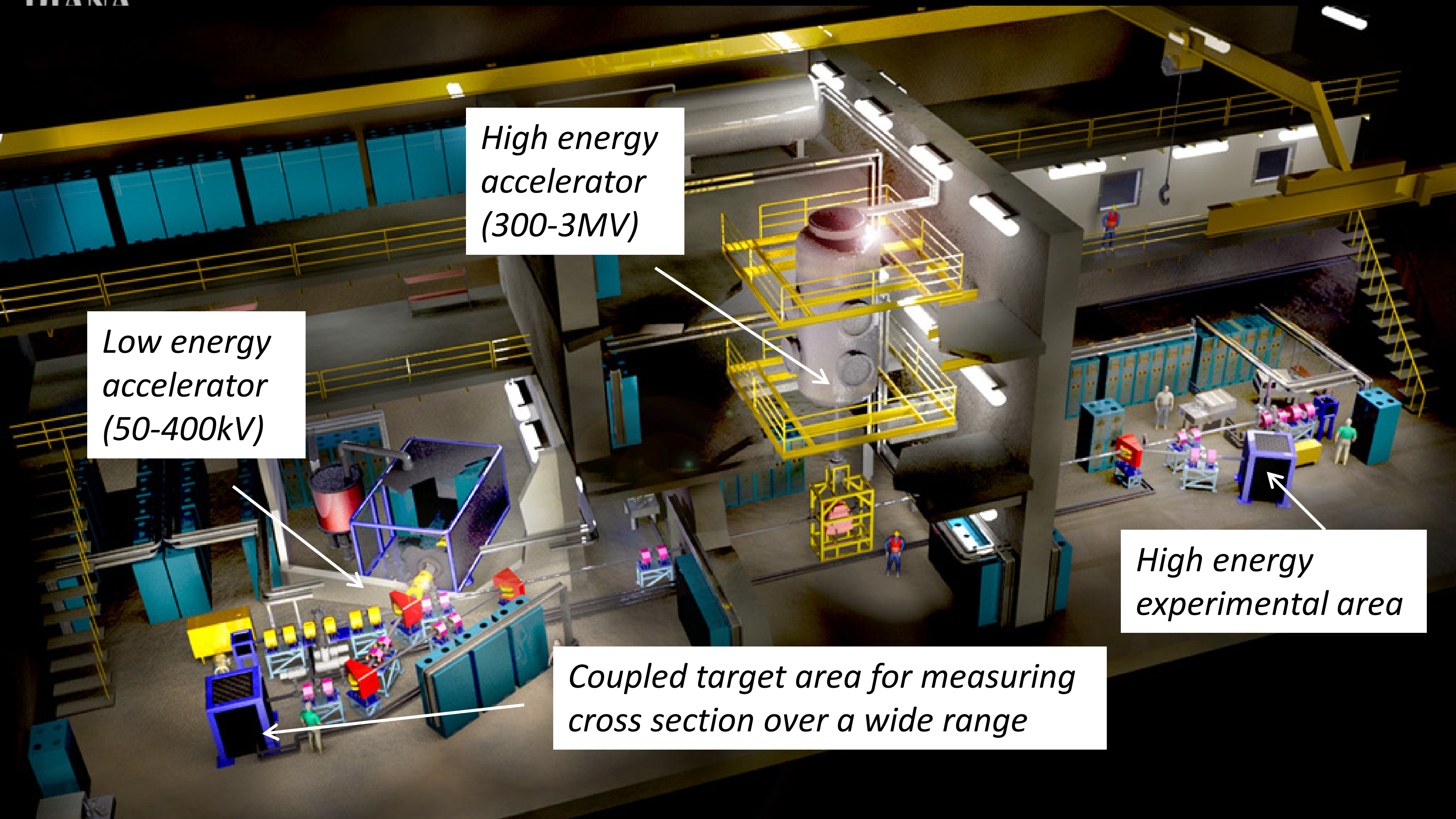
Background reduction at the LUNA facility in the Gran Sasso National Laboratory

1400 m deep (= 3800 meter of water equivalent shielding)

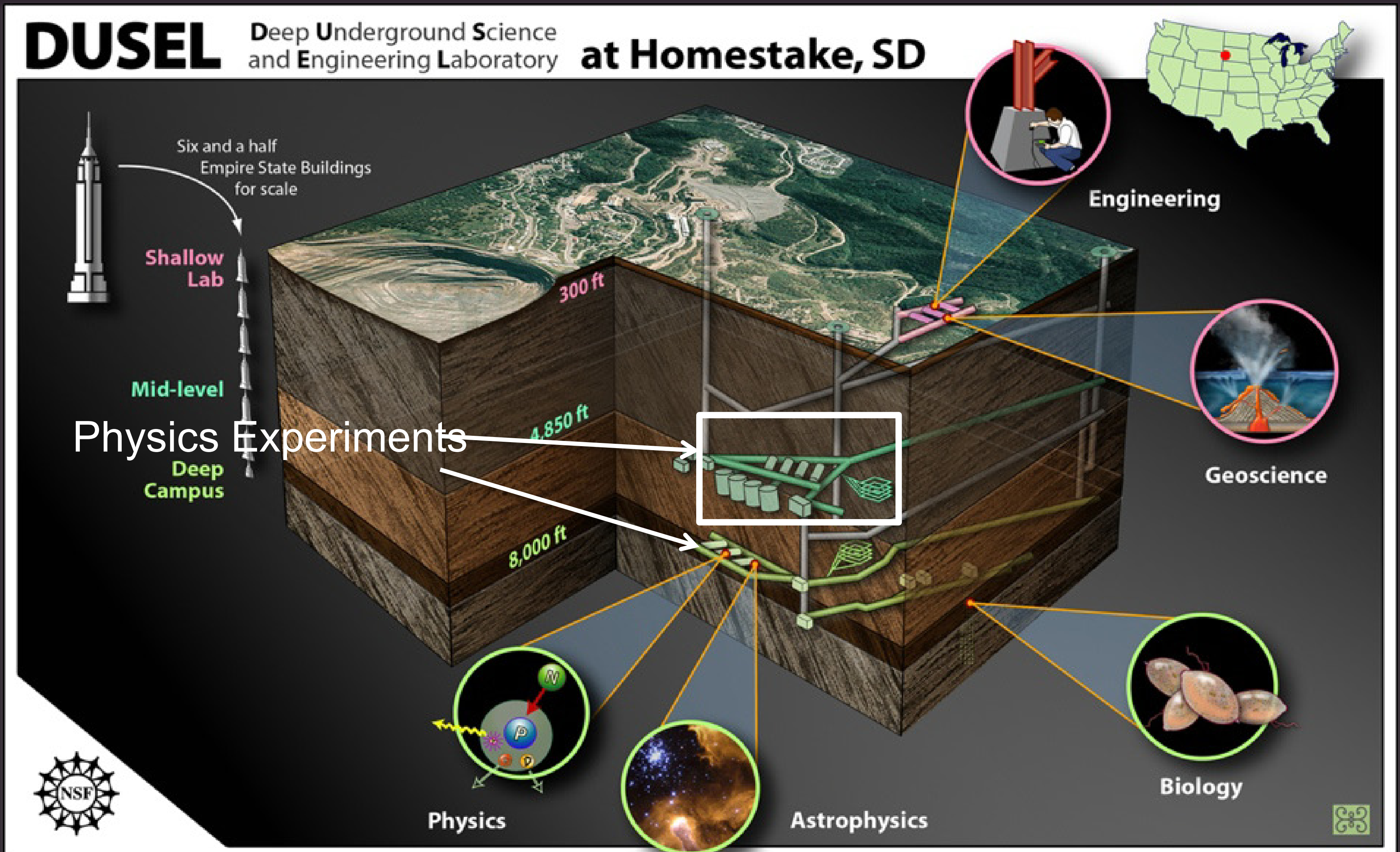
Muon flux is reduced by 6 orders of magnitude

→ **Need fully automated operation for several months of running time**

DIANA FACILITY LAYOUT



Possible location: DUSEL Project at Homestake



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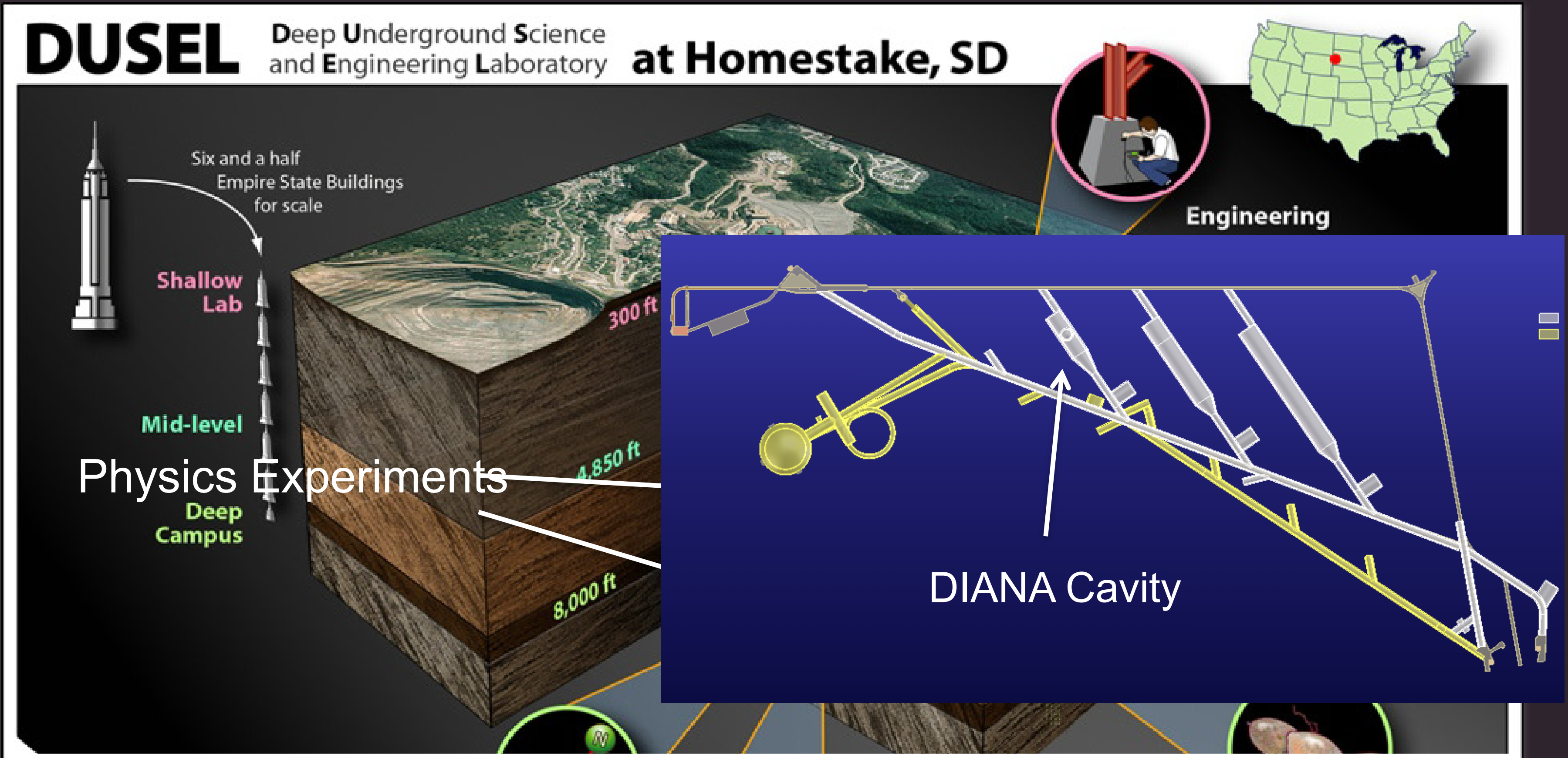
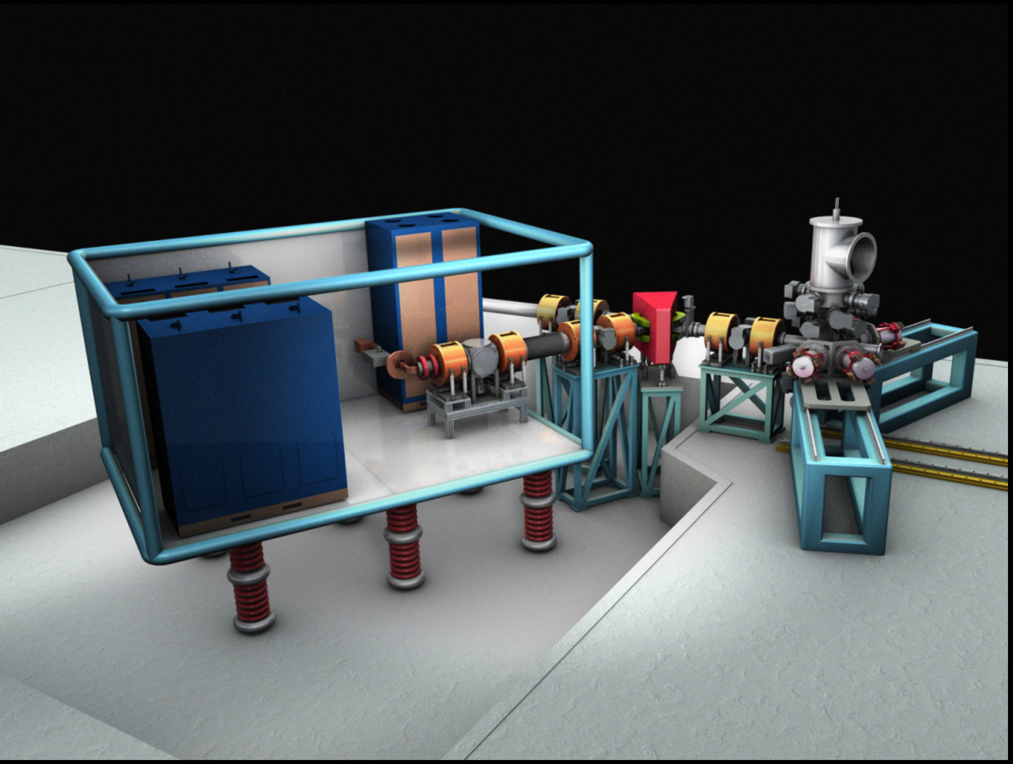


With current uncertainty of DUSEL, its not clear where DIANA will be located, but several locations in the US are suitable

PDR/CDR is site independently funded

Low Energy Accelerator Challenges and R&D items

DIANA

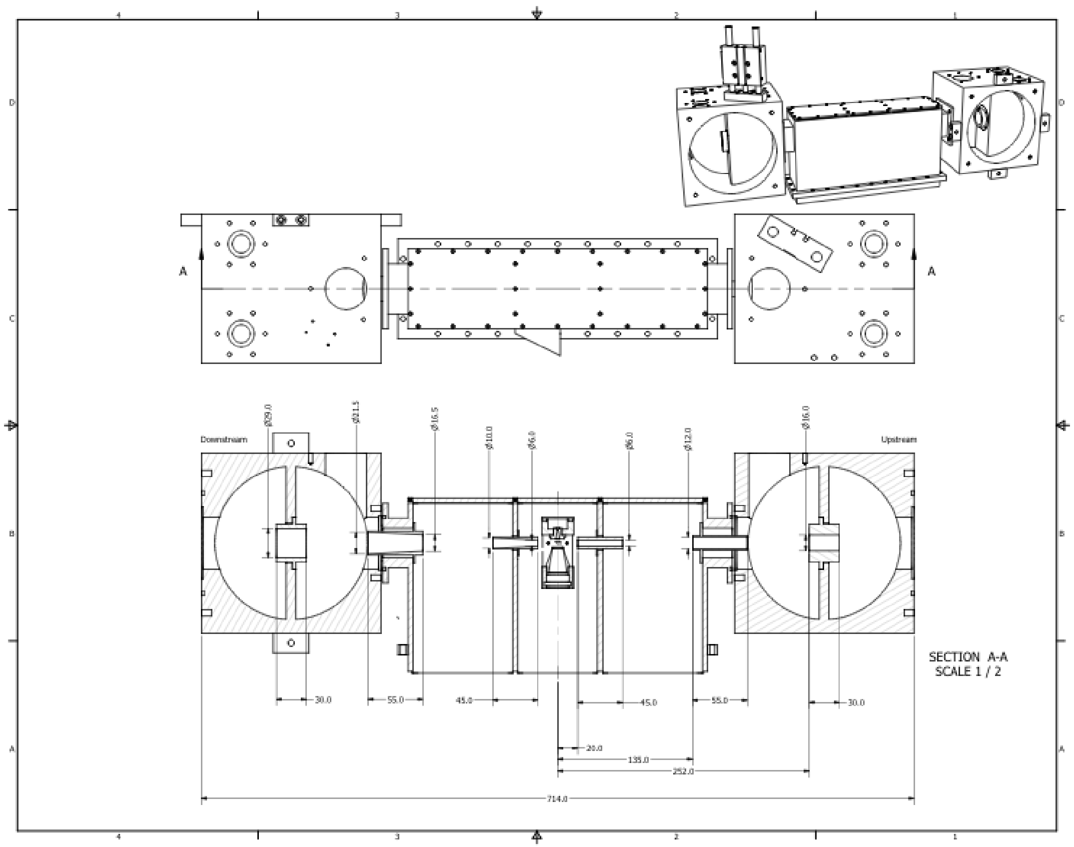


Unique Features

- high intensity from 50kV-400kV (up to 100 mA proton and 50 mA helium beam)
- beam focus < 1 cm
- energy Distribution: +/- 0.05 % of beam energy
- unique high density jet gas target
- coupled target with the high energy accelerator
- open-air high voltage platform for easy access

Up to 2 orders of magnitude higher beam current than presently available at state of the art facilities (to address the low count rates)

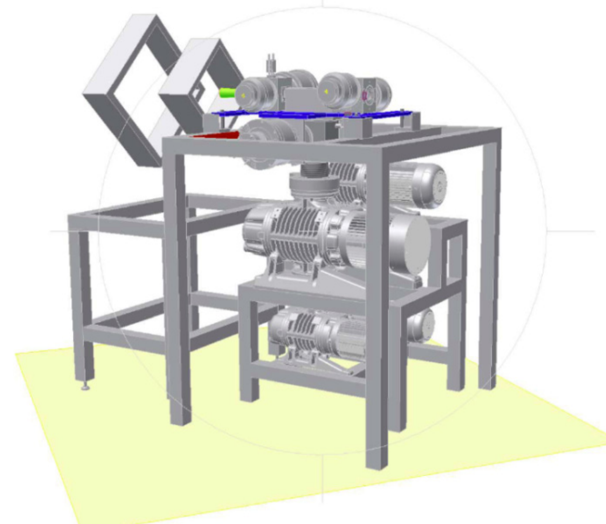
DIANA Jet Gas Target Design (Notre Dame + Colorado School of Mine)



High Density Supersonic Jet Gas Target>

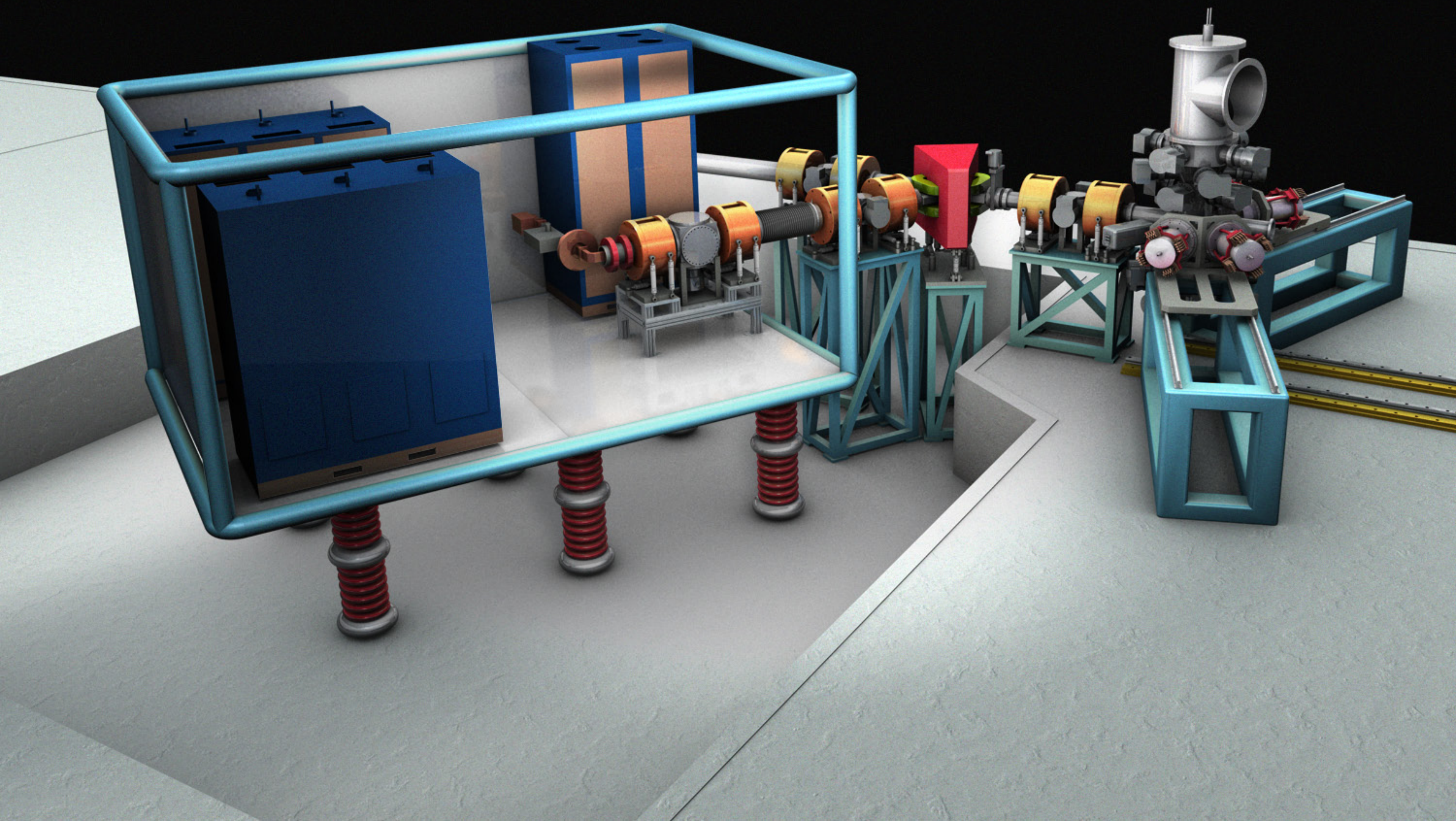
2×10^{17} per cm^2

Goal : 2×10^{18} per cm^2



Jet Stream constrains the low energy beam diameter to be ≤ 1 cm

An adjustable high voltage gap is necessary to control beam blow up in the acceleration gap



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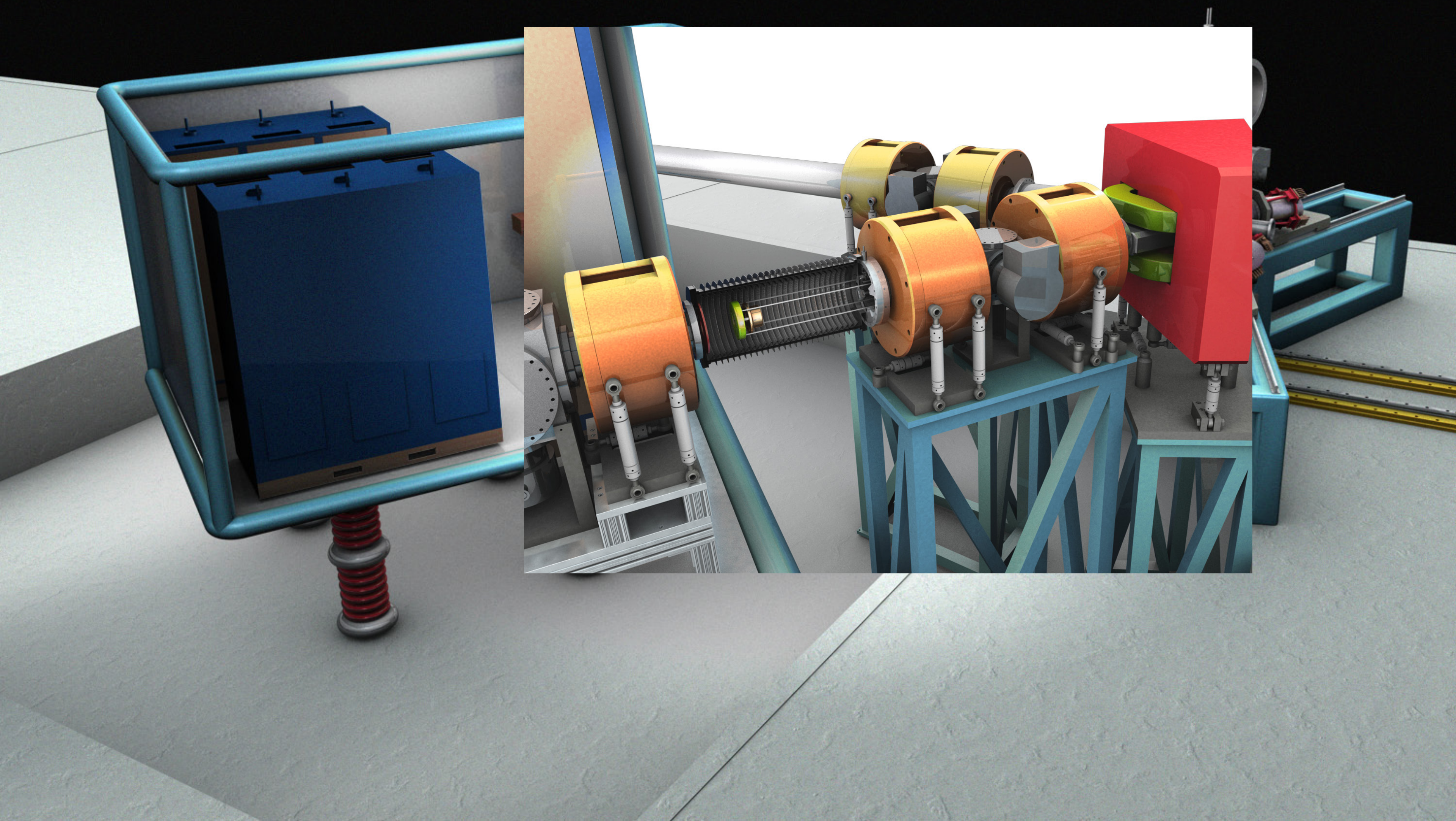

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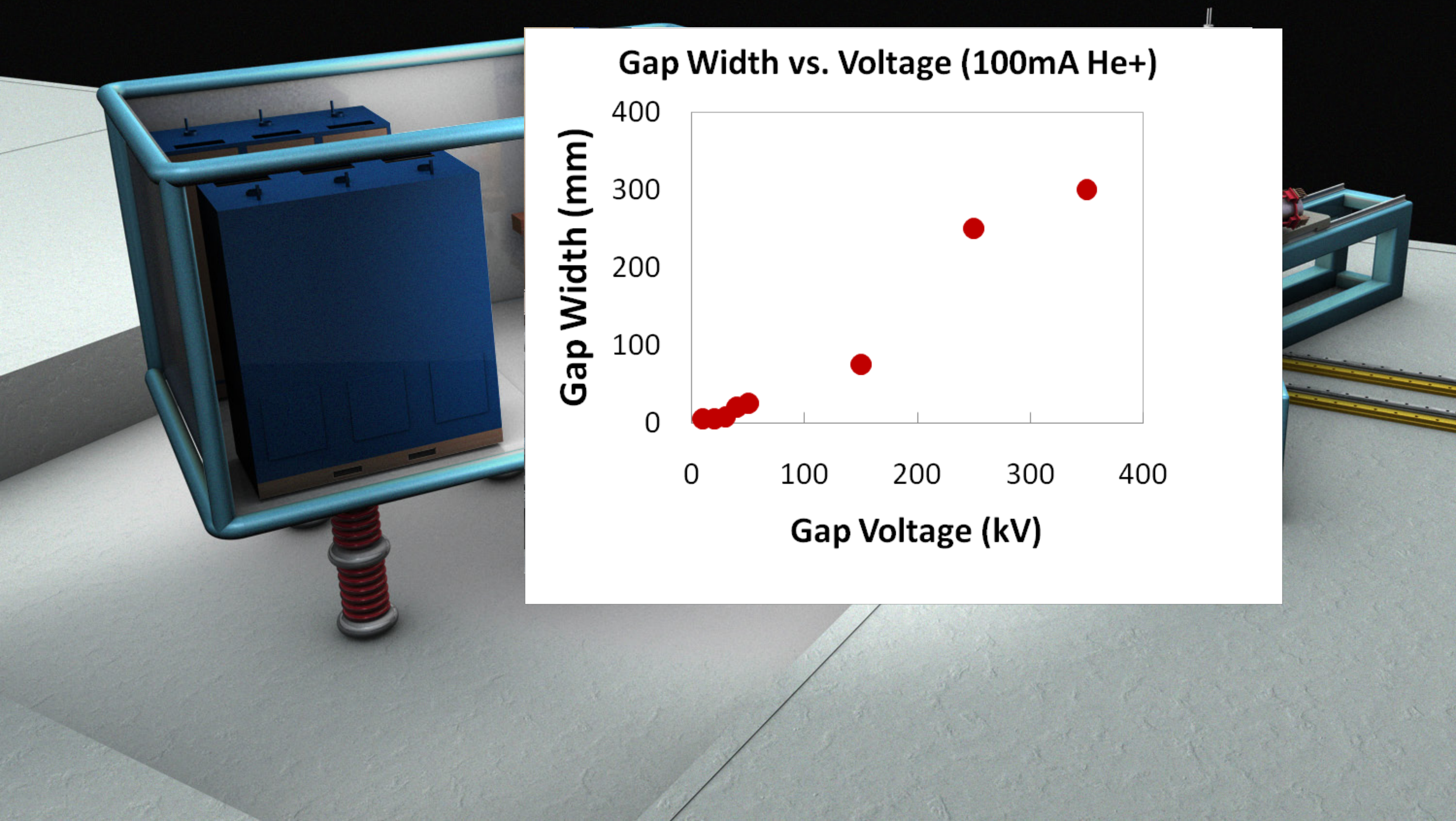
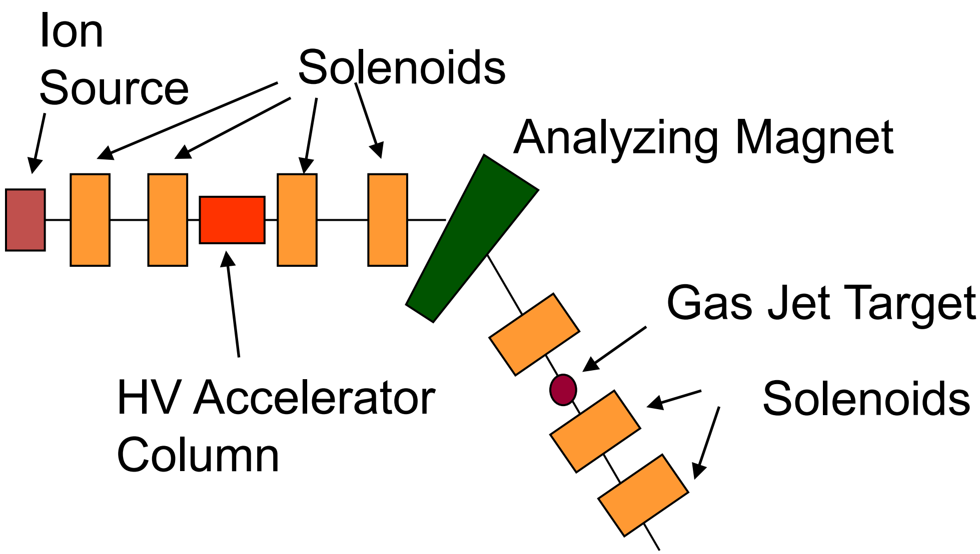
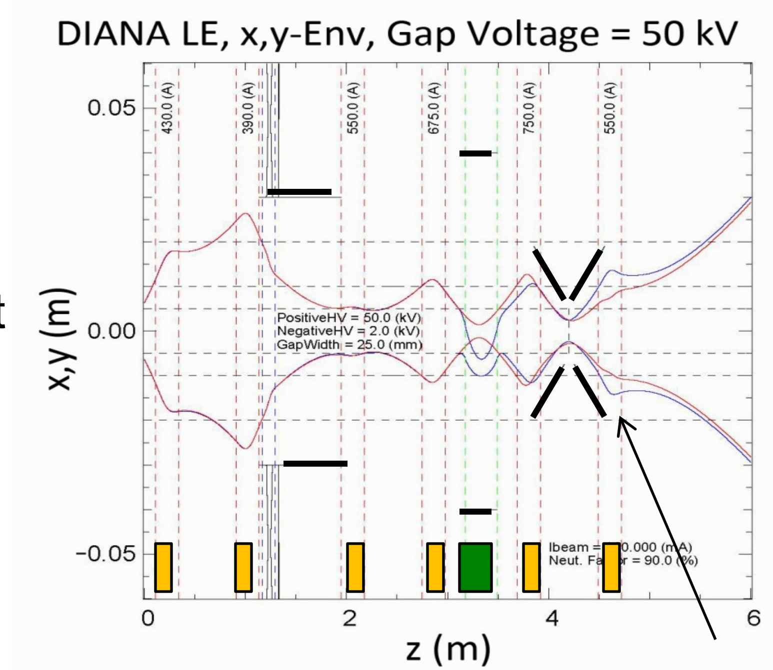


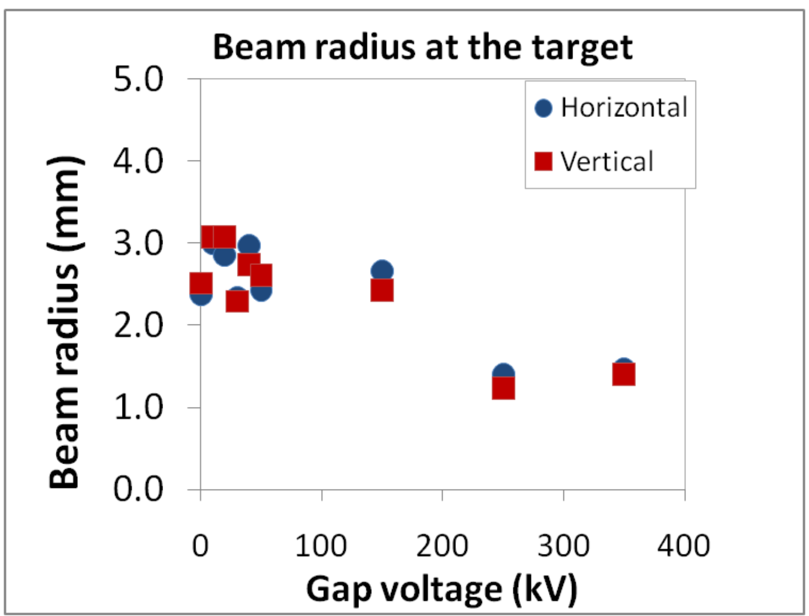
End-to-end simulation for the compact design



Beam envelope



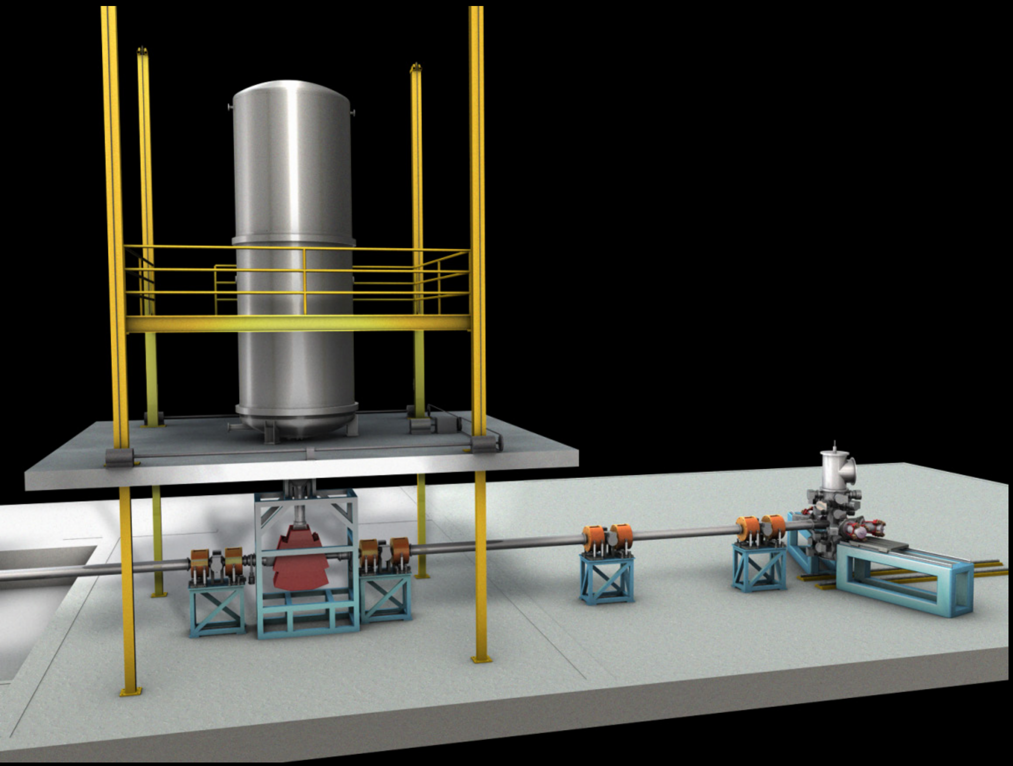
Gas jet apertures



By adjusting the accelerator gap lengths and the focusing strength in the solenoids the beam diameter on target is less than 6mm on target over the whole energy range

Further optimization and integration with target and diagnostics is in progress.

High Energy Accelerator And Target Stations

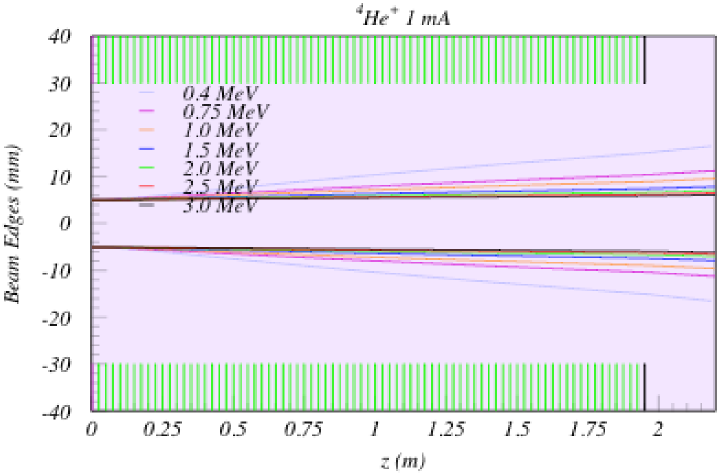


Commercial accelerator with some unique features:

- High intensity from 300kV to 3MV (≥ 1mA)
- Coupled targets with the low energy accelerator
- 2 independent target station for simultaneous experiments and future expansion

The high energy accelerator allows consistent measurements of resonant structures and expands the physics program to helium burning reactions and late stellar evolution reaction

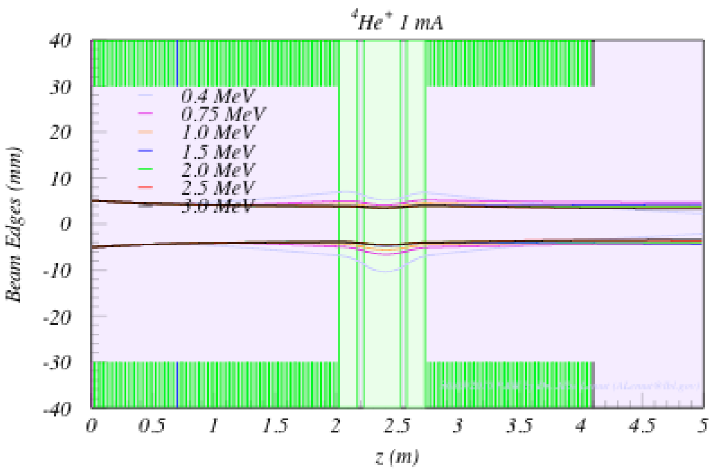
Simulation of the accelerator column



DIANA requires higher beam current at low energies than at higher energies, but
a standard constant gradient requires scaling of the intensities to counteract the space charge as the beam energy is reduced to preserve the beam envelope

$$I = I_{tune} * \left(\frac{V}{V_{tune}}\right)^{3/2}$$

V = 400kV	V = 3MeV
50µA	1000µA

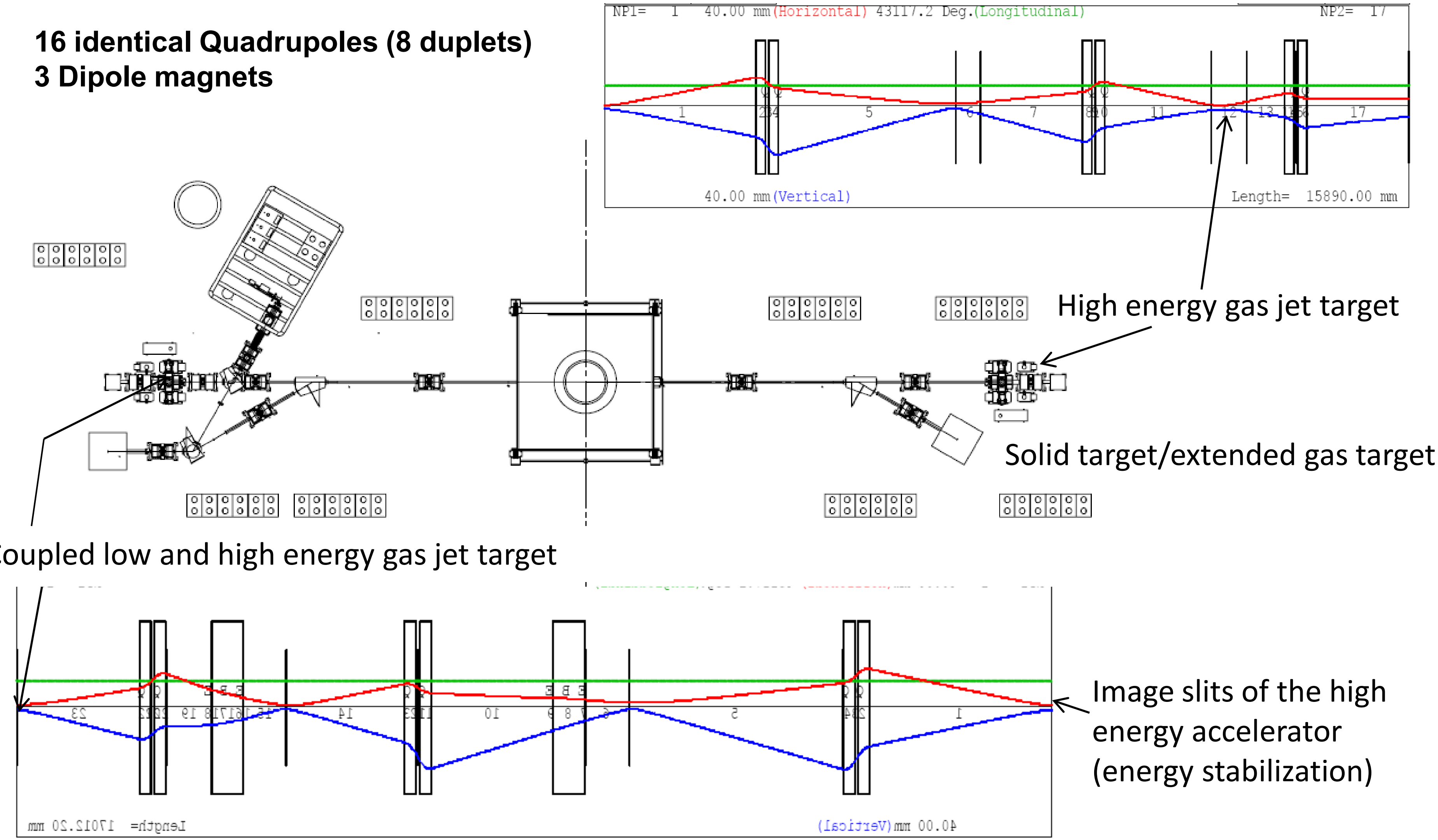


Possible technical solution

Combine tuned, variable lengths column (shortening rod) with a focusing element in the middle of the column to compensate for the mismatch in intensity.

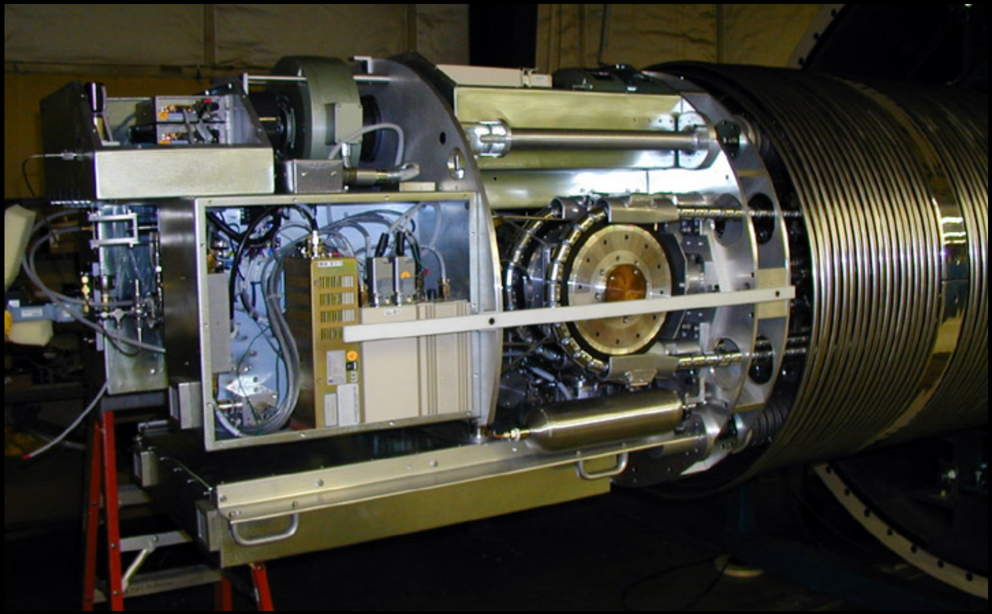
High energy ion beam optics (ND and LBNL)

16 identical Quadrupoles (8 duplets)
3 Dipole magnets

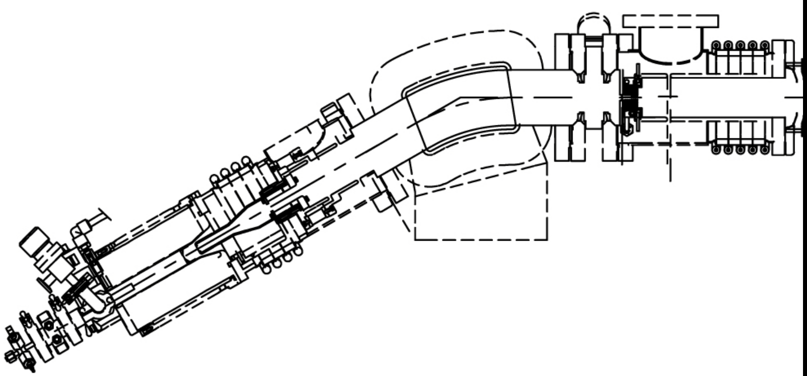


Milestone 12/30/2010 Ion optics completed

ECR Source on Dynamitron/Pelletron Platform with 1mA intensity is challenging



Picture of a NEC Pelletron Platform



Layout of a NEC Pelletron Platform using a commercial Nanogun

Examples:
5.5 MeV van de Graaf of the Hahn Meitner Institure in Berlin
10 GHz Nanogun on a 3 MeV NEC Pelletron
Challenges for DIANA
Vacuum Pumping, Extraction, Mass Analysis, high total current

Summary

- DIANA will be a unique astrophysics accelerator:
  - Broad range of energies
  - Significantly higher beam currents than currently achievable
  - Target stations can be operated with overlapping beam energies

- Low energy beam line challenges:
  - Space charge neutralization
  - Compact beam transport with moveable acceleration gap
  - Focal spot size and target integration

- High energy beamline challenges:
  - Ion source vacuum pumping
  - Constant ion beam current over a wide energy range

- Status: CDR/PDR will be completed in 1.5 years after which the facility needs to be sited and construction can start