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Dream for the Stars or at least way to store anti-matter

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Acknowledgements

Current:

- K Lynn M Weber L Pilant Joshah Jennings

Students: Jia Xu John Cox(undergraduate) D Solodovnikov

- **John Bumgarner –SRI (MEMS Technology)**

Former Team Members:

- **A Hunt (ISU)**
- S McNeil(graduate student)
- D. Cassidy –has moved on to BEC and annihilation lasers

Recent and Past support (for the accelerator):

- WM Keck Foundation
- SMDC
- DOE

Number 1:

Positrons made the Newsweek hitlist

It is not

FOX News

Mr. Potato Head

Outline

- Why? Highest energy density
- How?
  - Making antimatter (positrons)
  - Bottles for antimatter
  - Filling the bottle (trap)
  - Storage and release
- Roadmap
- Beyond proof of concept…
- Particle optics before plasmas

Outline

- We need to develop out of the box methods to store the maximum number of anti-matter that can be used at a later time for various applications.
- Our work is not similar of Surko and team. Multi-Cell is an extension of Greaves & Surko previous work.
- We plan to use small diameter, and long aspect ratio traps and their multi-cell trap.

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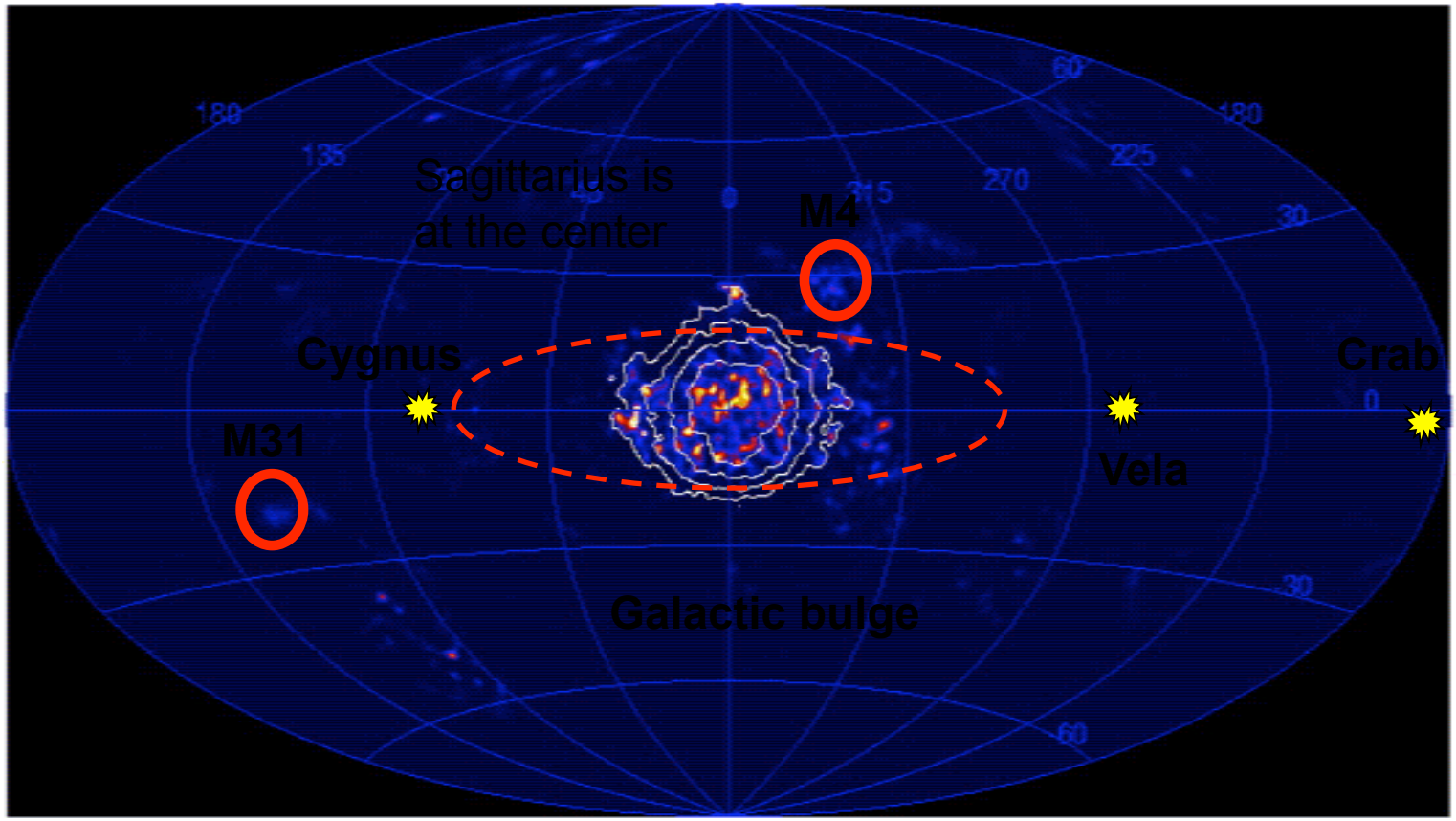
Outline on Storage Talks

- Production of Positrons (Weber and many others) various ideas
- Moderators ideas are especially needed for parallel filling approaches
- Recapping standard high density traps-brief
- Idea of micro-traps (never tried) not for high density plasmas but for storage of positrons
- Modeling of the particle optics in micro traps is considered important and has not be done by USCD as per many discussion..

Galactic positrons



10^{50} positrons/year (**3 billion metric tons/sec**) annihilate in the Galactic center (inside red dashed circle), other source in red circles. Some stars (yellow) for orientation. **Work may help reveal the nature of Dark Matter.**

J. Knodlseder, et al., Astronomy and Astrophysics, **441**, 513-532 (2005).

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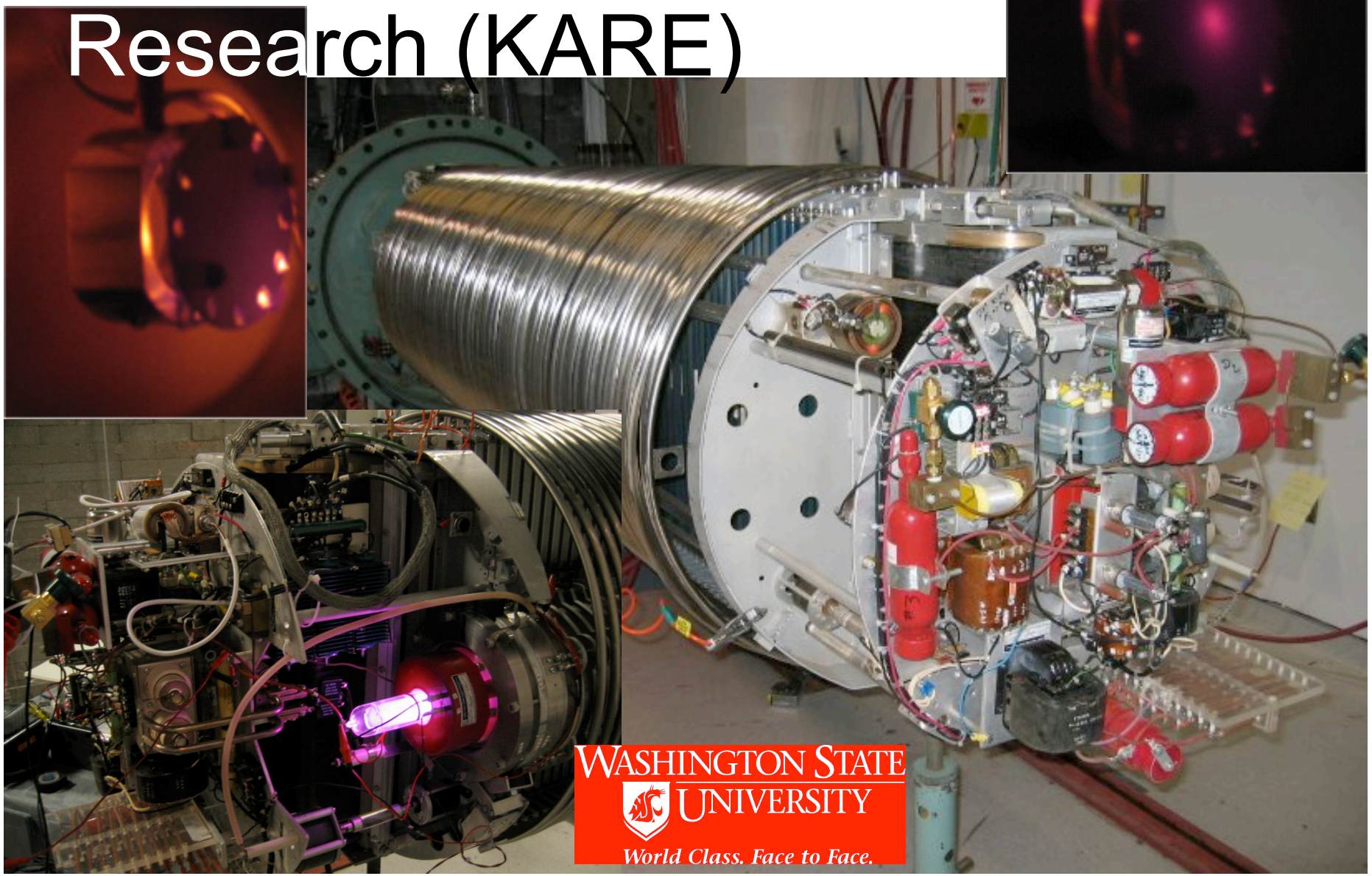
Why store antimatter?

Reaction / source of energy	Specific energy (J/kg)	Fraction used For energy
Antimatter (e.g. positrons) Plus matching mass of matter	$1.8 \cdot 10^{17}$	100%
Fusion of deuterium-tritium	$3 \cdot 10^{14}$	0.34%
Fission of ^{235}U	$8 \cdot 10^{13}$	0.09 %
TNT	$5 \cdot 10^{6}$	$7 \cdot 10^{-9}$ %

KECK Antimatter Positron Research (KARE)



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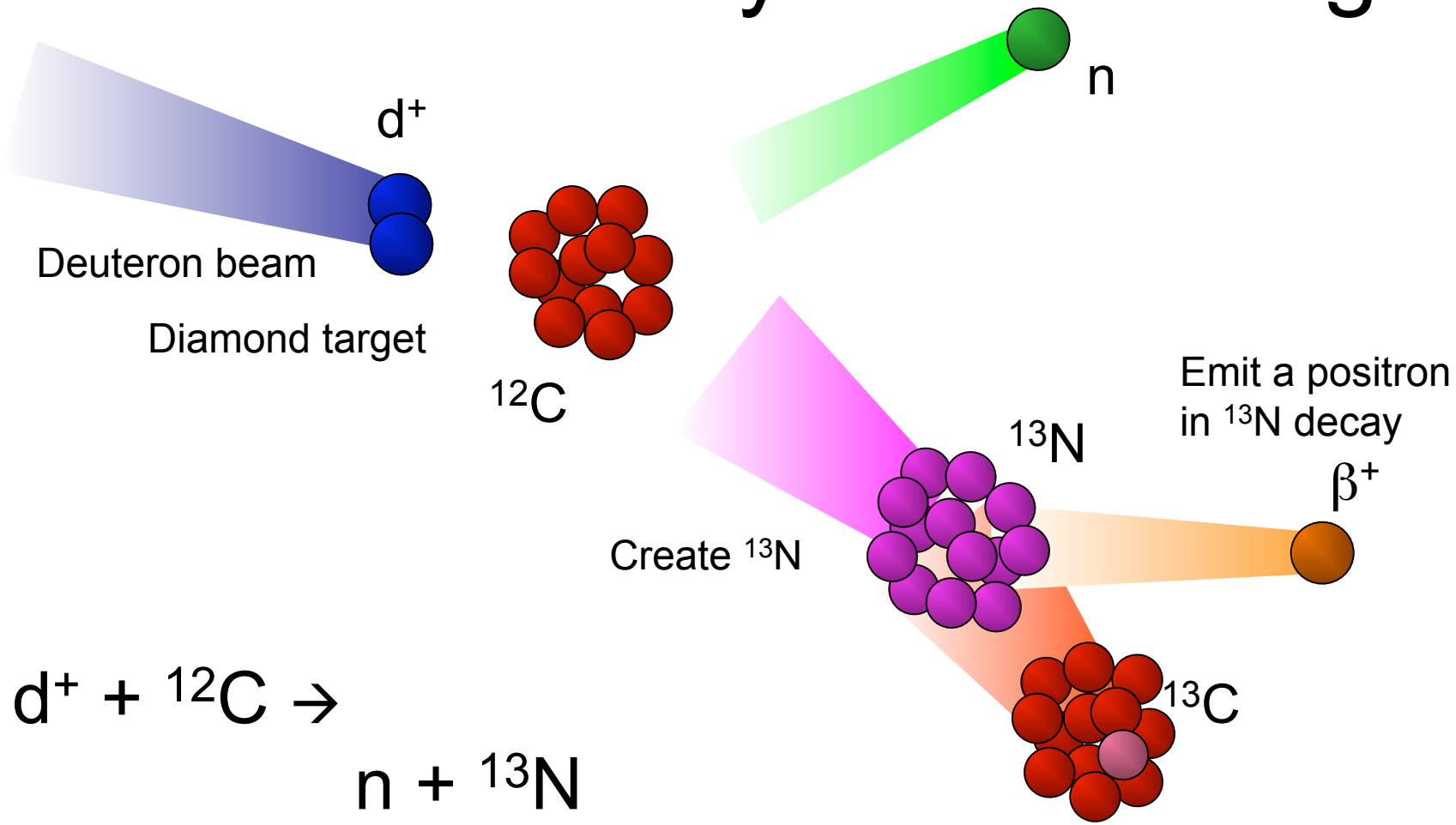
A way we are using



$$d^+ + {}^{12}C \rightarrow n + {}^{13}N$$

$$^{13}N \rightarrow {}^{13}C + \nu + \beta^+$$

$\tau \approx 10$ minutes halflive

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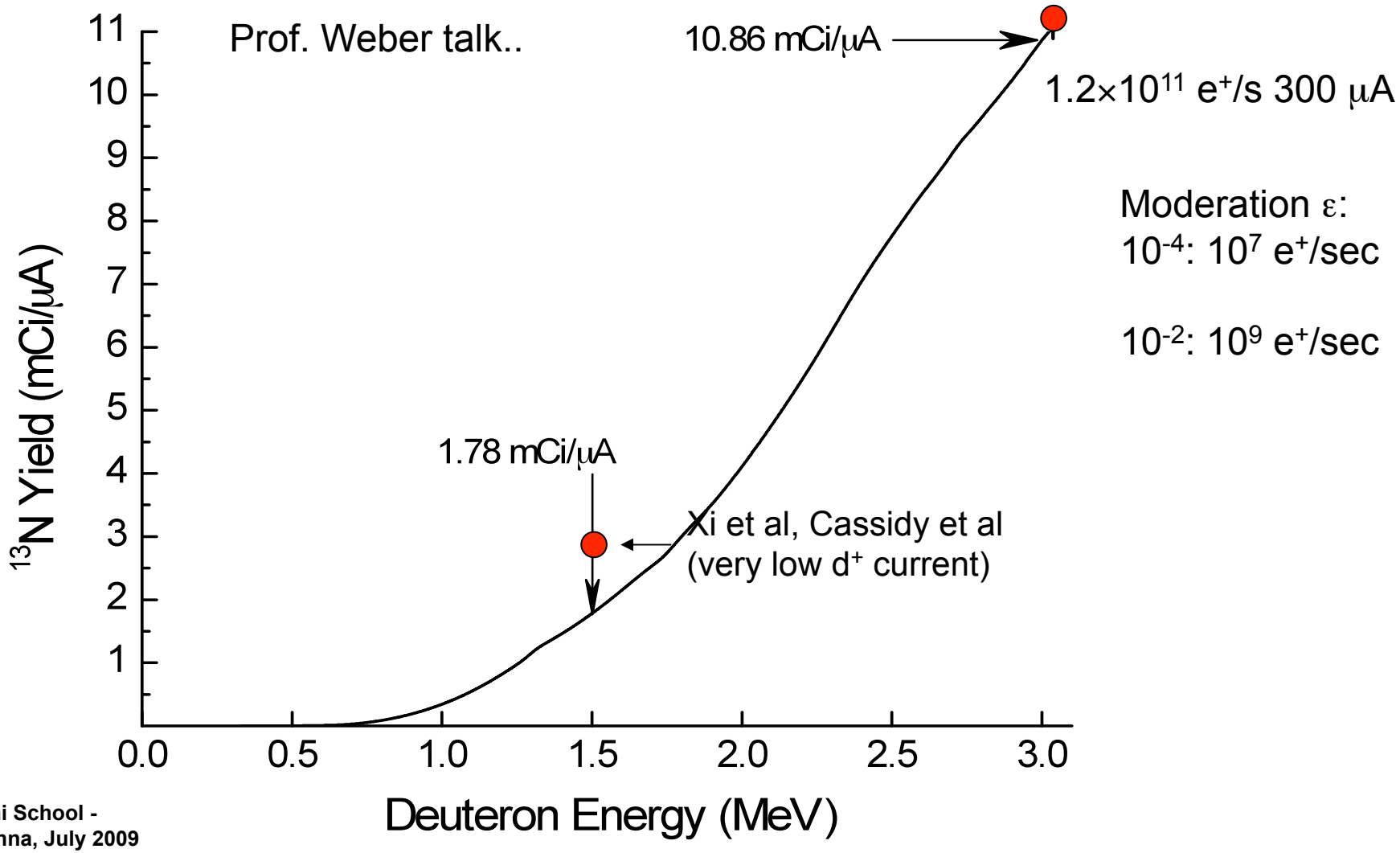
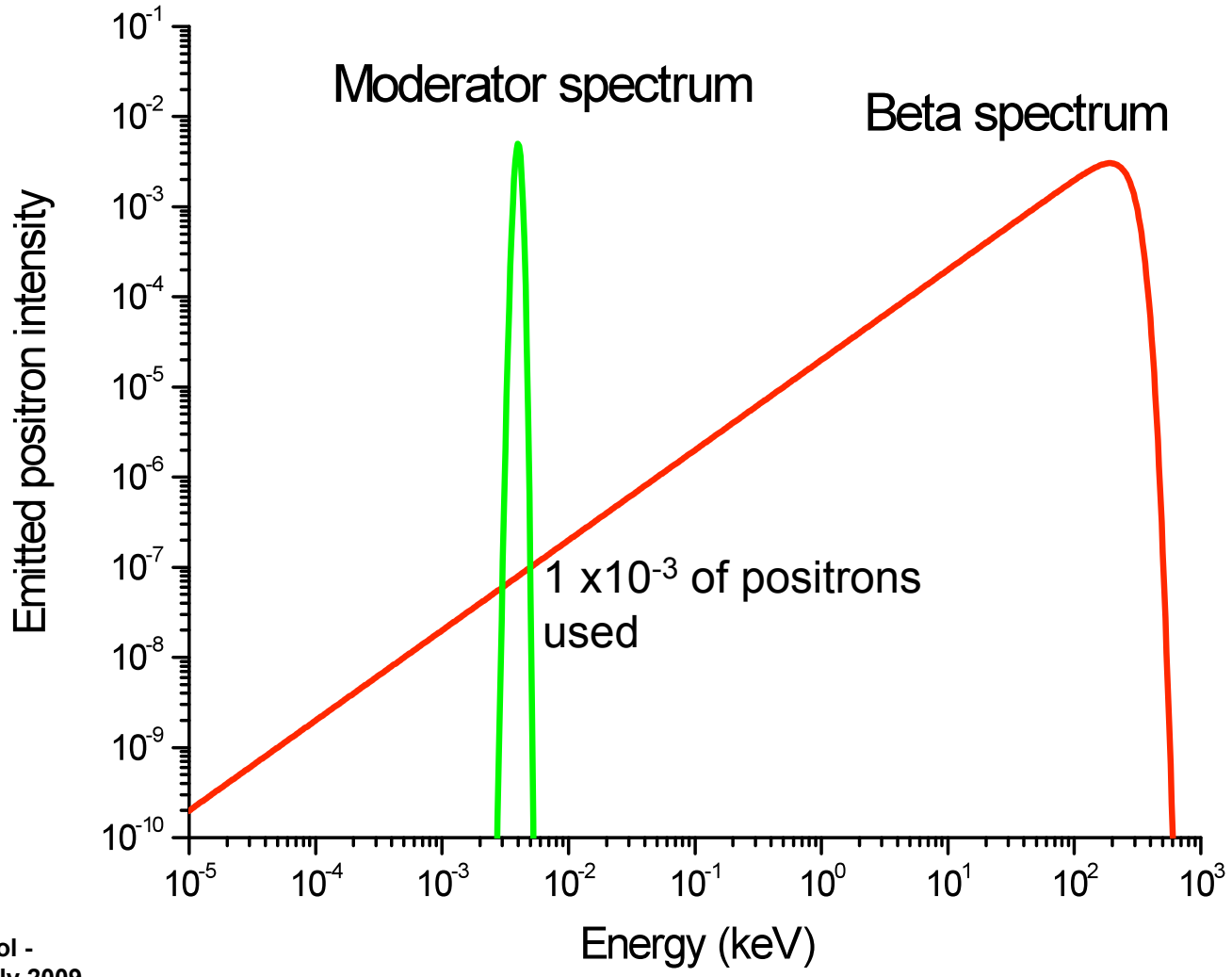
WSU Yield (total)



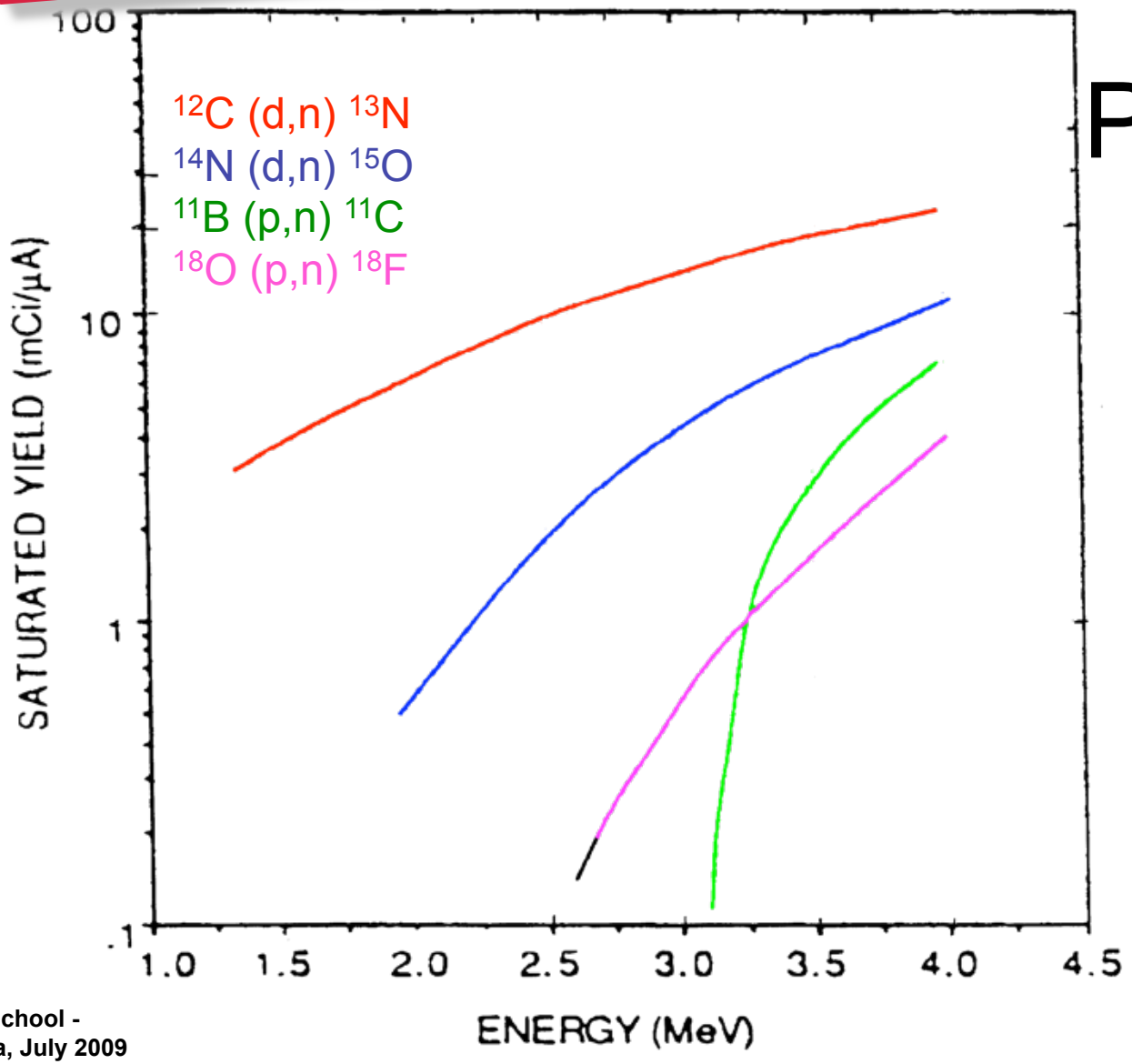
Positron moderation

- Positrons are generated with a broad range of energies up to few MeV (and higher)
- They need to be slowed down to have a narrow energy distribution for use in a beam or trap
- Single crystal W is the current workhorse with an efficiency of $<10^{-3}$ and thickness of 1 μm or less but solid rare gas is an another useful moderator (Ne or Kr).
- To produce better moderators, we spray electrons onto the surface of SiC and show the first success
- The depth from which positrons are drifted towards the surface out increases more than 15 times when a field is applied.

Current moderation scheme



Production of isotopes



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Production of positrons at Jefferson Lab

We estimated a high intensity source would take ~3 weeks
to "charge up" the milligrams! of e+ needed. Sounds very neat.

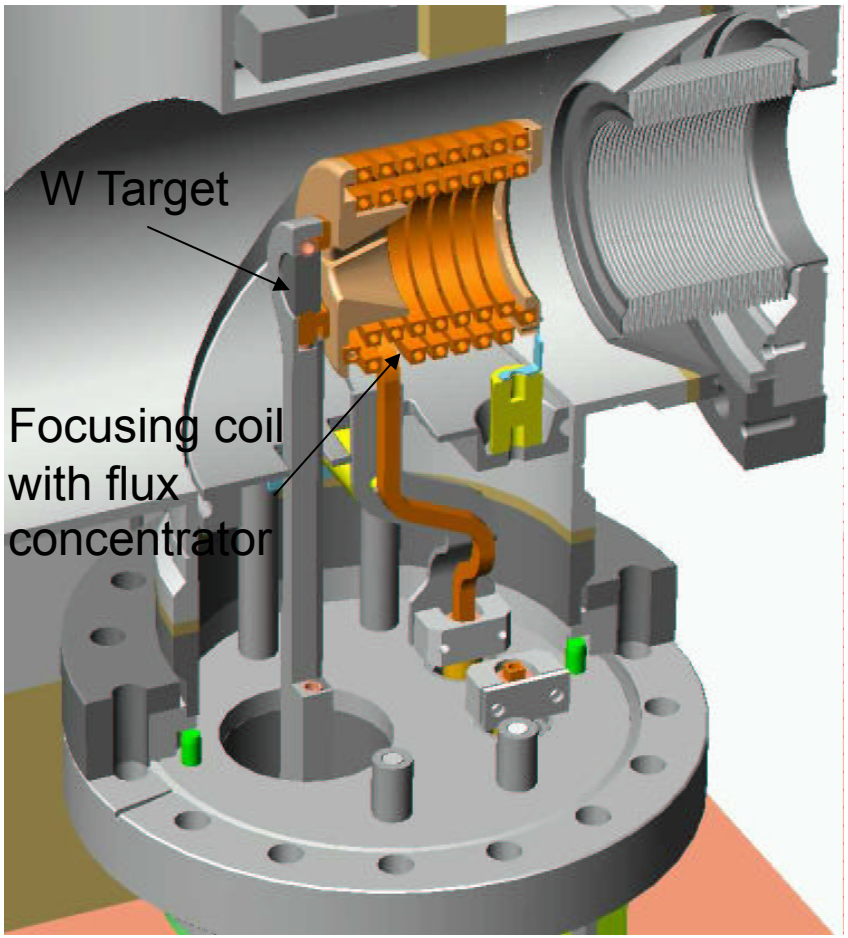
Cheers,
Joe Grames
Center for Injectors and Sources,
Jefferson Lab NewPort New Va

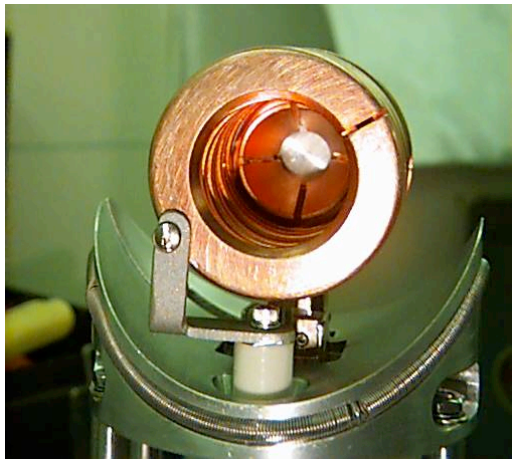
High Power Polarized Positron Source

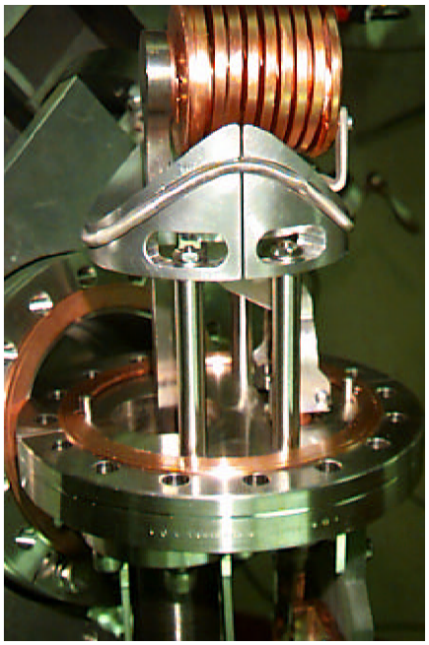
A.Mikhailichenko Cornell LEPP

Polarized electron source of necessary intensity may be borrowed from ILC. One can expect minimal efficiency ~0.1% of electron-positron conversion up to a max of ~ 1%.

CORNELL POSITRON SOURCE







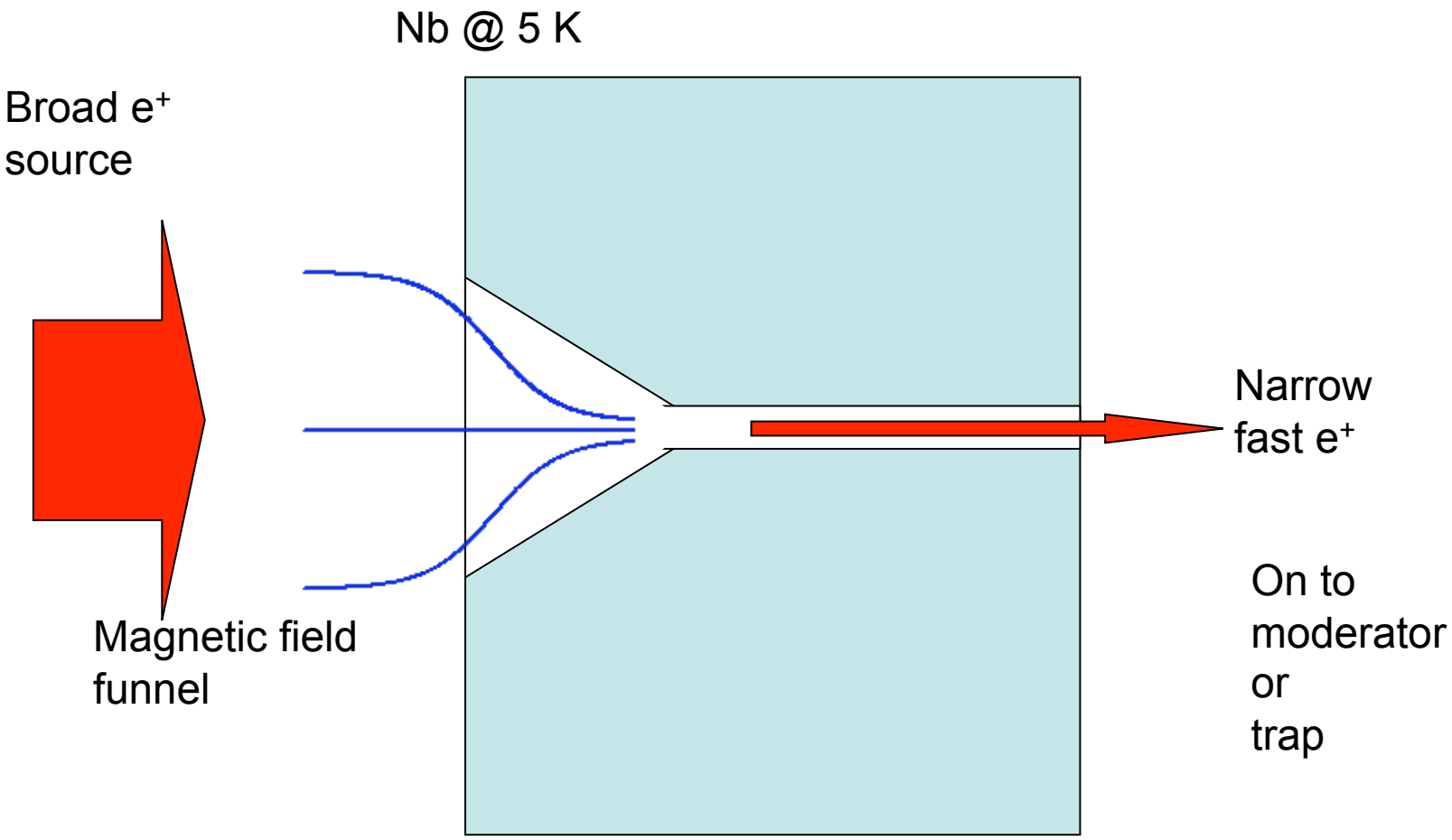
This short-focusing lens followed by RF structure immersed in solenoid

Positron rate ~10^{11} /sec at 50 Hz operation at ~200 MeV

Conversion efficiency~2.5%, DC power consumption ~2.5 kW

J. Barley, V. Medjidzade, A. Mikhailichenko, "New Positron Source for CESR", CBN-01-19, Oct 2001. 16pp.

New idea- magnetic funnel



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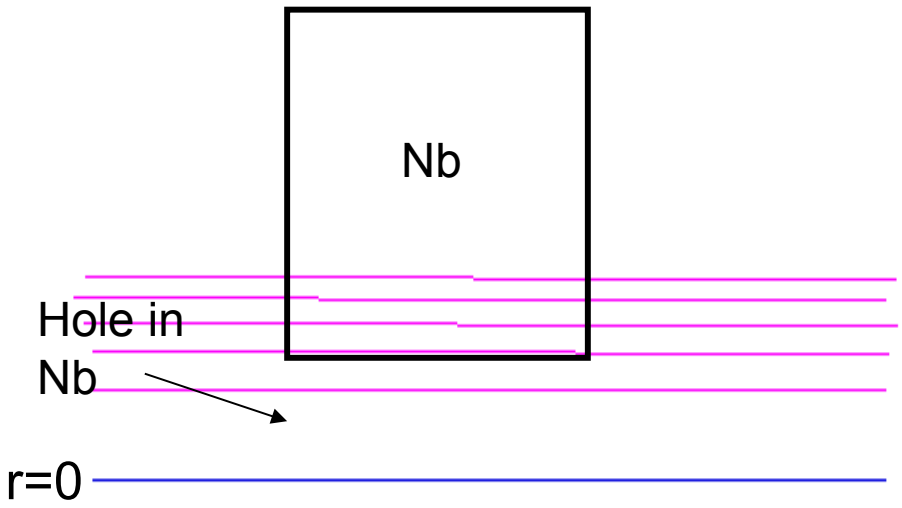
Using the **Meissner** Effect to Increase the Fill of a Trap

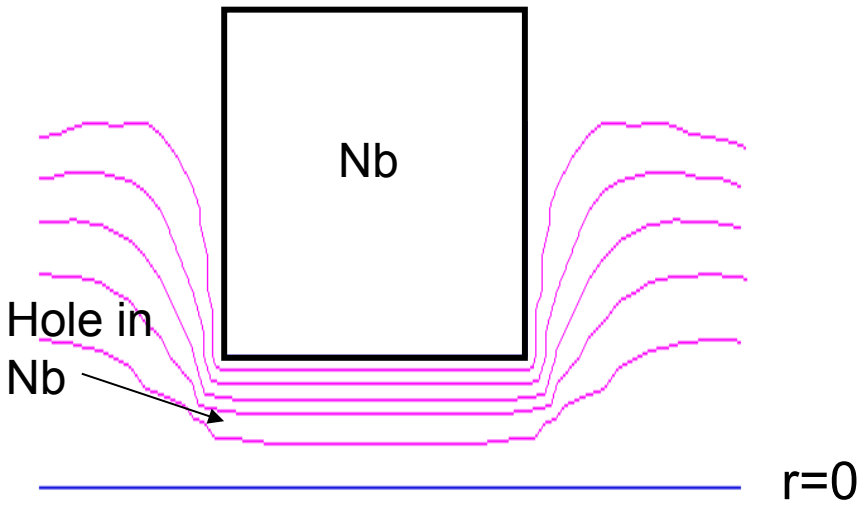
T > 10 K

Field inside hole: 340 G Field outside hole: 340 G

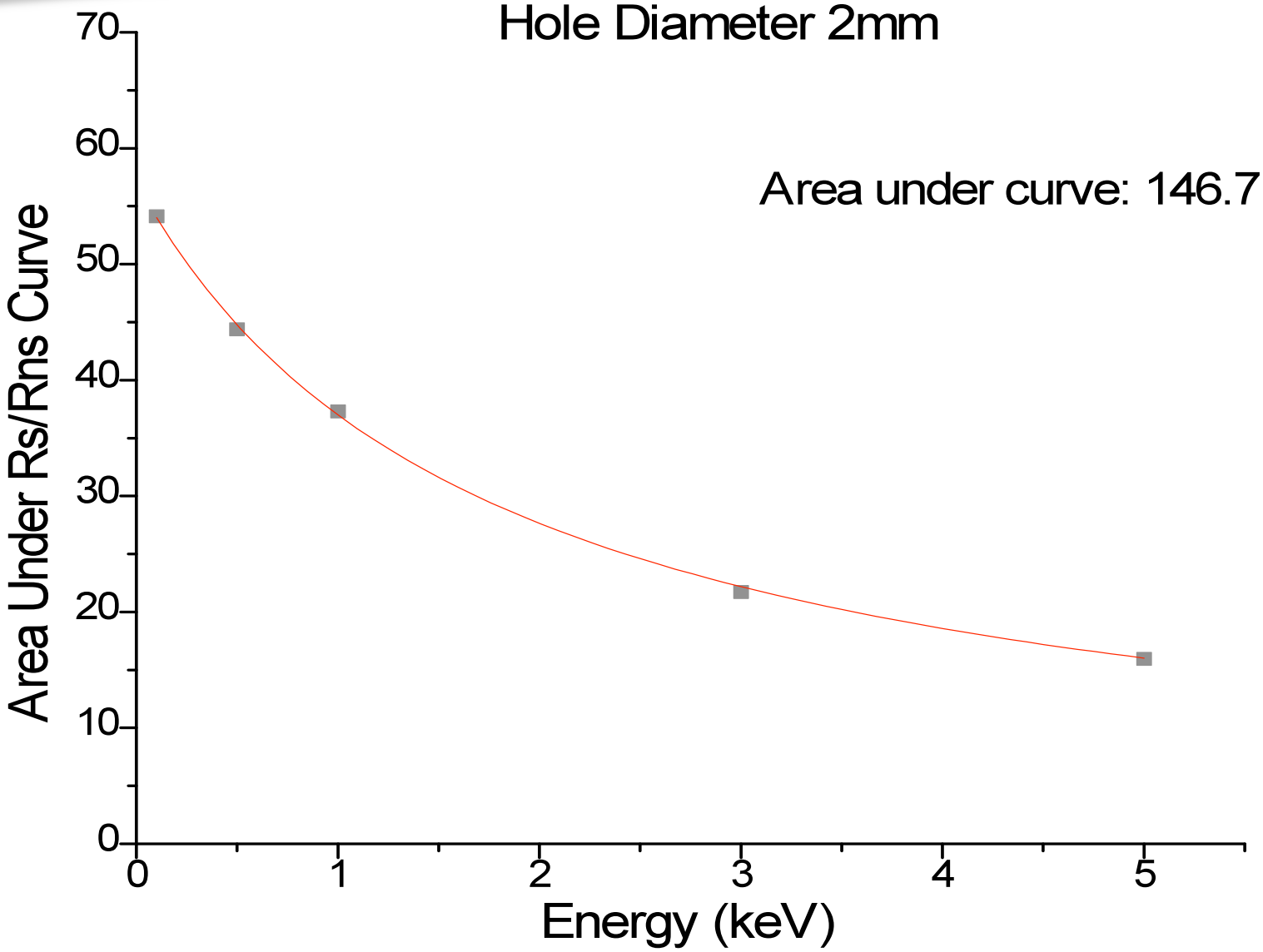


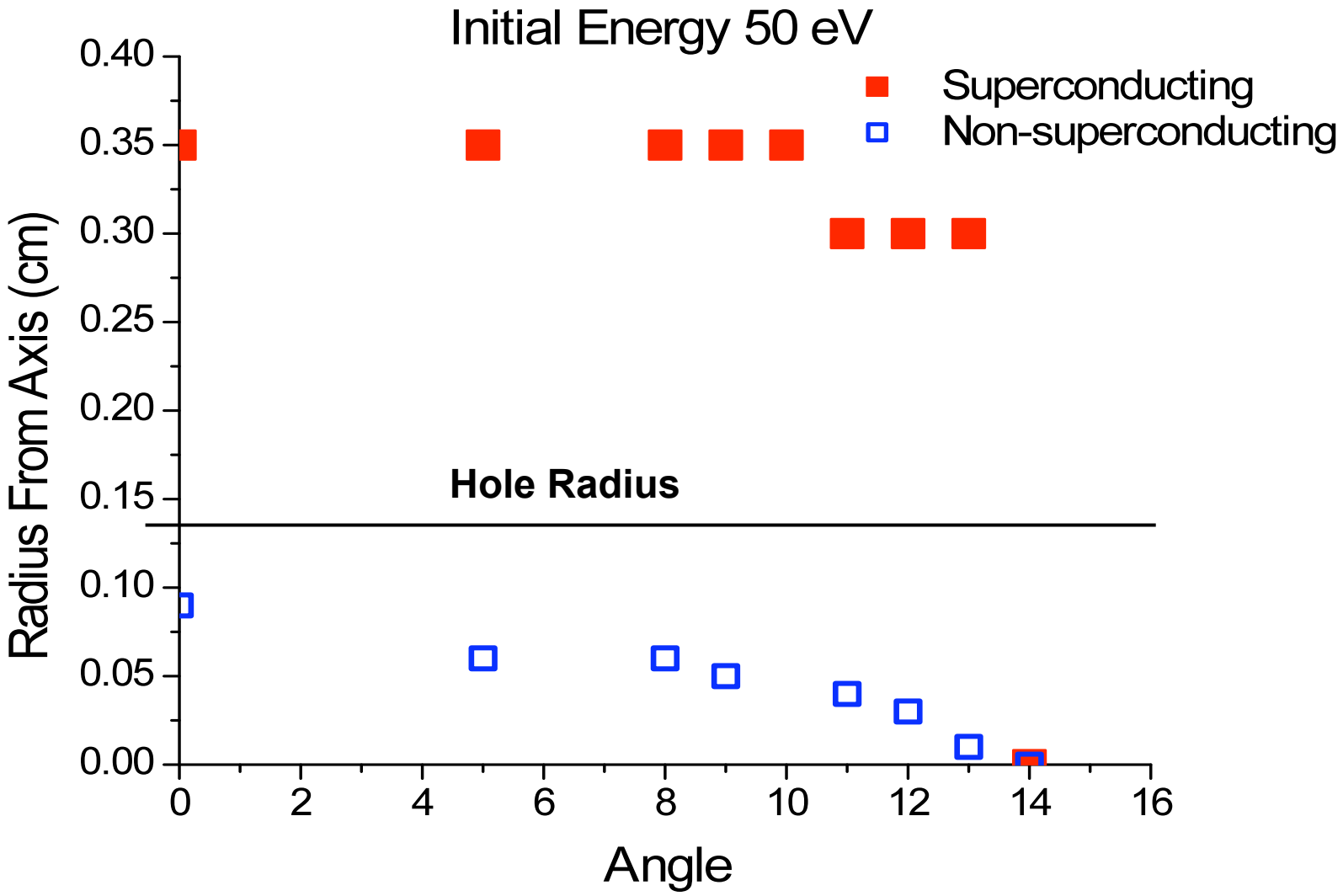
$T \leq 4.2$ K
$HC_1 = 2$ kG

Field inside hole: 1700 G
Field outside hole: 340 G

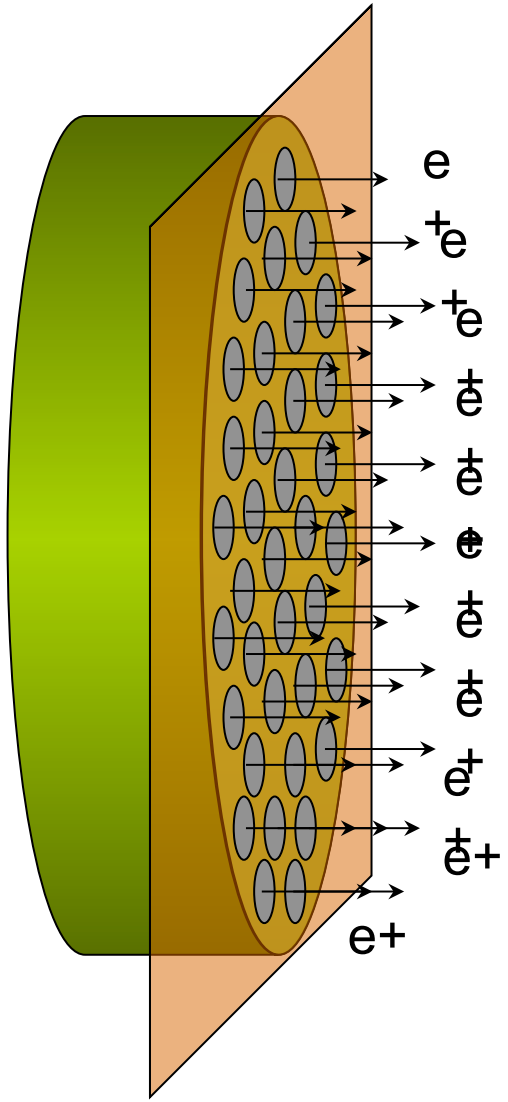


Cylindrical symmetry about r=0


Hole Diameter 2mm
Area under curve: 146.7
Area Under Rs/Rns Curve
Energy (keV)
0
10
20
30
40
50
60
70
0
1
2
3
4
5


Initial Energy 50 eV
Superconducting
Non-superconducting
Hole Radius
Radius From Axis (cm)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
2
4
6
8
10
12
14
16
Angle

Apply This Idea To Many Holes
(Remember the Holes-Not in this Presentation)



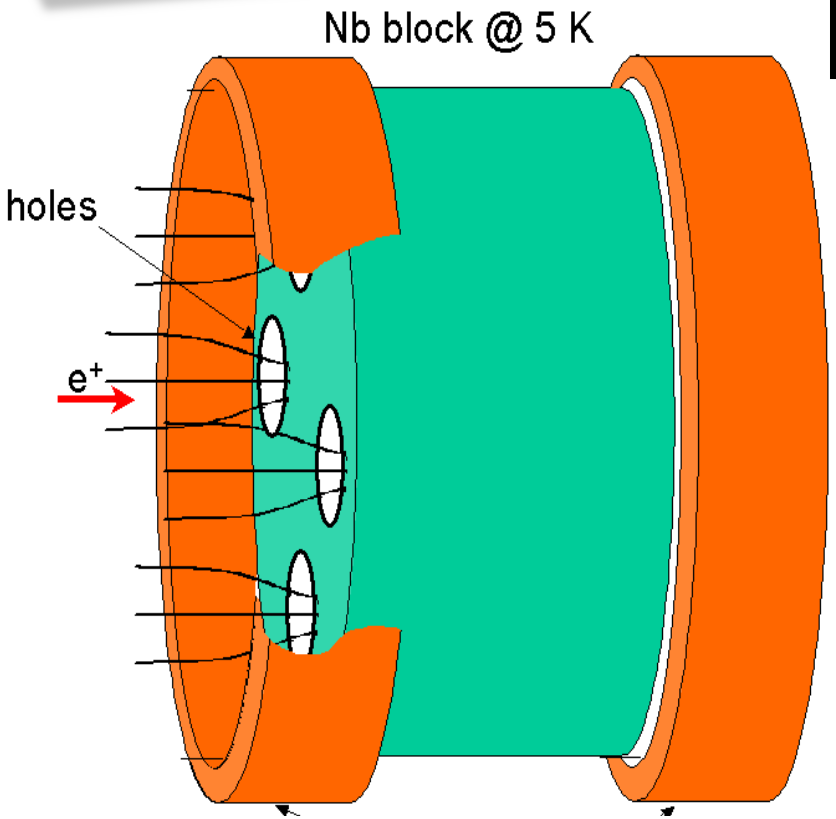
Moderation using Ni(100)

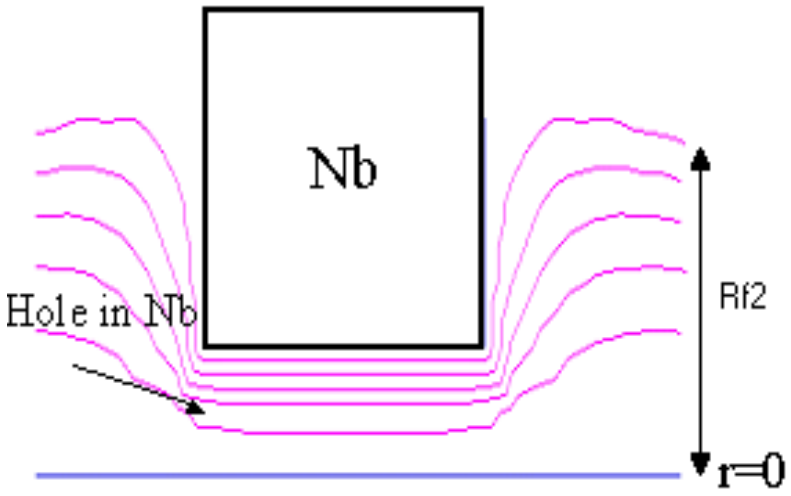
(20% positrons emitted)

Work Function at 23 K:
1.5 eV
$\Delta E < 0.024$ eV
$\theta_{FWHM} < 20°$

Fisher et al PRB

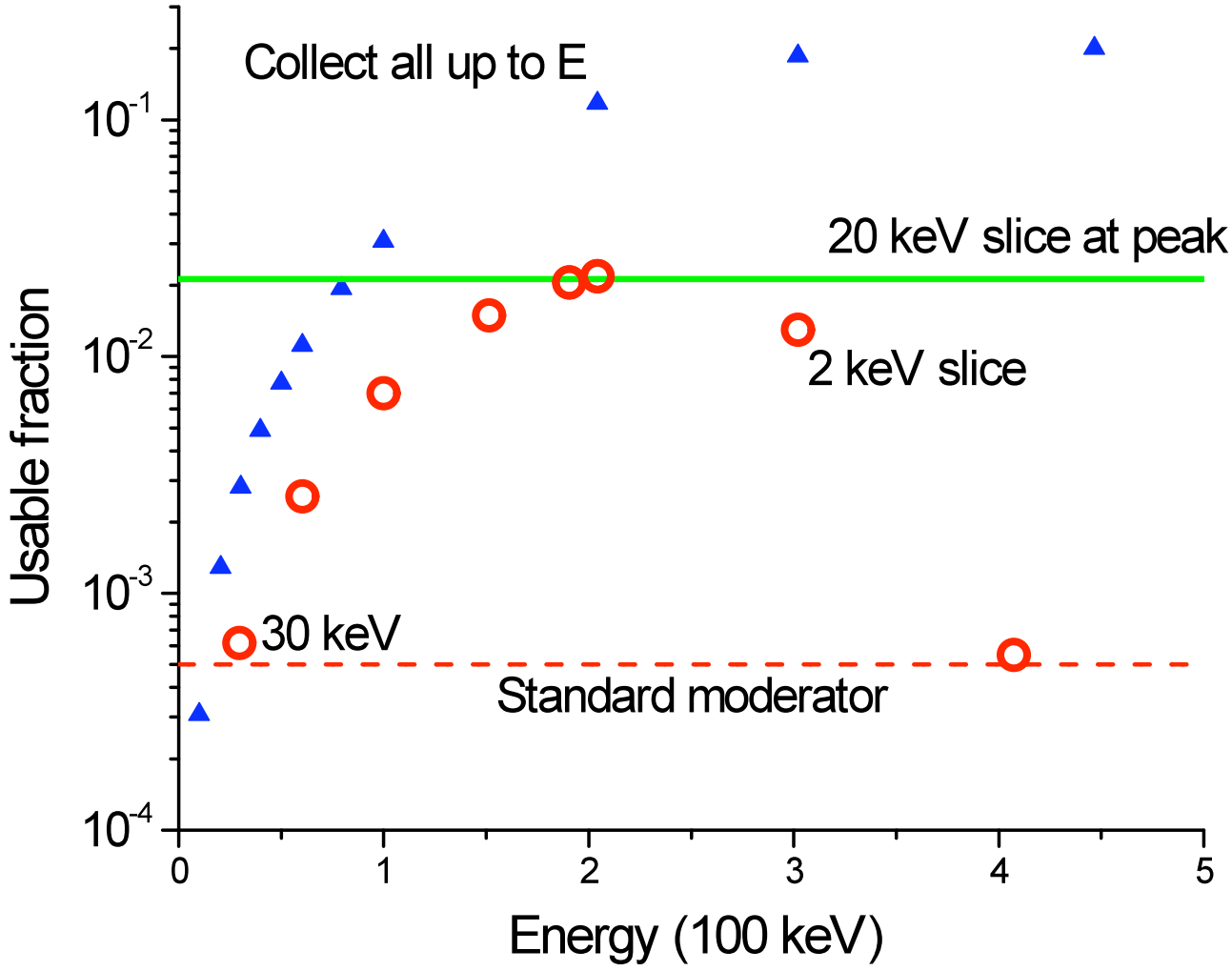
Magnetic funneling

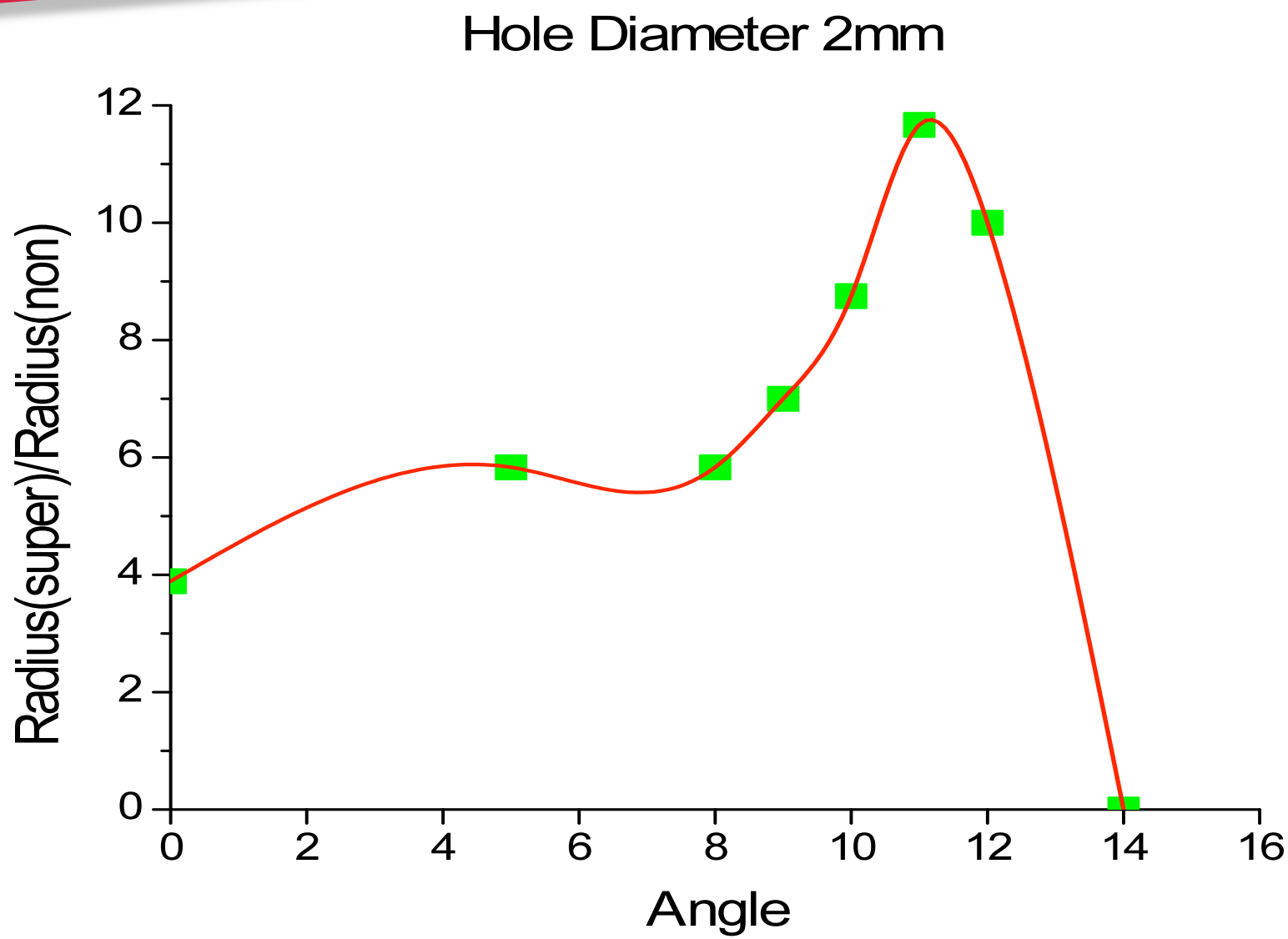




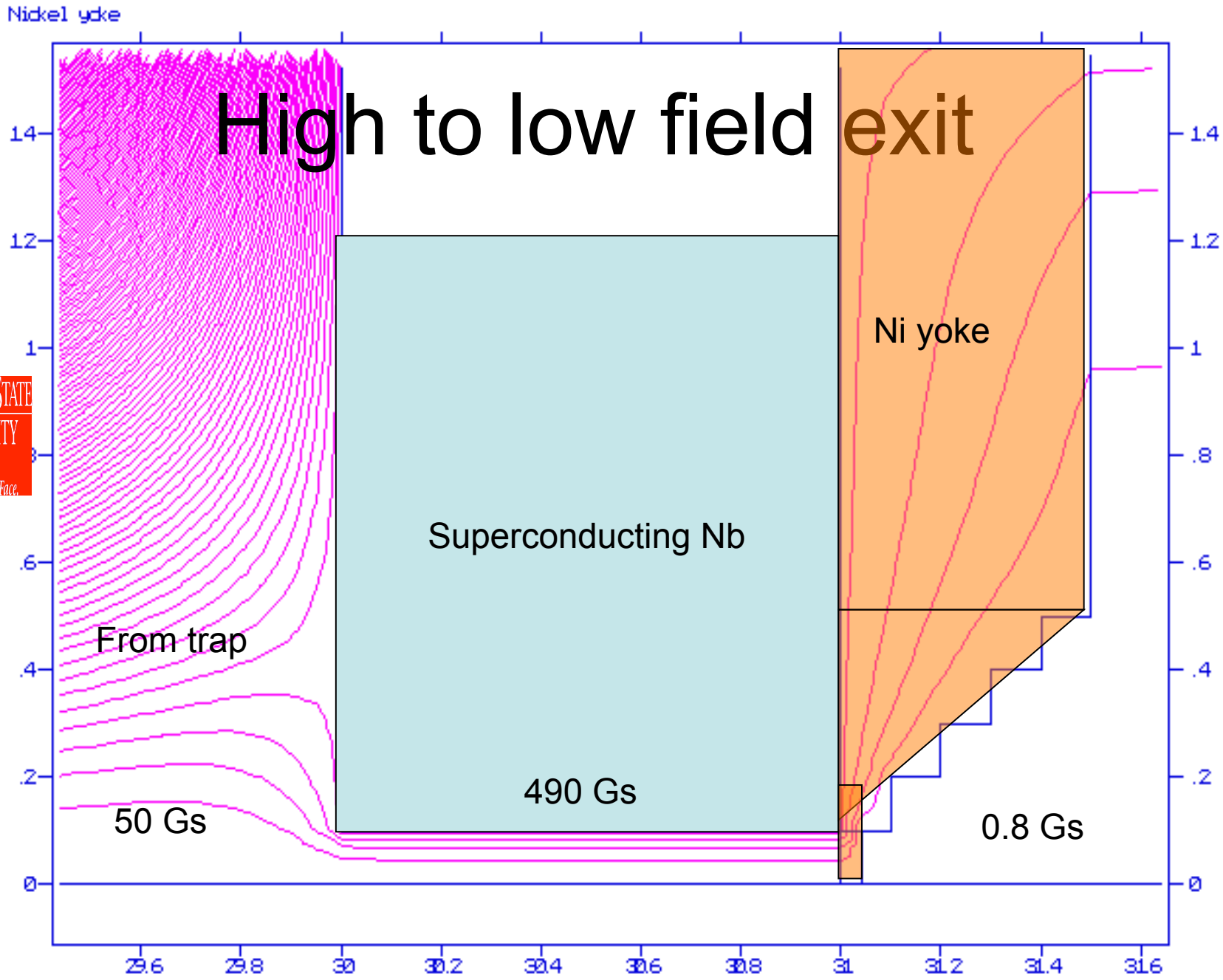
Schematic view of the type I superconducting Nb magnetic funnel (left). The Nb is located in front of the superconducting trap magnet, which contains the micro Malmberg-Penning trap array. The Meissner effect pinches the field lines and hence the positrons through an array of holes passing through the niobium. This is shown on the right for one hole from the center axis up.

Magnetic trap moderation



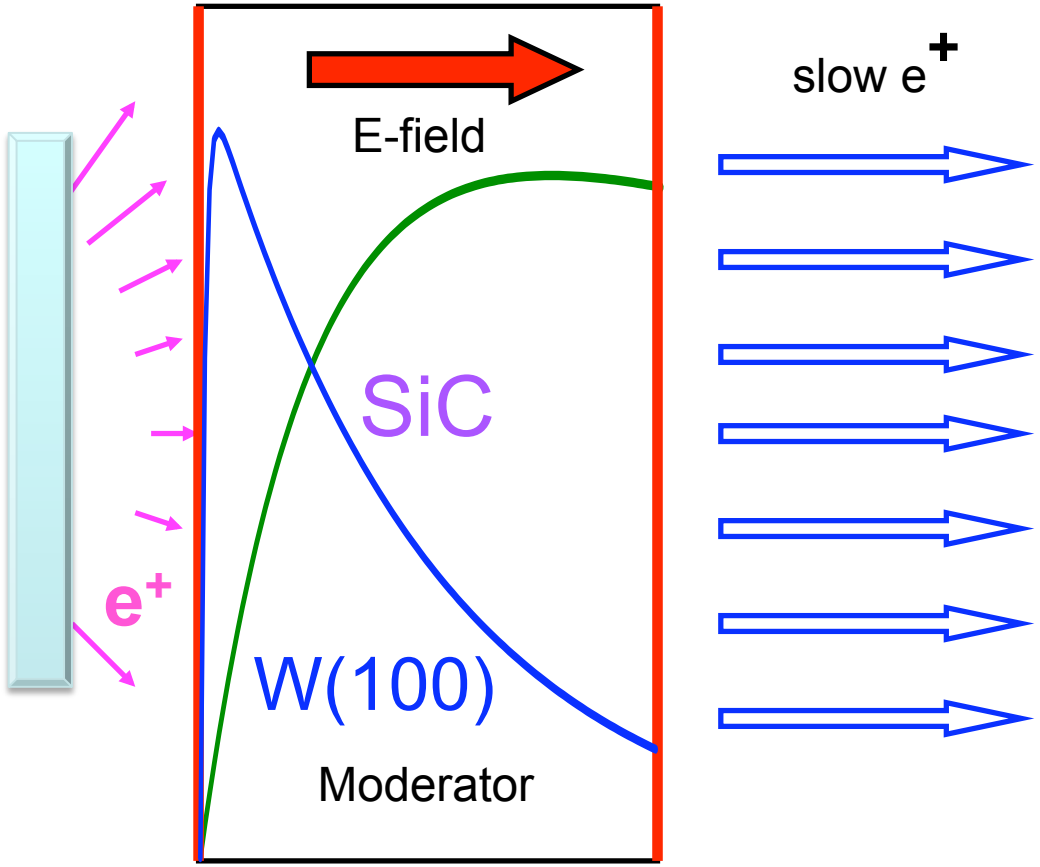

Hole Diameter 2mm
Radius(super)/Radius(non)
0
2
4
6
8
10
12
0
2
4
6
8
10
12
14
16
Angle

High to low field exit

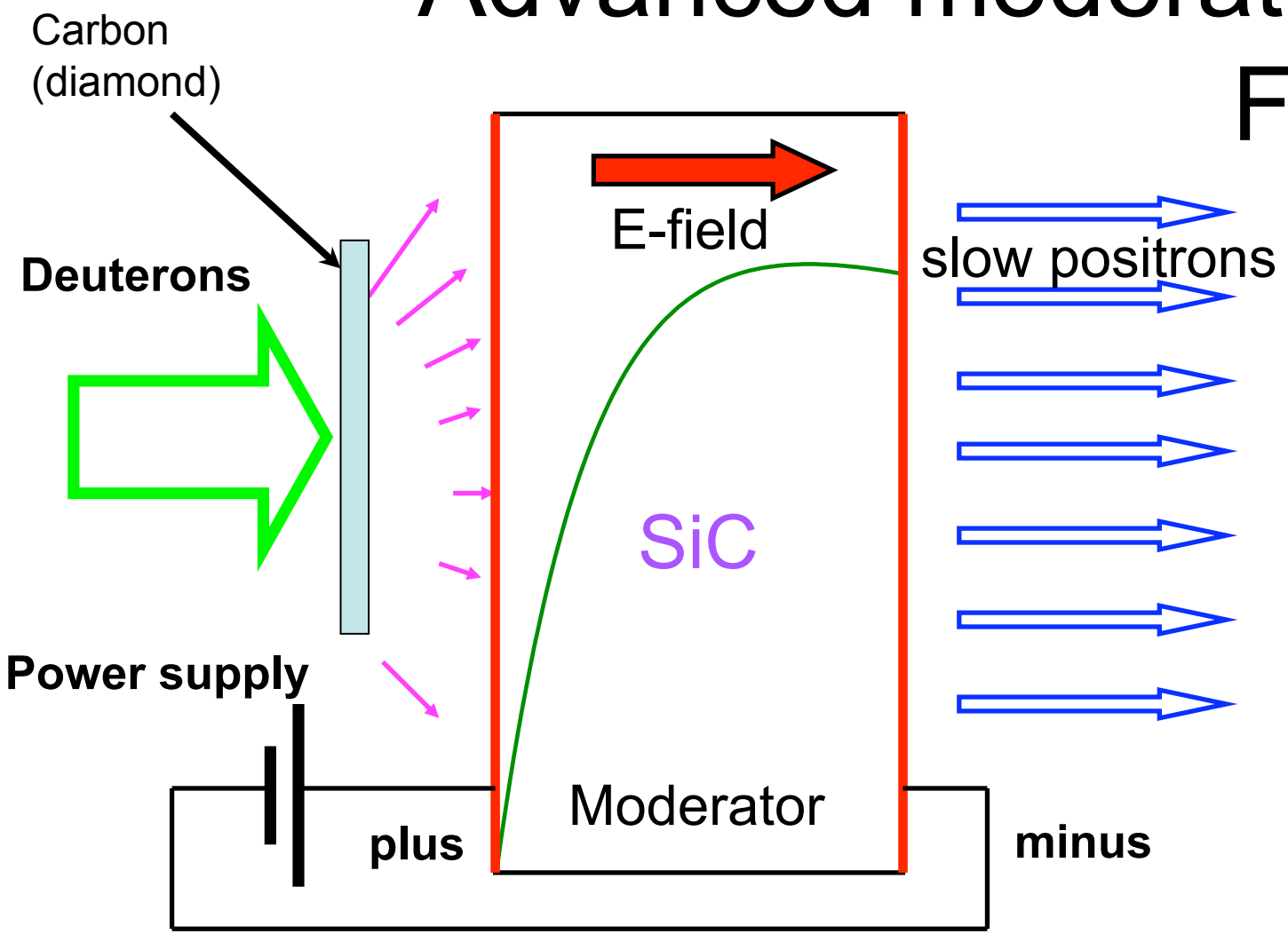


Advanced moderation

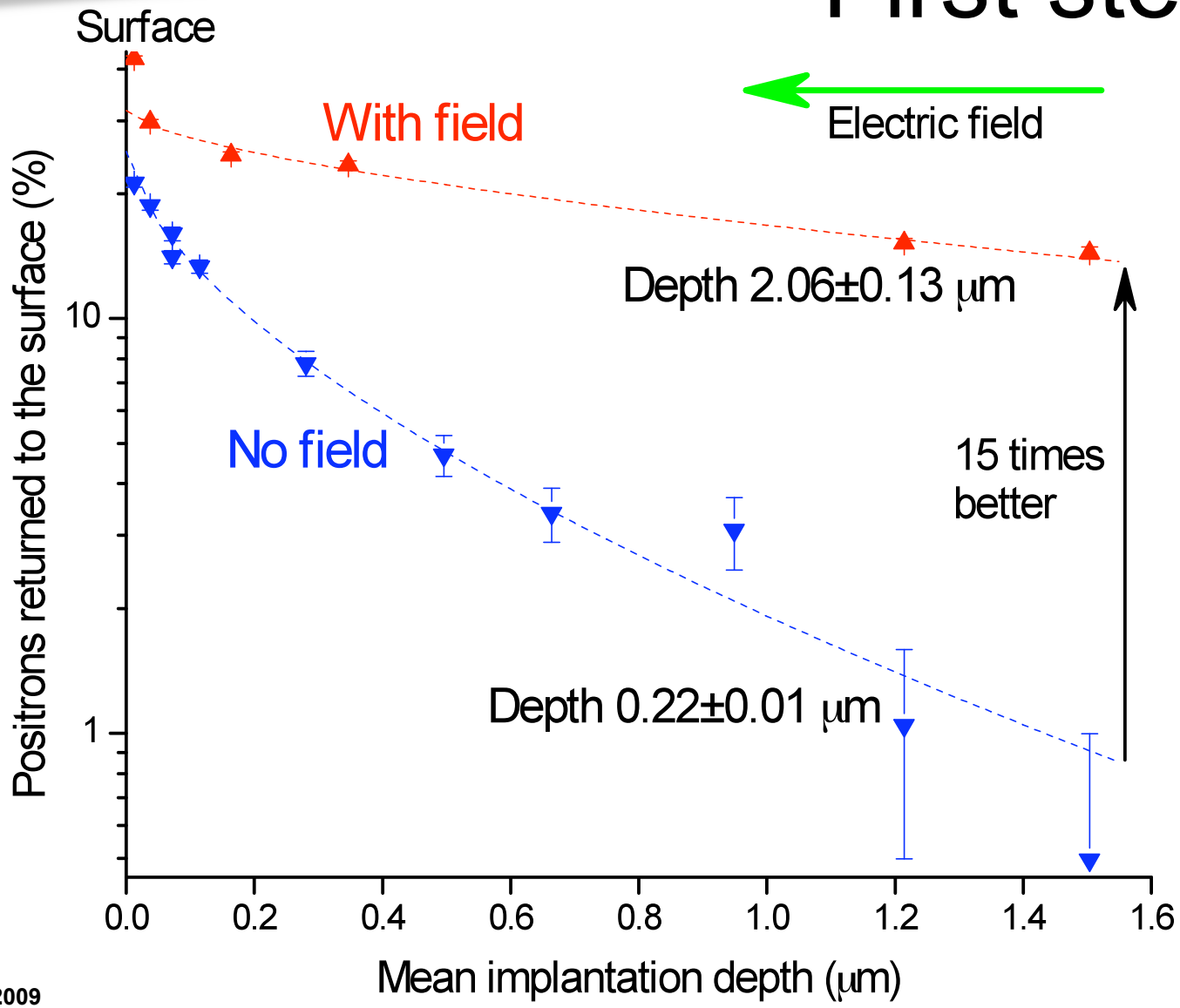
Solid Nitrogen produced from the accelerator



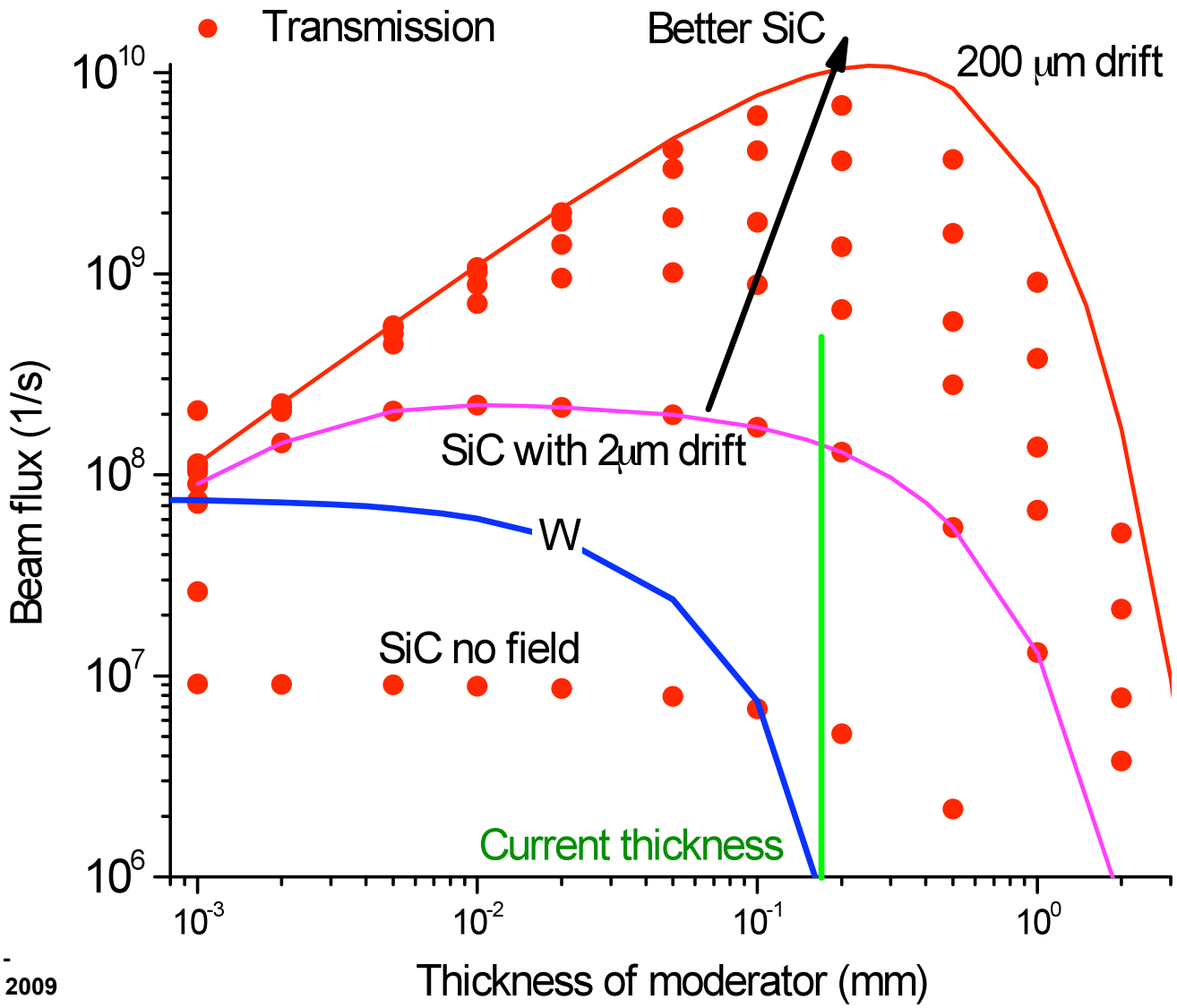
Advanced moderation: FAM



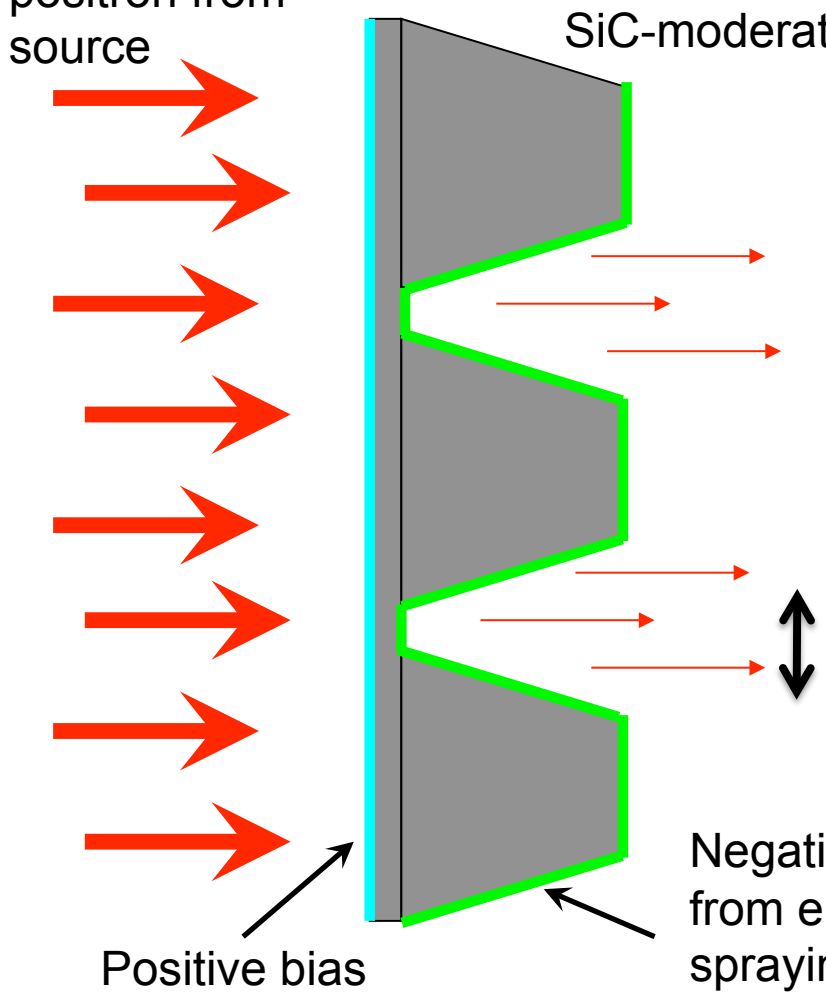
First steps…


Surface
With field
Electric field
Depth 2.06±0.13 μm
No field
15 times
better
Depth 0.22±0.01 μm
Positrons returned to the surface (%)
10
1
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Mean implantation depth (μm)

Moderator efficiency



The "holy" field assisted moderation



Slow, moderated positrons are pulled out by electric field;
Funnels patterned to match micro trap array

Diameter is smaller than hole diameter and cold and energy spread around 3/2 kT

Why store antimatter?

Reaction / source of energy	Specific energy (J/kg)	Fraction used For energy
Antimatter (e.g. positrons) Plus matching mass of matter	$1.8 \cdot 10^{17}$ or 1.8 J/10^{14} positrons	100%
Fusion of deuterium-tritium	$3 \cdot 10^{14}$	0.34%
Fission of ^{235}U	$8 \cdot 10^{13}$	0.09%
TNT	$5 \cdot 10^{6}$	$7 \cdot 10^{-9}$%

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Conclusion need moderated positrons to realistically store

- "Most cost effective" means to create antimatter
- However it does costs energy to produce but can use as stored energy
- Portable positron sources without the need of radioactive sources could be used research and industry.
- Need to have a method to store macroscopic amounts.- Need new ideas>>>>>