EXO

Status

Giorgio Gratta
Physics Dept, Stanford

DUSEL Workshop, Lead, Oct 1, 2009

K.Barry, E.Niner, A.Piepke
Physics Dept, U. of Alabama, Tuscaloosa AL
P.Vogel *Physics Dept Caltech, Pasadena CA*
A.Bellerive, M.Bowcock, M.Dixit, K.Graham,
C.Hargrove, E.Rollin, D.Sinclair, V.Strickland
Carleton University, Ottawa, Canada
C. Benitez-Medina, S.Cook, W.Fairbank Jr., K.Hall,
B.Mong *Colorado State U., Fort Collins CO*
M.Moe *Physics Dept UC Irvine, Irvine CA*
D.Akimov, I.Alexandrov, A.Burenkov, M.Danilov, A.Dolgolenko, A,Karelin, A.Kovalenko,
A.Kuchenkov, V.Stekhanov, O.Zeldovich *ITEP Moscow, Russia*
B.Aharmim, K.Donato, J.Farine, D.Hallman, U.Wichoski *Laurentian U., Canada*
H.Breuer, C.Hall, L.Kaufman, D.Leonard, S. Slutsky, Y-R. Yen
U. of Maryland, College Park MD
K.Kumar, A.Pocar *U. of Massachusetts, Amherst*
M.Auger, G.Giroux, R.Gornea, F.Juget, G.Lutter, J-L.Vuilleumier,
J-M.Vuilleumier *Laboratory for High Energy Physics, Bern, Switzerland*
N.Ackerman, M.Breidenbach, R.Conley, W.Craddock, J.Hodgson, D.McKay, A.Odian,
C.Prescott, P.Rowson, K.Skarpaas, J.Wodin, L.Yang, S.Zalog
SLAC, Menlo Park CA
P.Barbeau, L.Bartoszek, R.DeVoe, M.Dolinski, B.Flatt, G.Gratta, M.Green, F.LePort,
M.Montero-Diez, R.Neilson, A.Reimer-Muller, A.Rivas, K.O'Sullivan, K.Twelker
Physics Dept Stanford U., Stanford CA
P.Fierlinger *TUM, Garching Germany*

Xe is ideal for a large experiment

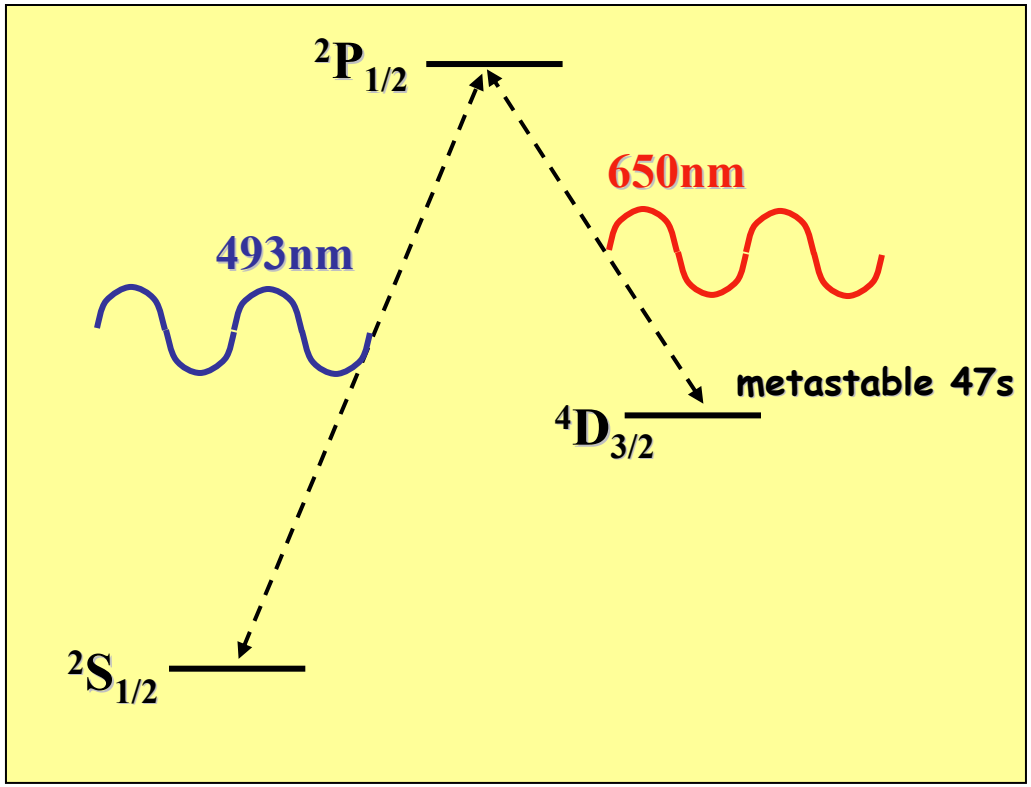
- No need to grow crystals
- Can be re-purified during the experiment
- No long lived Xe isotopes to activate
- Can be easily transferred in different detectors if alternate technologies become available
- Noble gas: easy(er) to purify
- ^{136}Xe enrichment easier and safer:
  - noble gas (no chemistry involved)
  - centrifuge feed rate in gram/s, all mass useful
  - centrifuge efficiency ~ Δm. For Xe 4.7 amu
- ^{129}Xe is a hyperpolarizable nucleus, under study for NMR tomography… a joint enrichment program ?

Xe offers a qualitatively new tool against background:

$^{136}Xe \rightarrow {}^{136}Ba^{++} e^- e^-$ final state can be identified using optical spectroscopy (M.Moe PRC44 (1991) 931)

Ba^+ system best studied (Neuhauser, Hohenstatt, Toshek, Dehmelt 1980)
Very specific signature "shelving"
Single ions can be detected from a photon rate of 10^7/s

- Important additional constraint
- Drastic background reduction



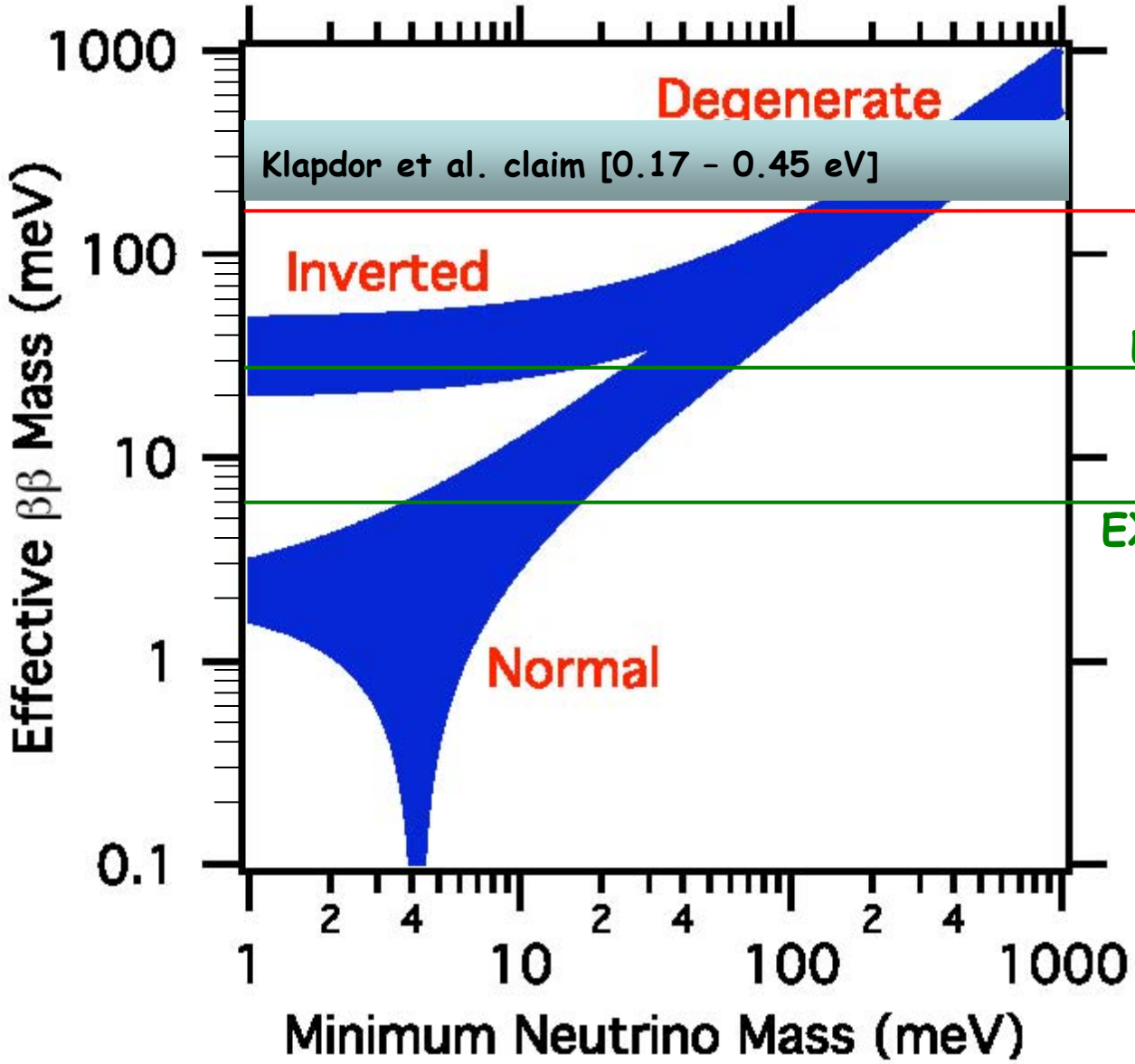
- This may be the only viable technique if <m> happens to be very small
- Xe (in gas phase) *is* the best way to try using decay kinematics to study the decay after it has been observed

Assume an "asymptotic" fiducial mass of 10 tons of ^{136}Xe at 80%

A somewhat natural scale:

- World production of Xe is ~40 ton/yr
- Detector size
- $2 \cdot 10^3$ size increase: good match to the 10^{-2} eV mass region

Mainly going in light bulbs, plasma displays and satellite propulsion



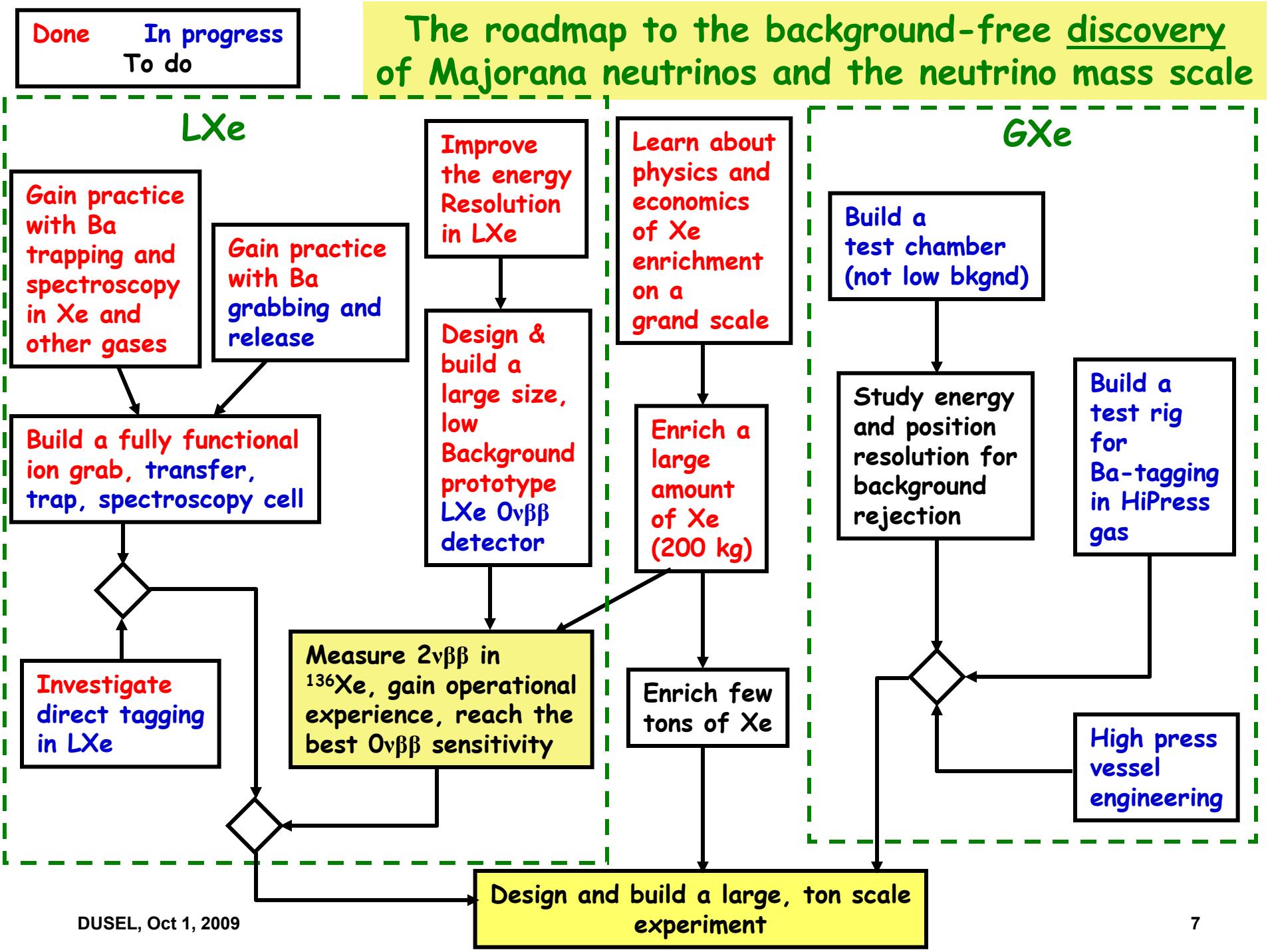
100kg-class detectors
~100-200 meV sensit.

EXO 1 ton, 5yr, 28 meV

EXO 10 ton, 10yr, 6 meV

Plot assumes
Majorana neutrinos

Plot from Avignone, Elliott, Engel arXiv:0708.1033 (2007)

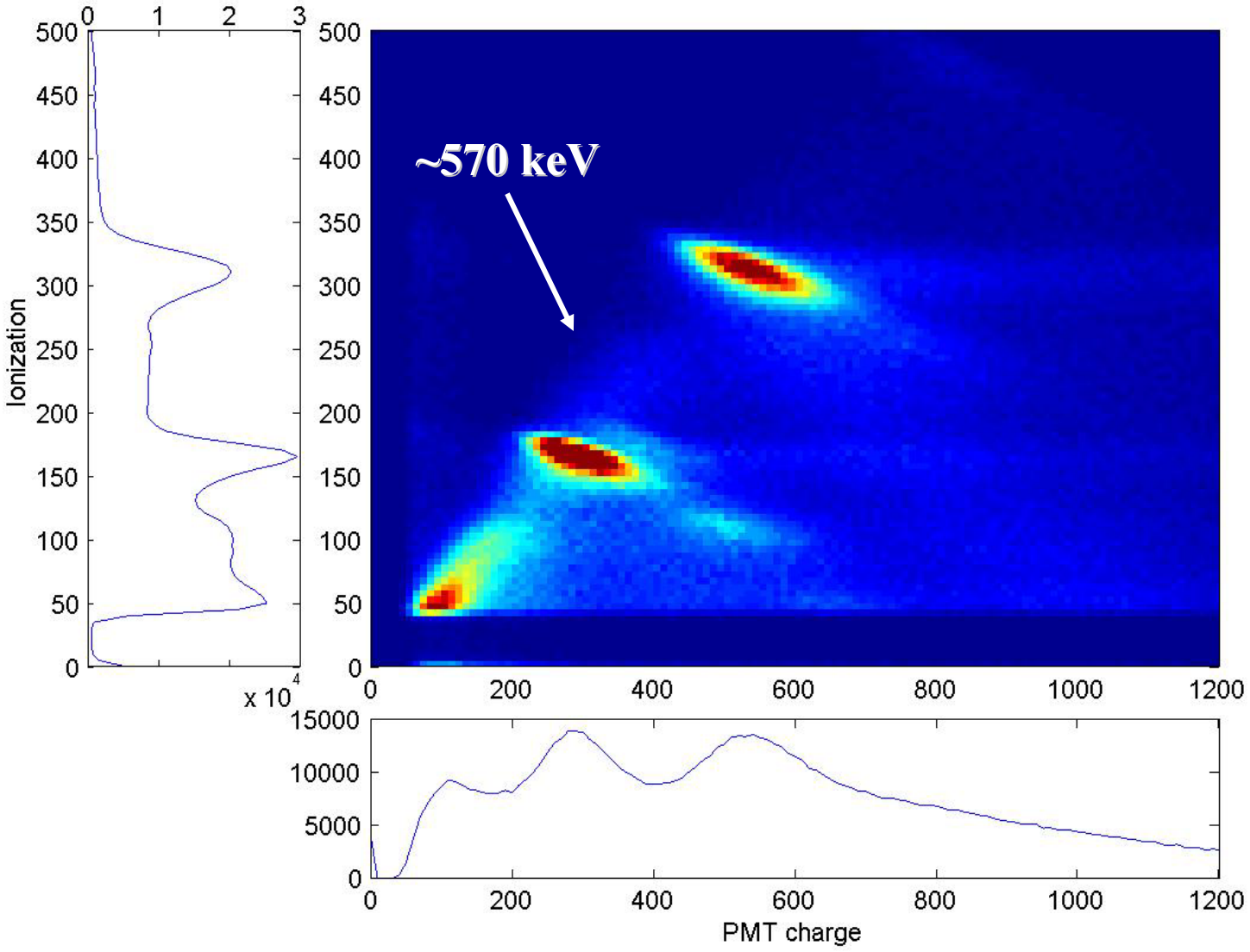

Done
In progress
To do
The roadmap to the background-free discovery of Majorana neutrinos and the neutrino mass scale
LXe
GXe
Gain practice with Ba trapping and spectroscopy in Xe and other gases
Gain practice with Ba grabbing and release
Improve the energy Resolution in LXe
Learn about physics and economics of Xe enrichment on a grand scale
Build a test chamber (not low bkgnd)
Build a fully functional ion grab, transfer, trap, spectroscopy cell
Design & build a large size, low Background prototype LXe 0νββ detector
Enrich a large amount of Xe (200 kg)
Study energy and position resolution for background rejection
Build a test rig for Ba-tagging in HiPress gas
Investigate direct tagging in LXe
Measure 2νββ in ^{136}Xe, gain operational experience, reach the best 0νββ sensitivity
Enrich few tons of Xe
High press vessel engineering
Design and build a large, ton scale experiment

EXO R&D structure (after S4 award)

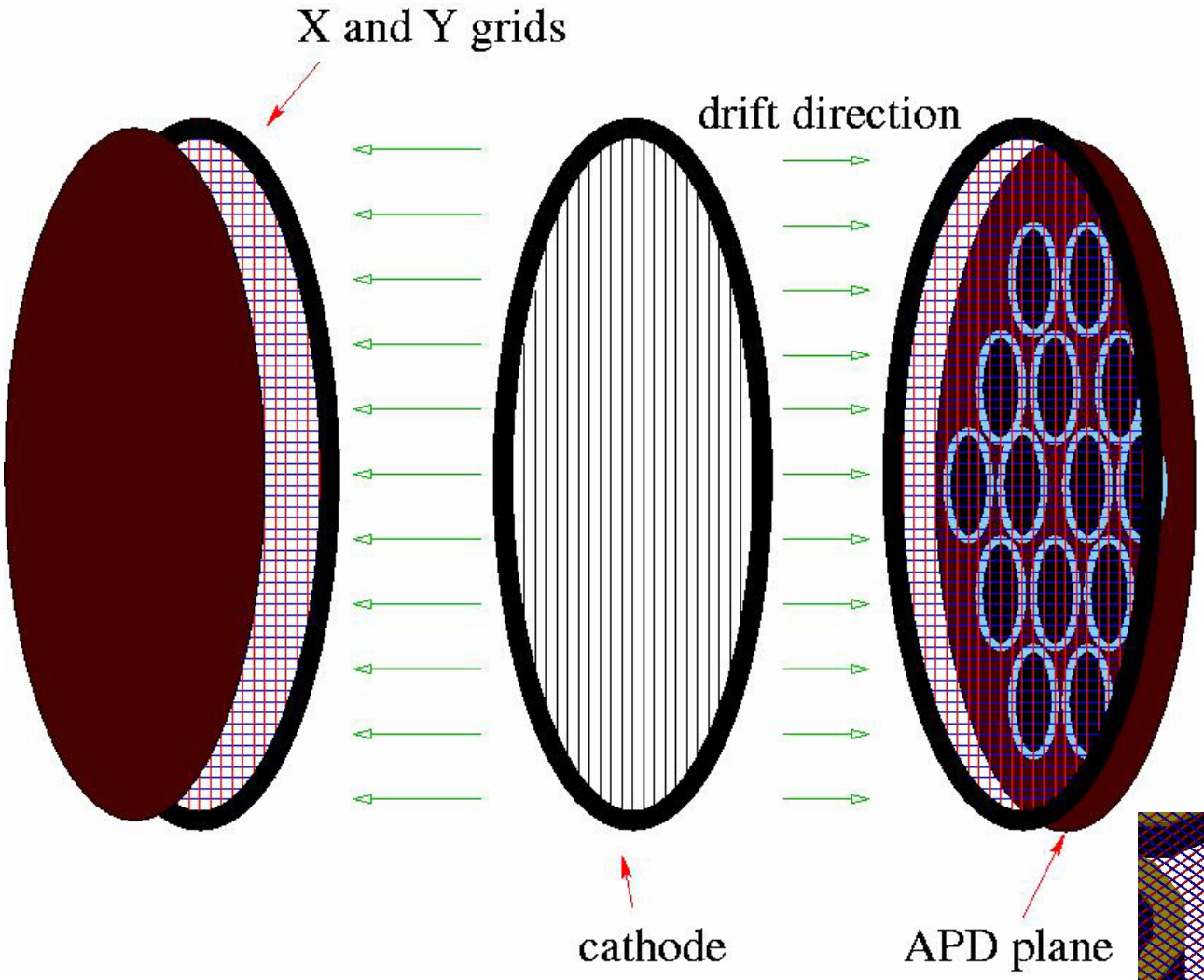
Task No	Task Name	Coordinator	Hub institution	Other institutions (as of Aug 12, 09)
-	EXO-200 construction /commissioning	M. Breidenbach	WIPP	All
1	Ba tag (LXe and GXe)	G.Gratta/W.Fairbank	Stanford	Carleton, CSU, UMD, SLAC, TUM
2	GXe detector	D.Sinclair	Carleton	Alabama, Bern, Laurentian, Stanford
3	LXe – Ba tag integration	TBD	TBD	Bern, UMass, SLAC
4	Conceptual Engineering	M.Breidenbach (after Jul 2010)	SLAC	Bern, Carleton
5	Low activity control	A.Piepke	None	Alabama, Bern, Laurentian

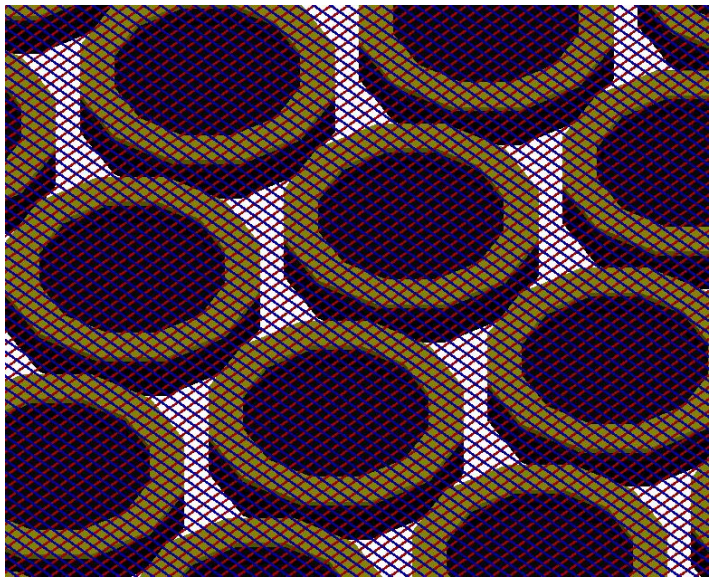
EXO-200

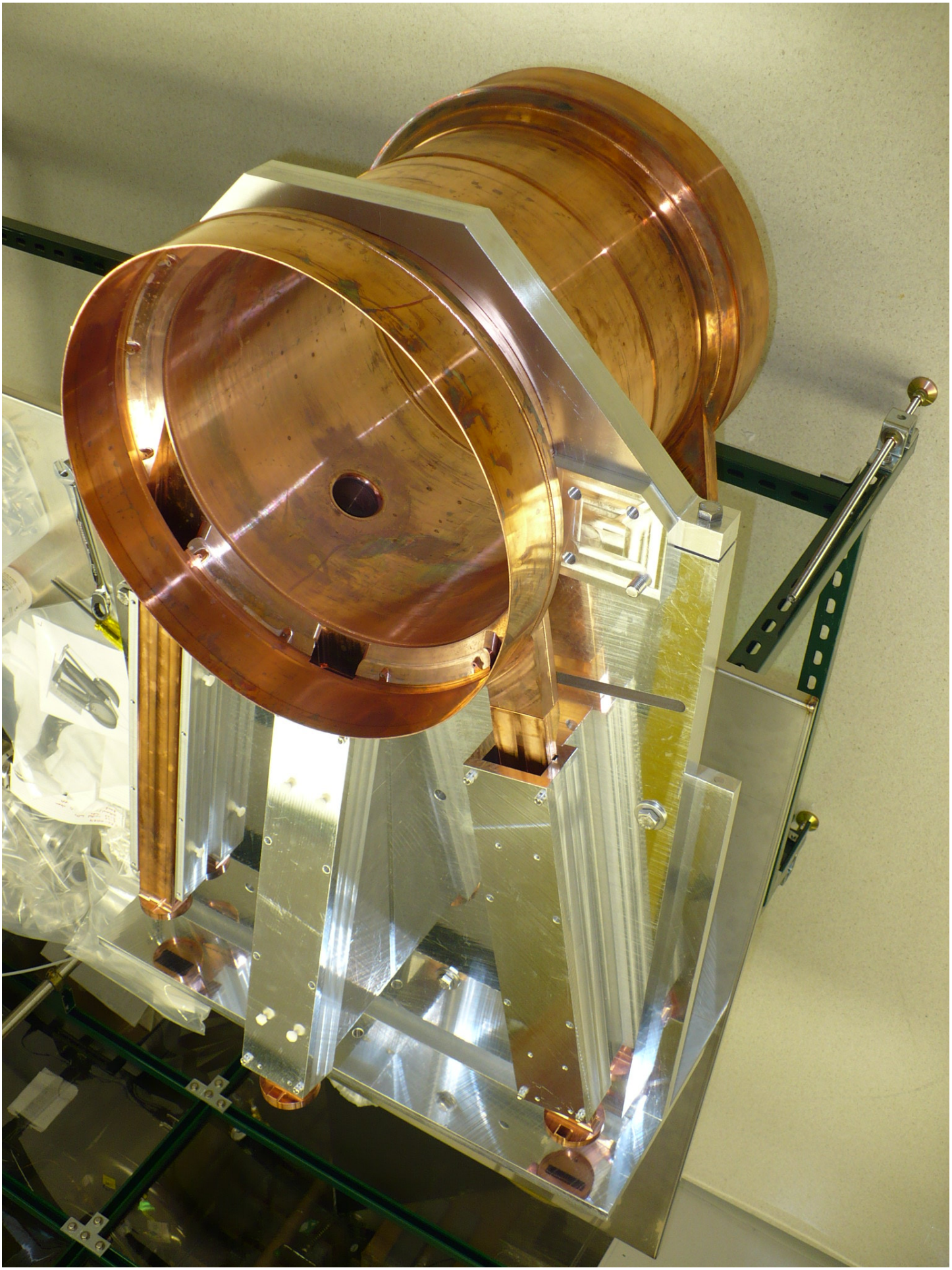
Both ionization and scintillation readout to optimize energy resolution



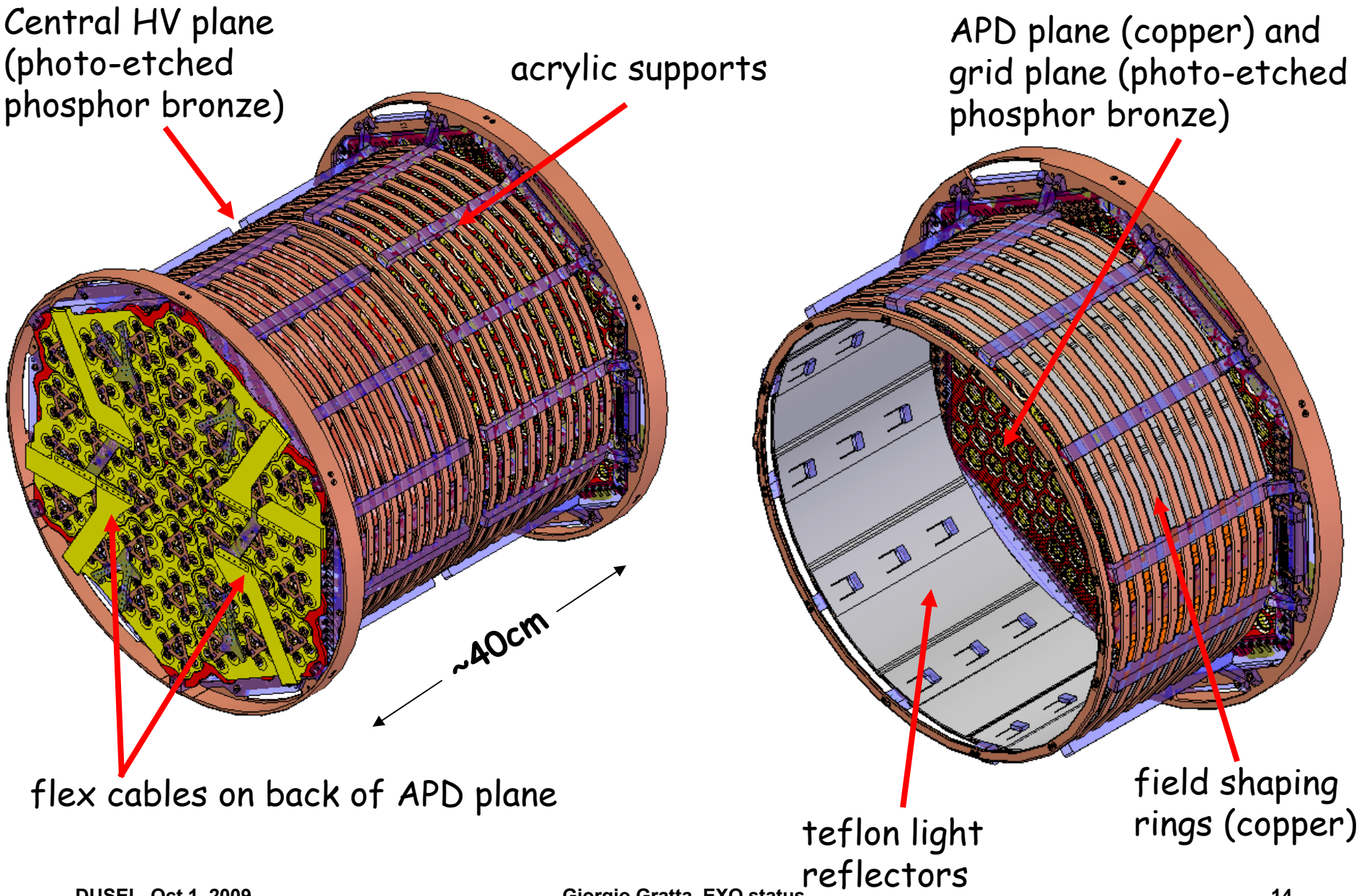
EXO-200 TPC basics

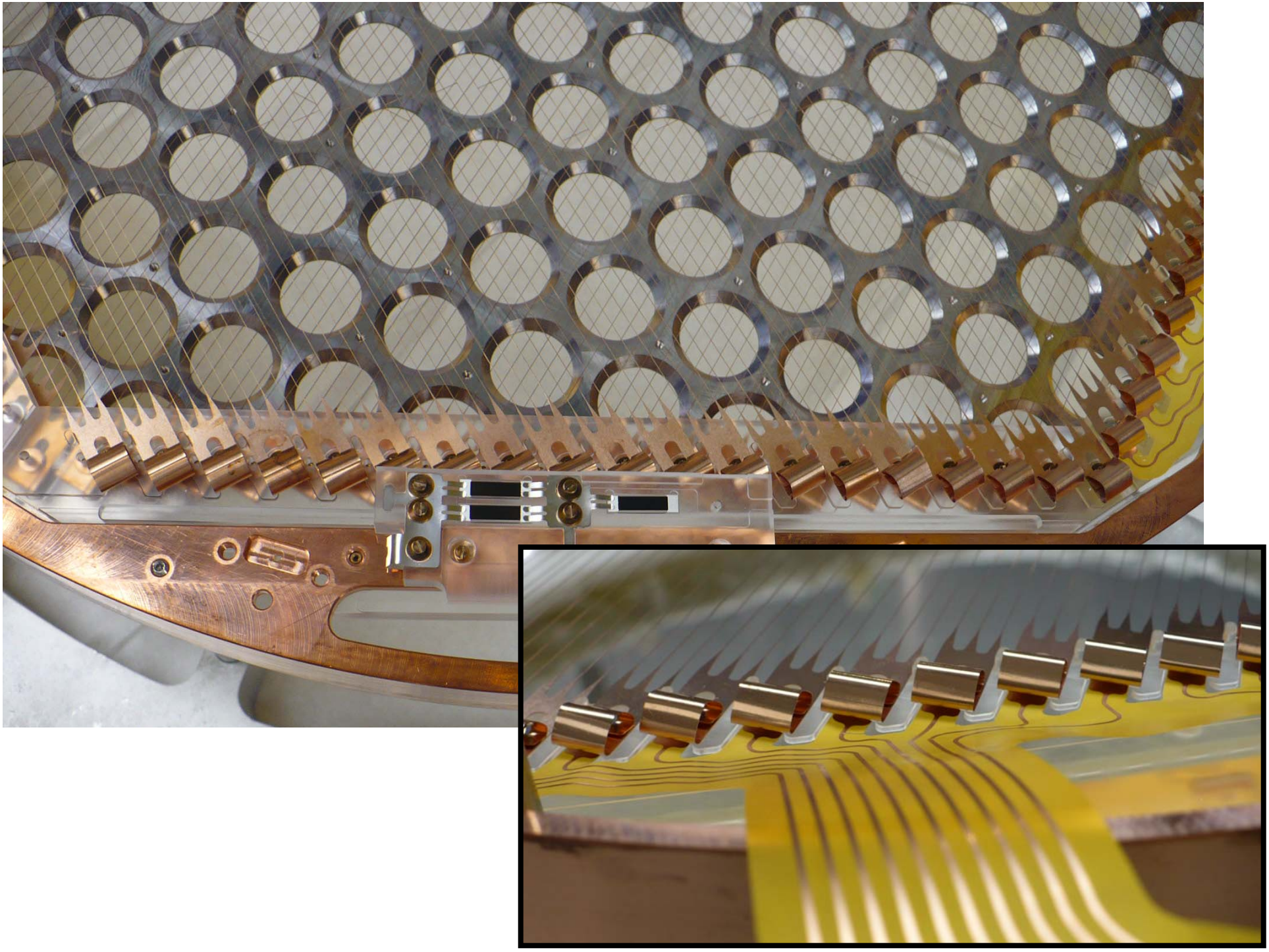


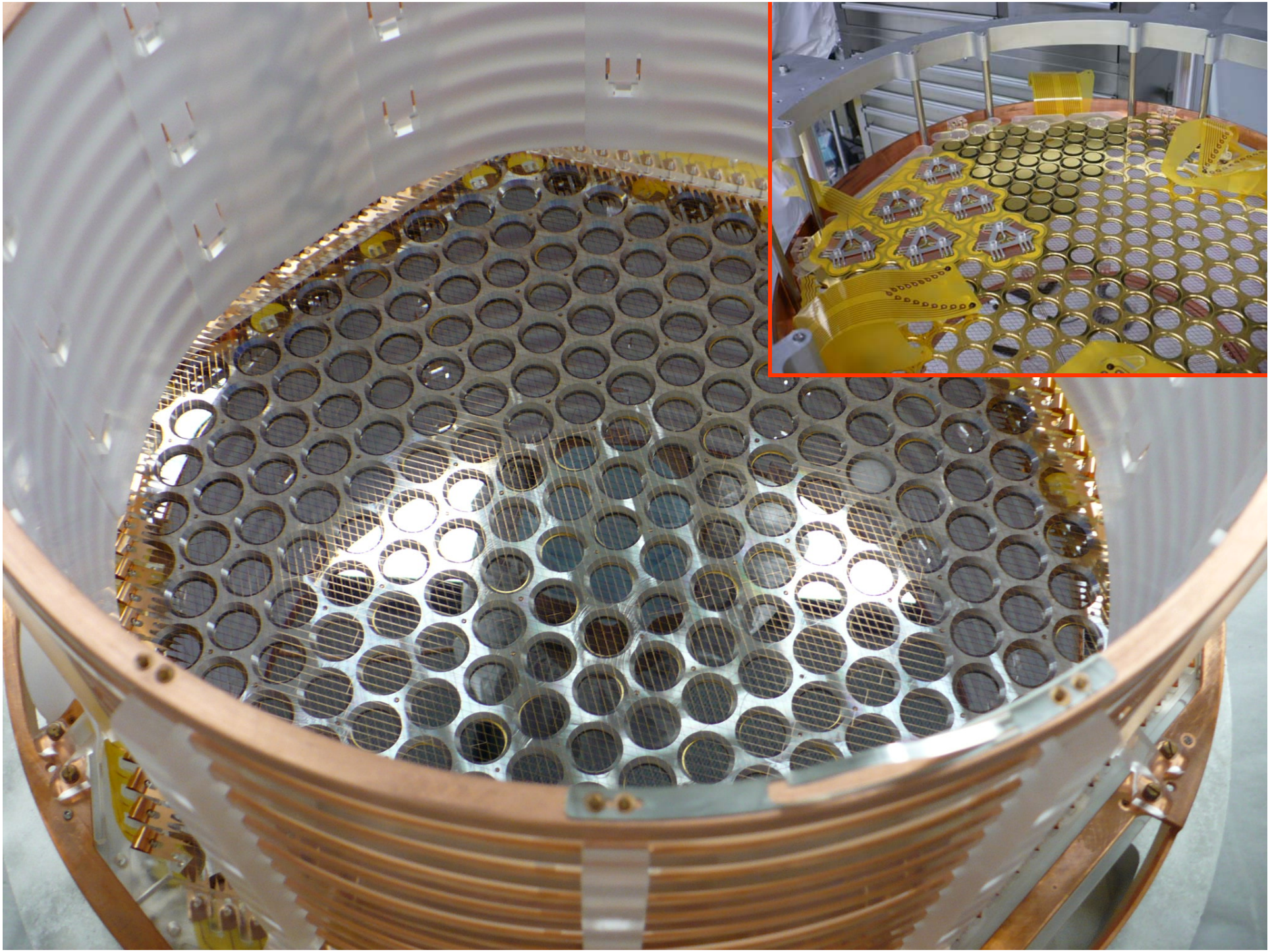


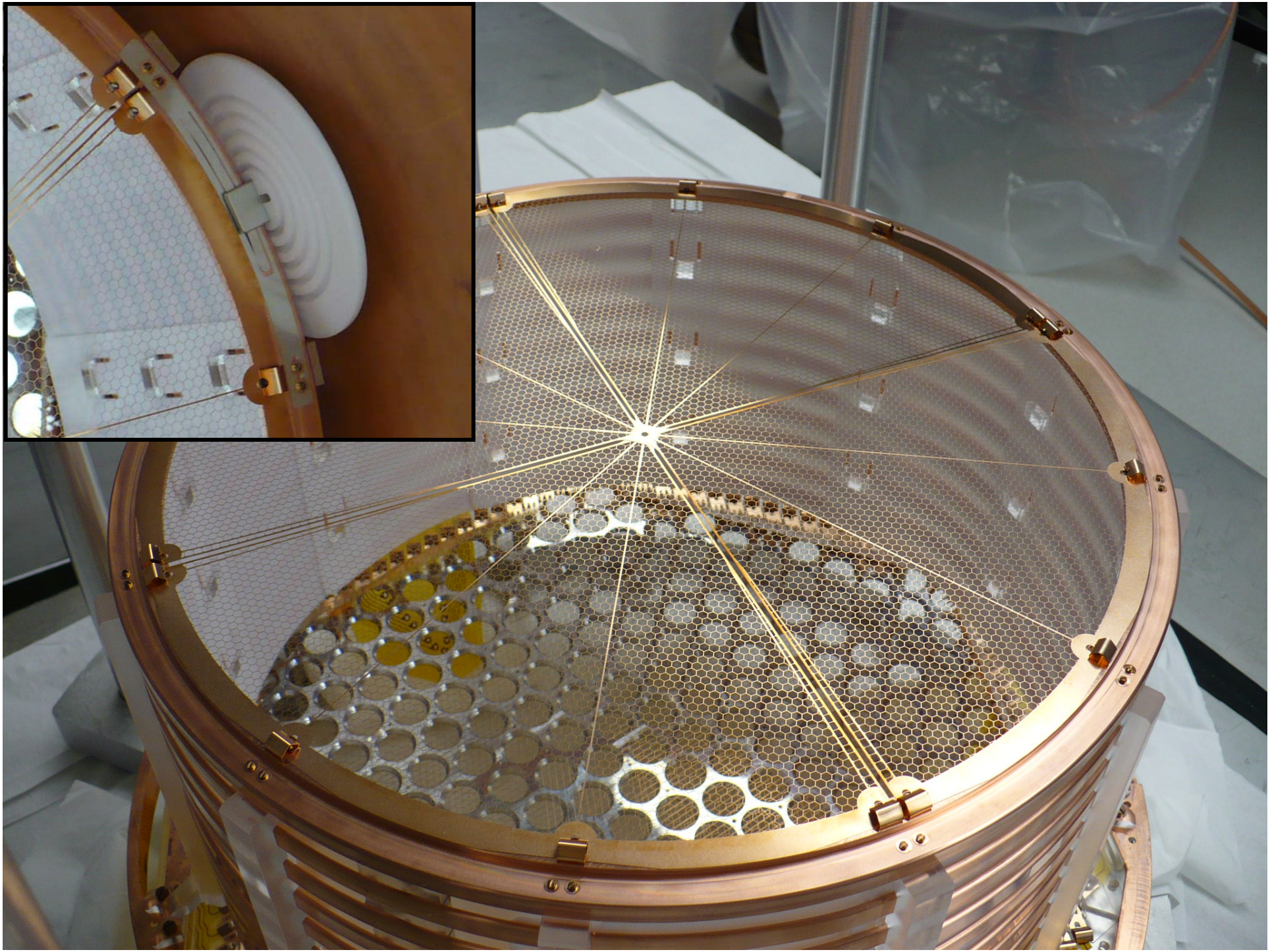


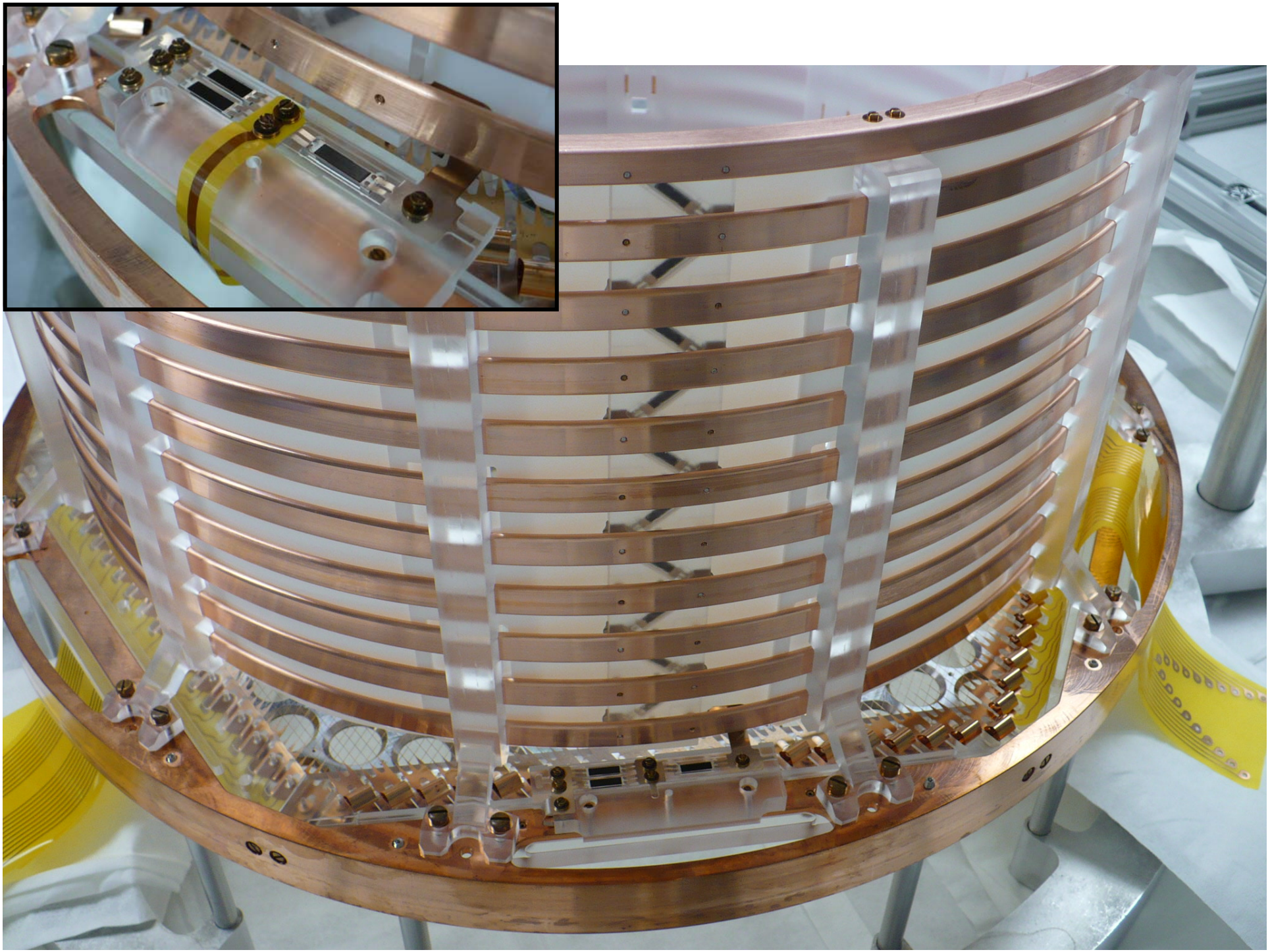
EXO-200 LXe TPC field cage & readout planes

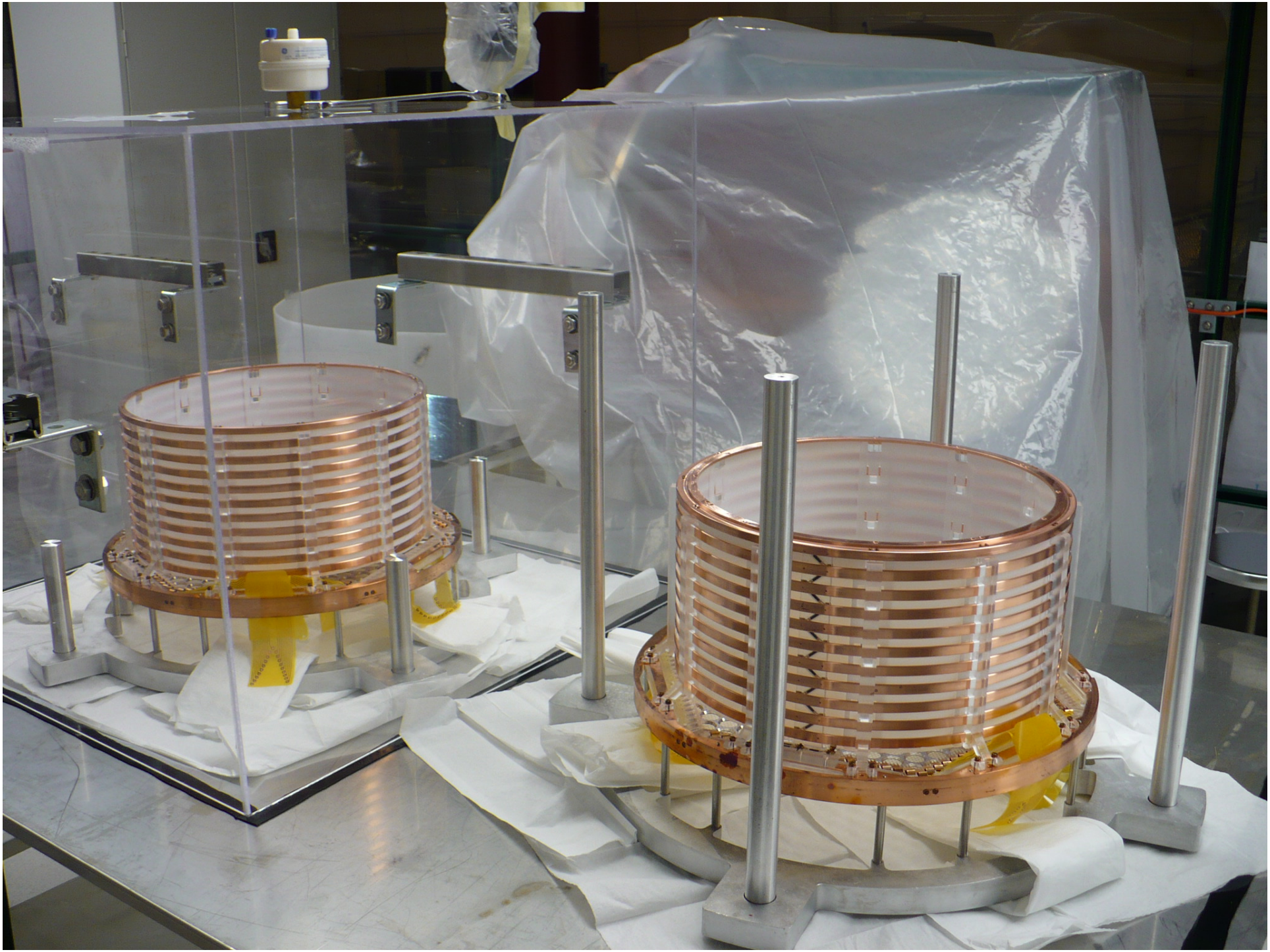


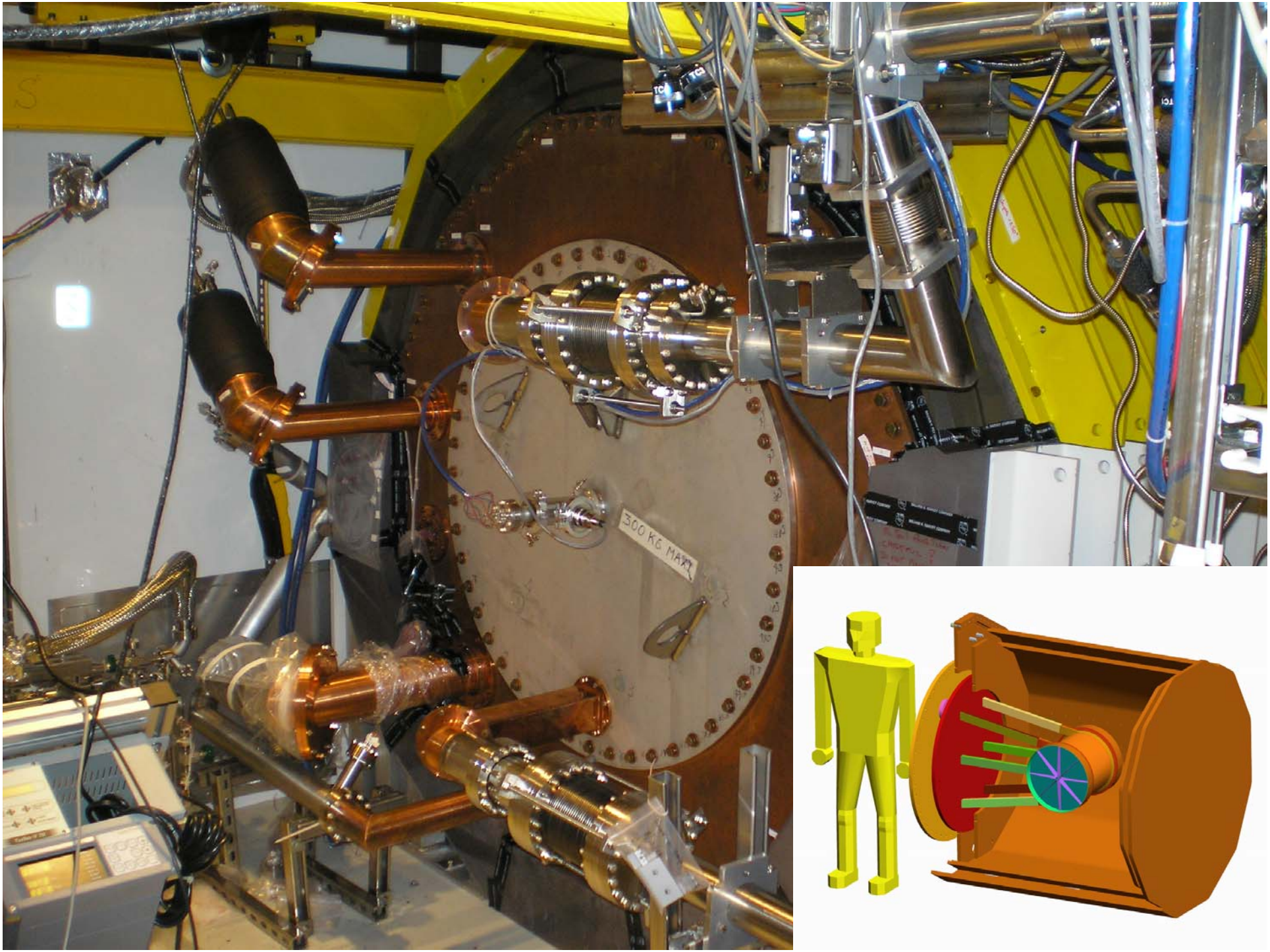






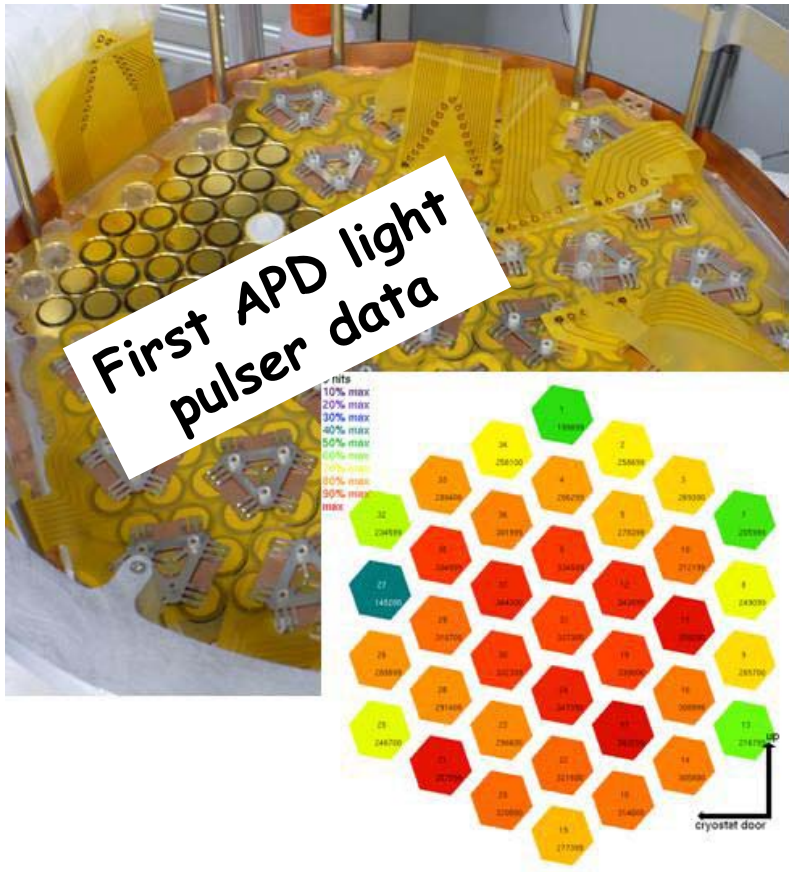




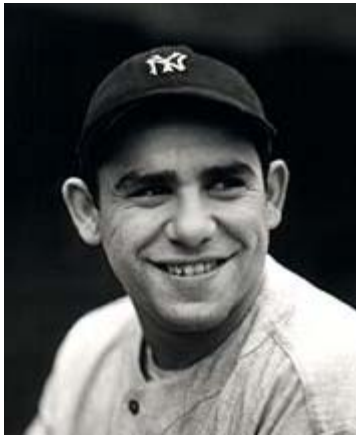

300 KG MAX

EXO-200 Summary

- TPC was tested with full electronics in the Summer 09 and passed all tests (but of course w/o LXe).
- TPC being packed, to arrive WIPP on Oct 31, 09
- Commissioning test run of all cryogenics at WIPP starting
- Expect to install TPC in the cryostat starting in ~ late Nov 09
- Expect to start running sometimes in early 2010



It's tough to make predictions… especially about the future



Case 1: EXO-200 sees nothing, really

→ Build the largest possible EXO, with Ba tagging unless the EXO-200 background is spectacular

Start in 5 to 8 yrs from now

Case 2: EXO-200 has a 2 or 3 sigma peak at the right place

→ Build a new ~500kg chamber maybe in the same cryostat and same mine

Start in <2 after signal is seen

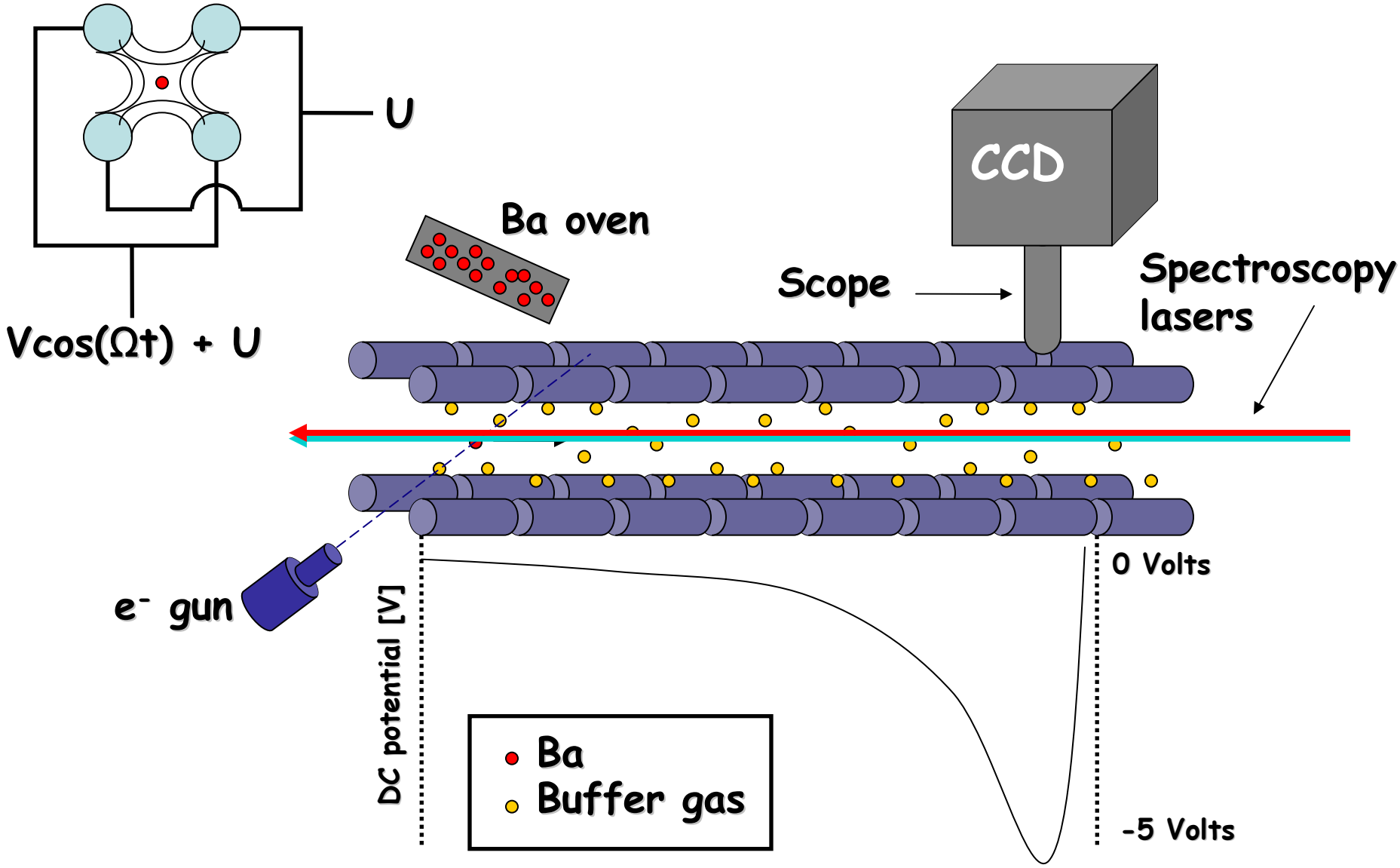
Case 3: EXO-200 has a clear signal

→ (open Champagne and) build a 1 bar GXe TPC for the very same 200kg of Xe to study angular correlations

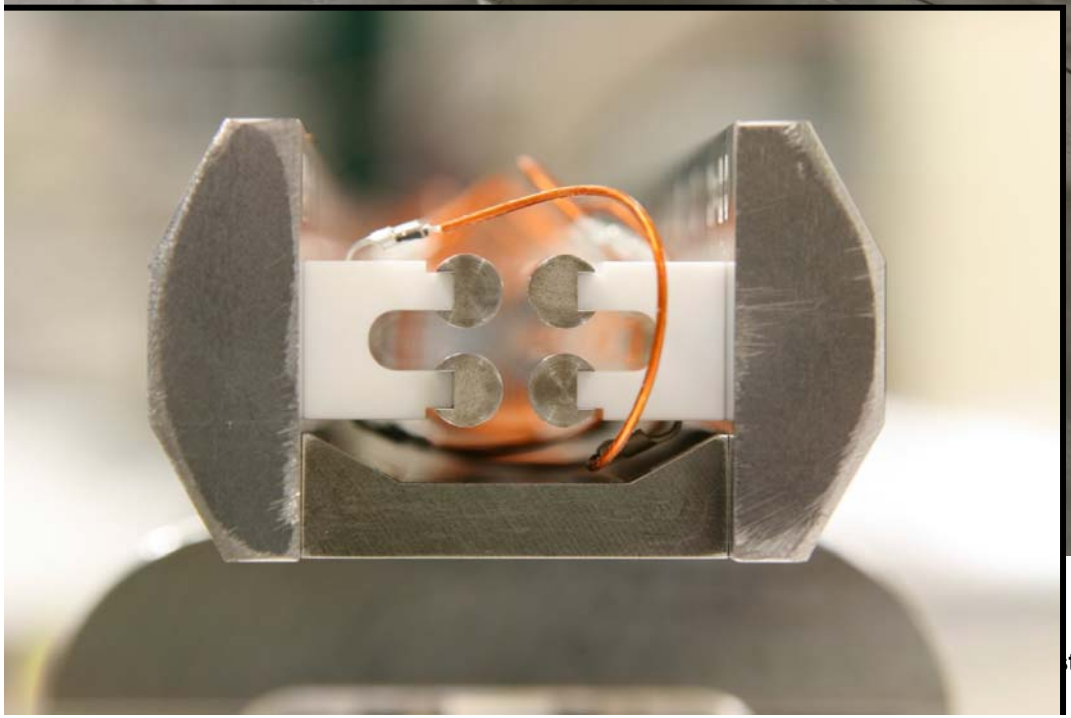
Start in 2014

Ba tagging R&D

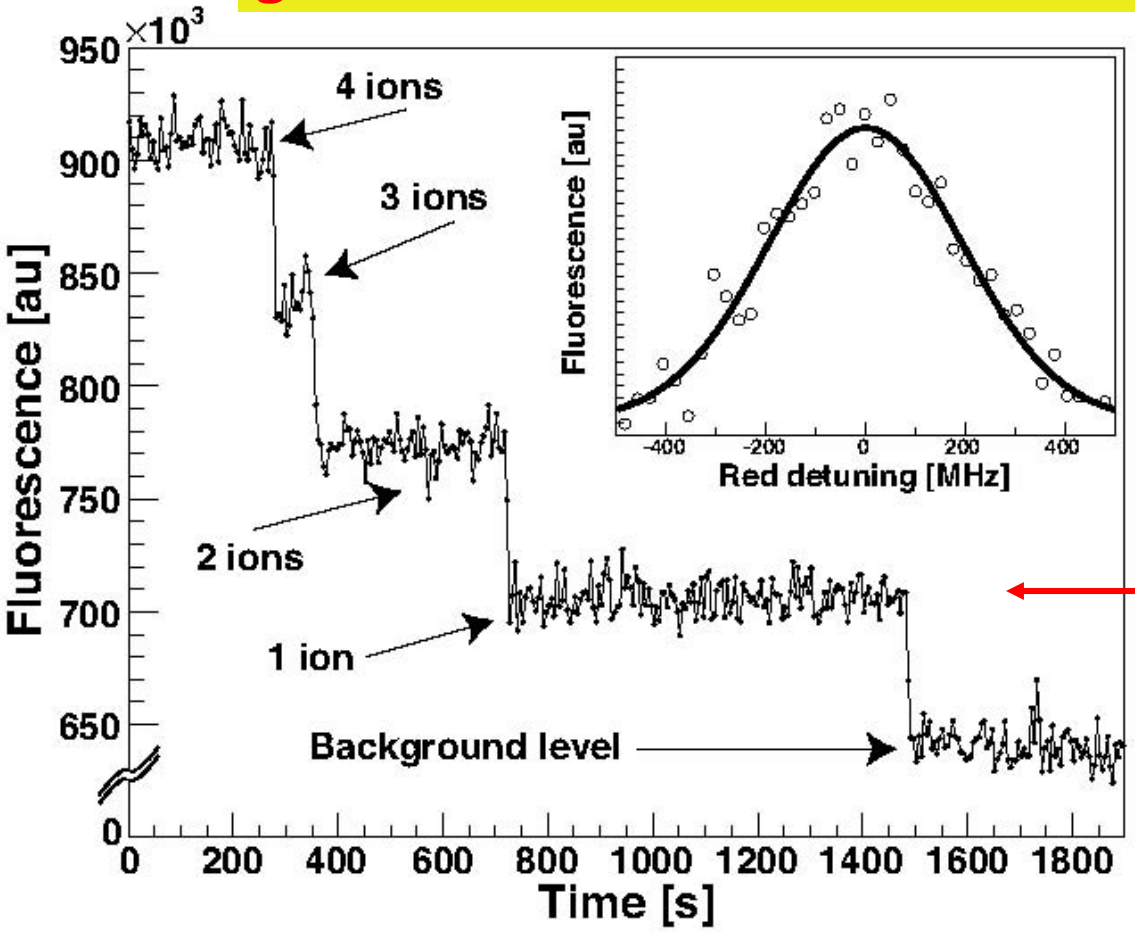
Ba^+ identification in a Linear Ion Trap



Electrode structure being prepared



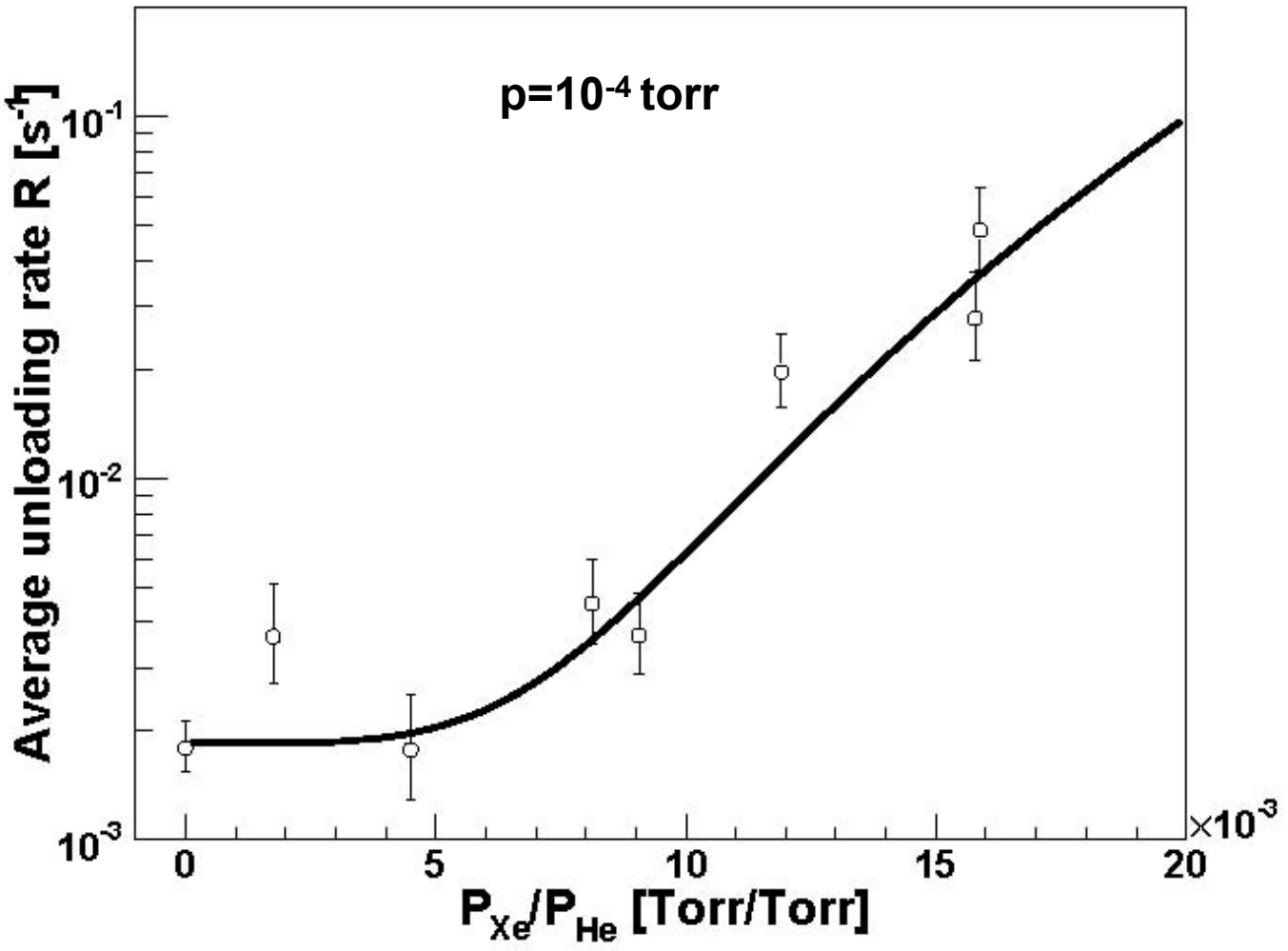
First single ion detection in high pressure gas (He, Ar)



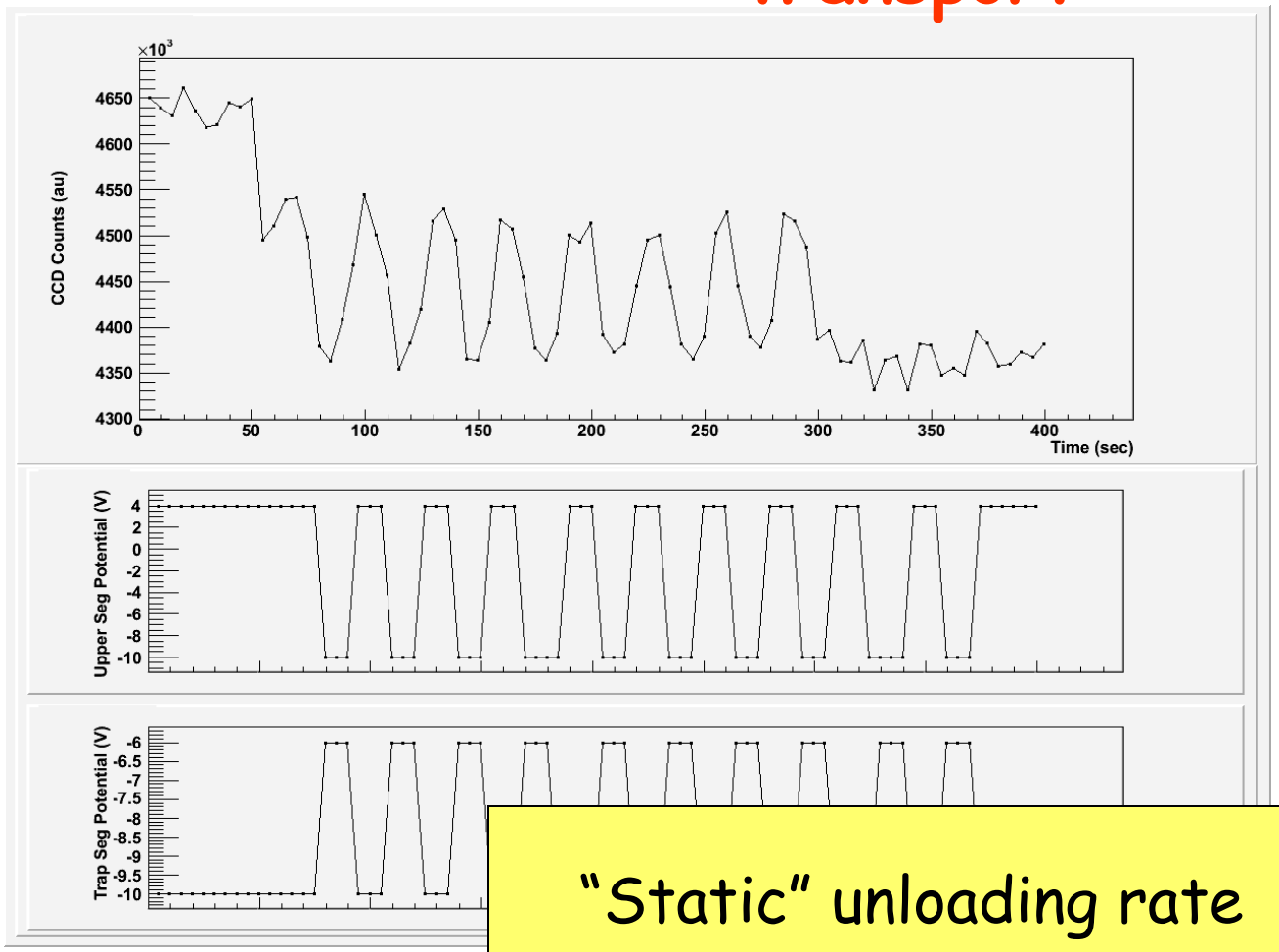
~9σ discimination in 25s integration

M.Green et al. arXiv:0702122, Phys Rev A 76 (2007) 023404
B.Flatt et al. arXiv:0704.1646, NIM A 578 (2007) 409

Single ion spectroscopy & identification possible in some Xe atmosphere provided He is added to the trap



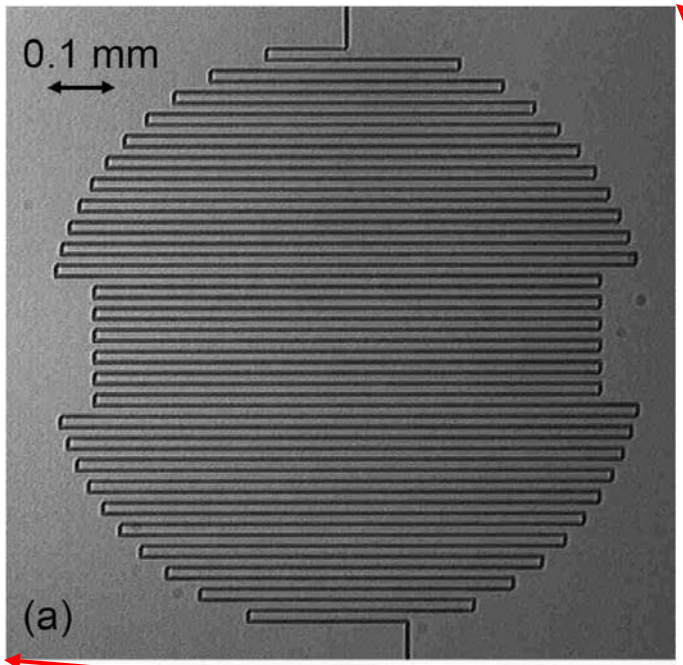
Trap also allows for very "clean" ion transport

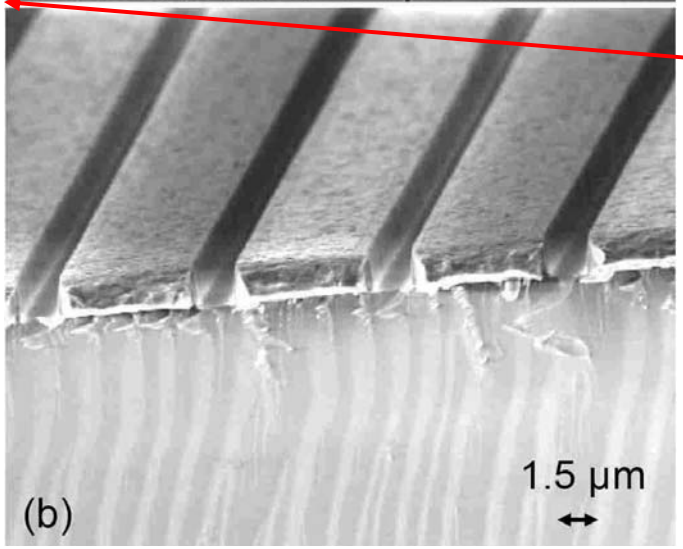


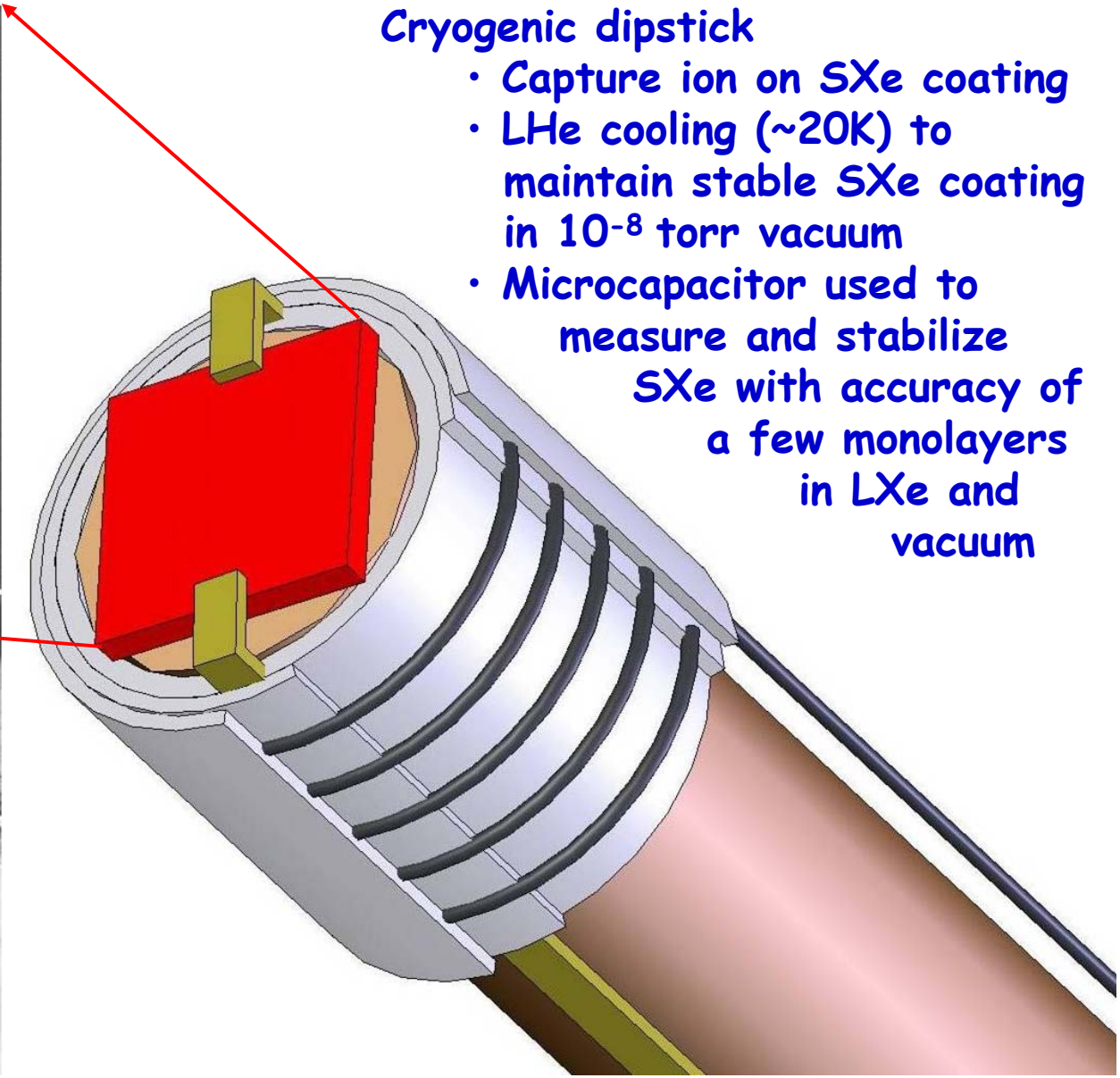
"Static" unloading rate $= 2.87^{+0.81}_{-0.67}\, mHz$

"Cycling" unloading rate $= 7.80^{+1.56}_{-2.34}\, mHz$

Remaining challenge is the efficient transfer of single Ba ions from LXe to the ion trap







Cryogenic dipstick

- Capture ion on SXe coating
- LHe cooling (~20K) to maintain stable SXe coating in 10^{-8} torr vacuum
- Microcapacitor used to measure and stabilize SXe with accuracy of a few monolayers in LXe and vacuum

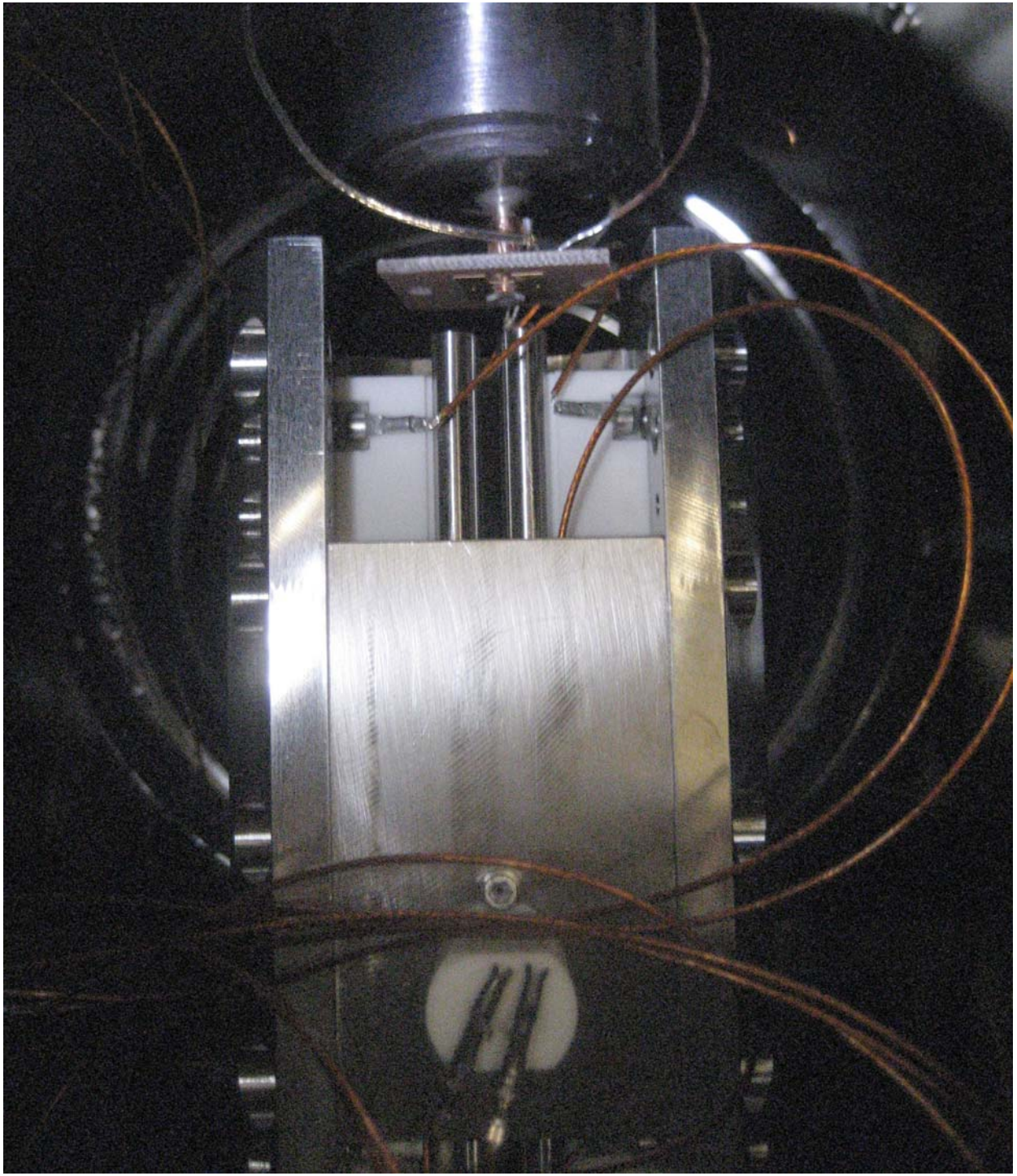
In progress…

Shoot ions from the trap onto the cryotip and back into the ion trap

Measure the product of efficiencies

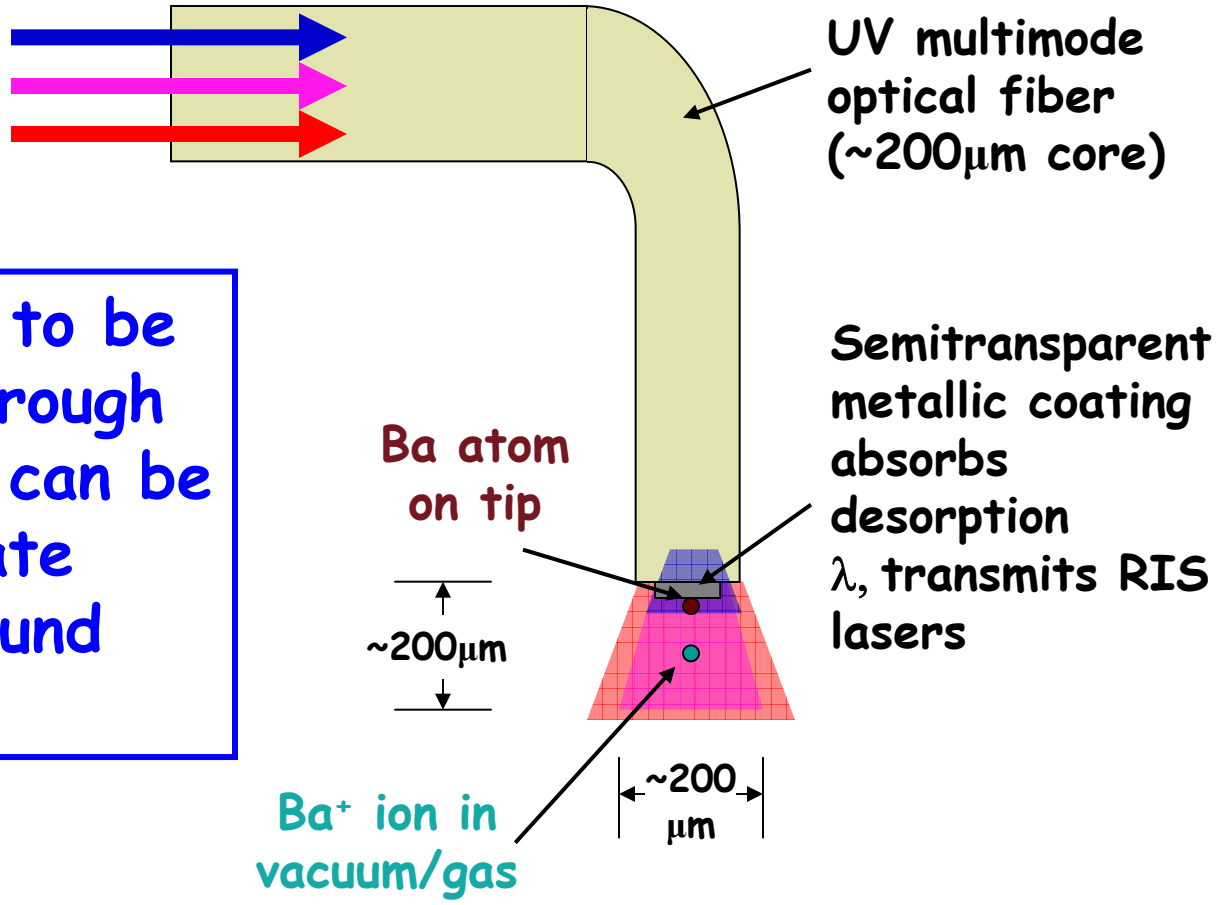
This does not work yet:

- *Does the Ba^+ neutralize in SXe?*
- *Does the Ba^+ get emitted coated with Xe?*



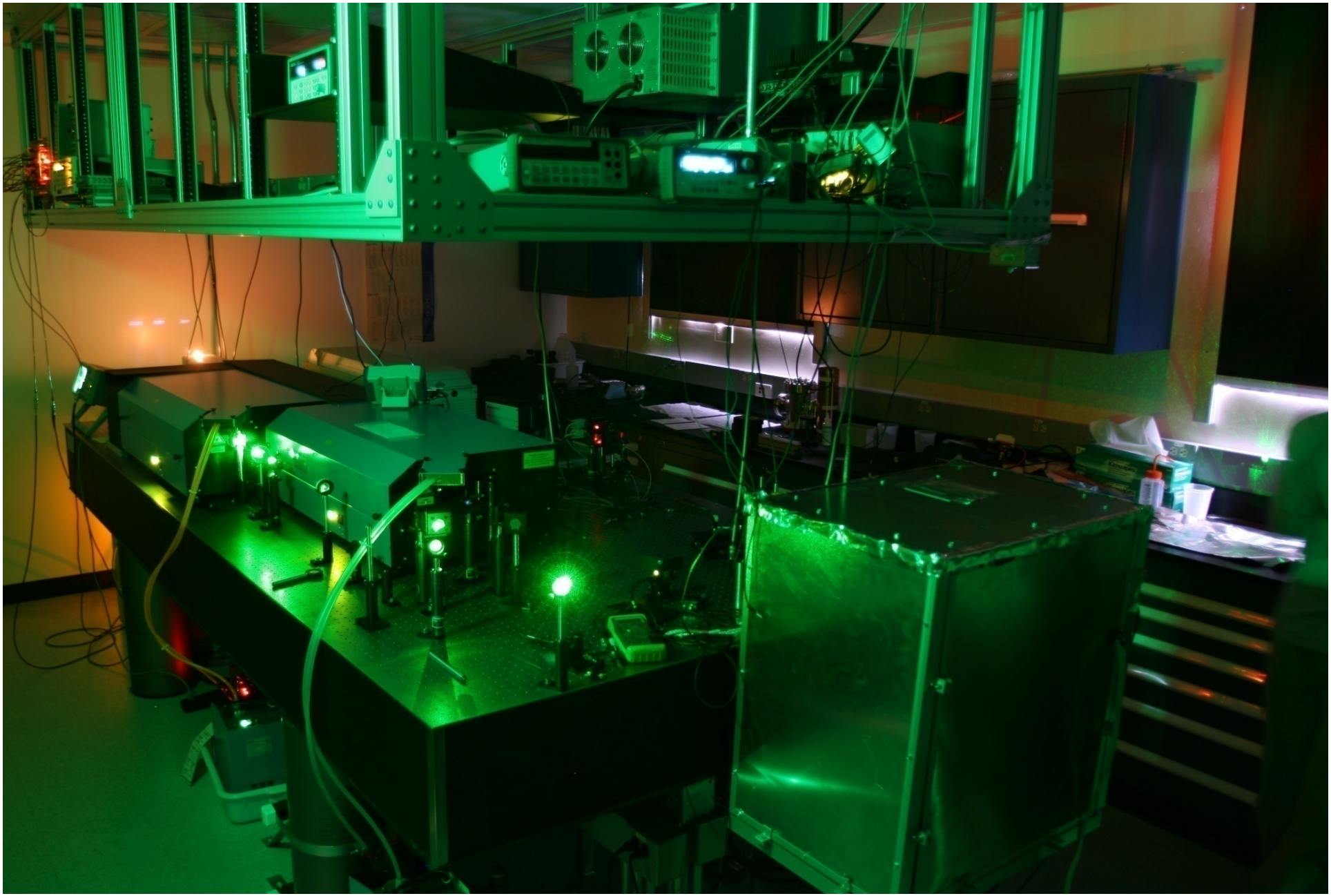
An alternative way to transport the Ba ion:

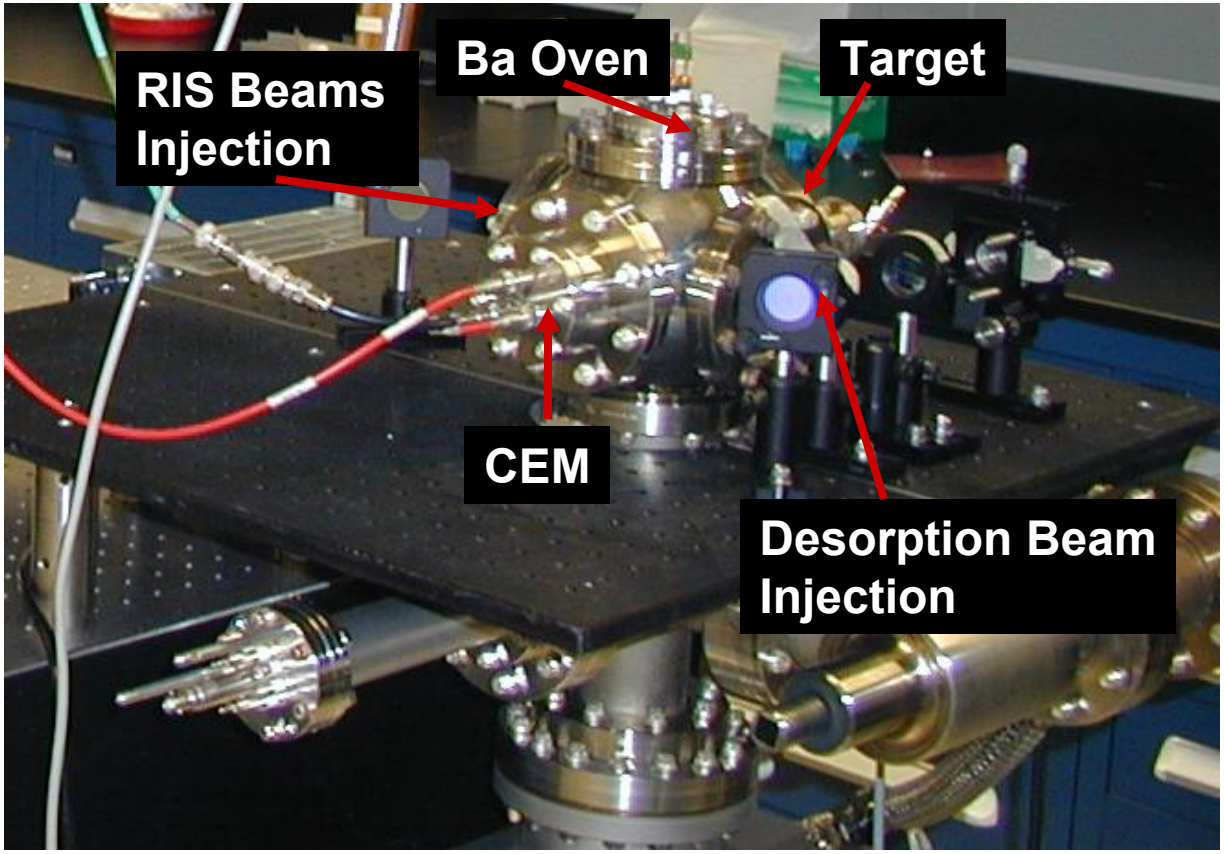
This does not have to be necessarily done through a fiber, the lasers can be shot at the substrate where the ion is bound from the "outside"



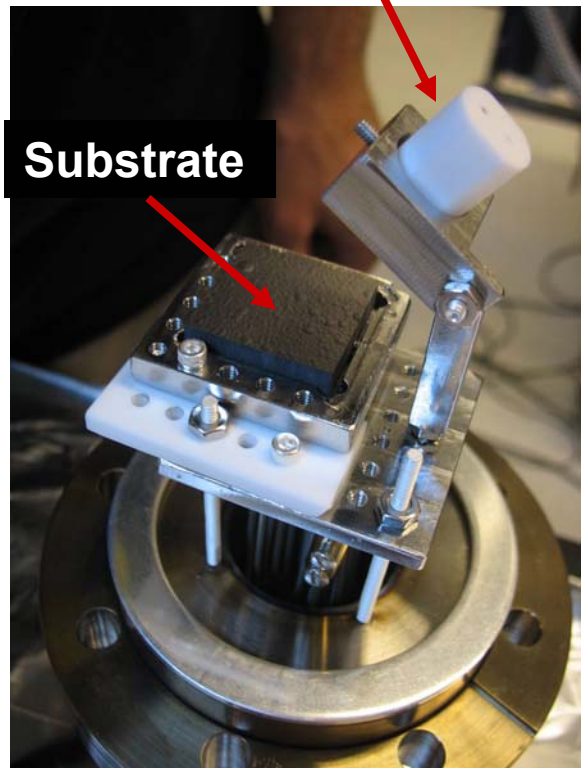
In this case *each step* can be documented to work with high efficiency in the literature !

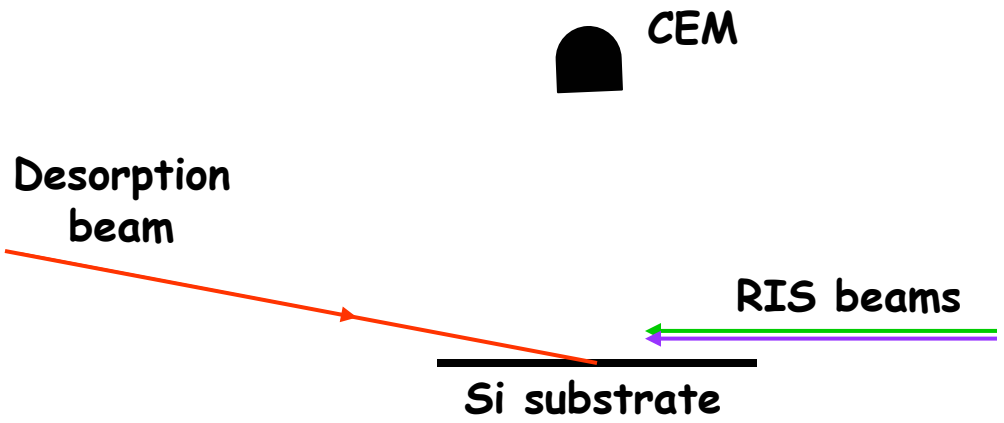
Resonant ionization spectroscopy lab



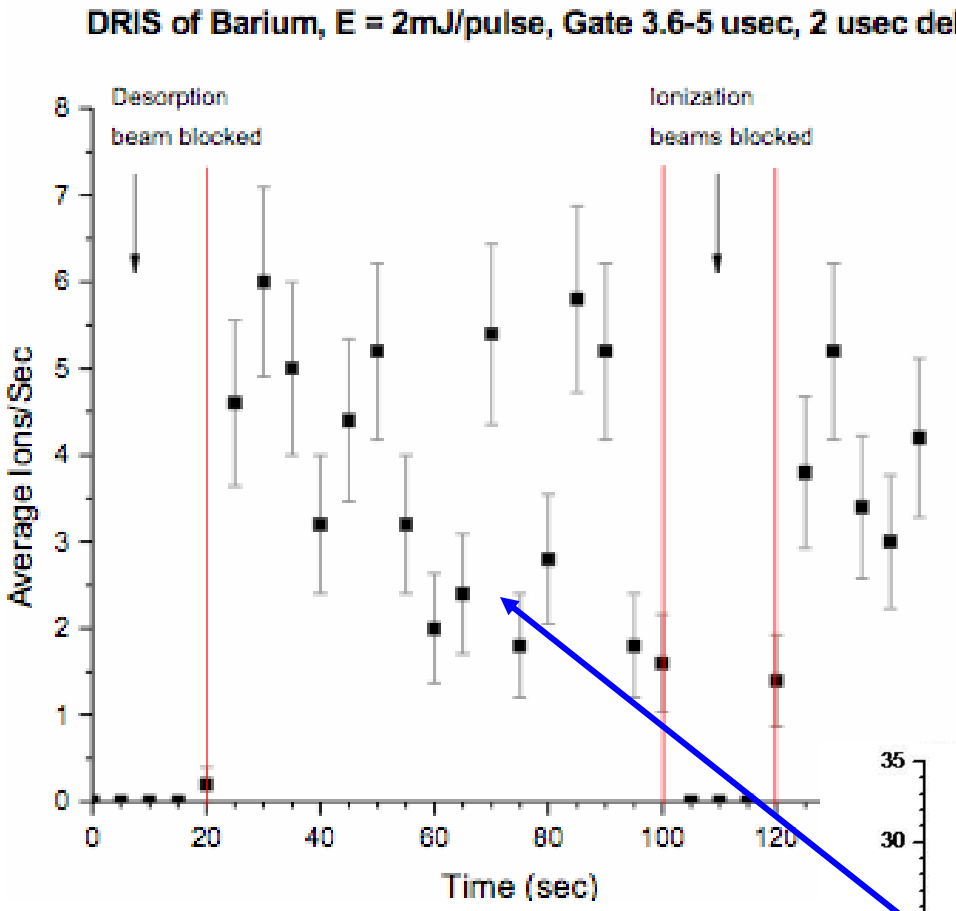

RIS Beams Injection
Ba Oven
Target
CEM
Desorption Beam Injection

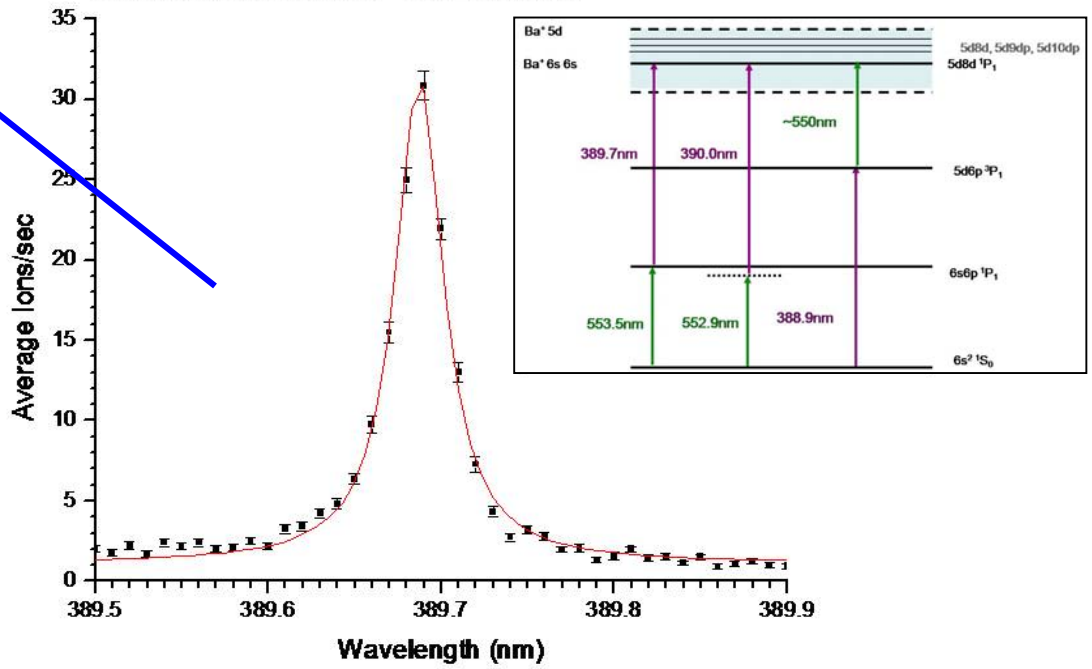
...and cell


Ba Oven
Substrate


CEM
Desorption beam
RIS beams
Si substrate

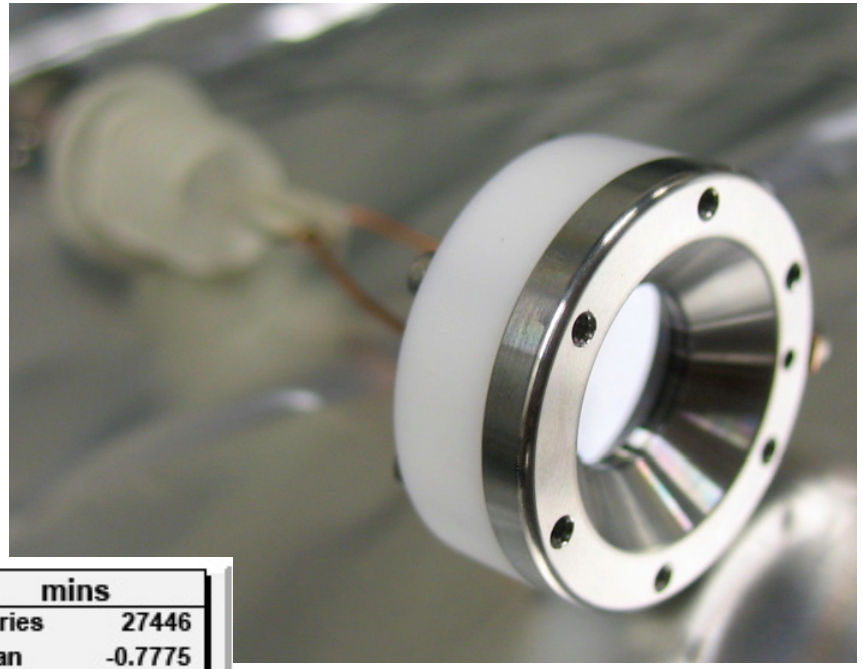
RIS of Ba from a Si surface

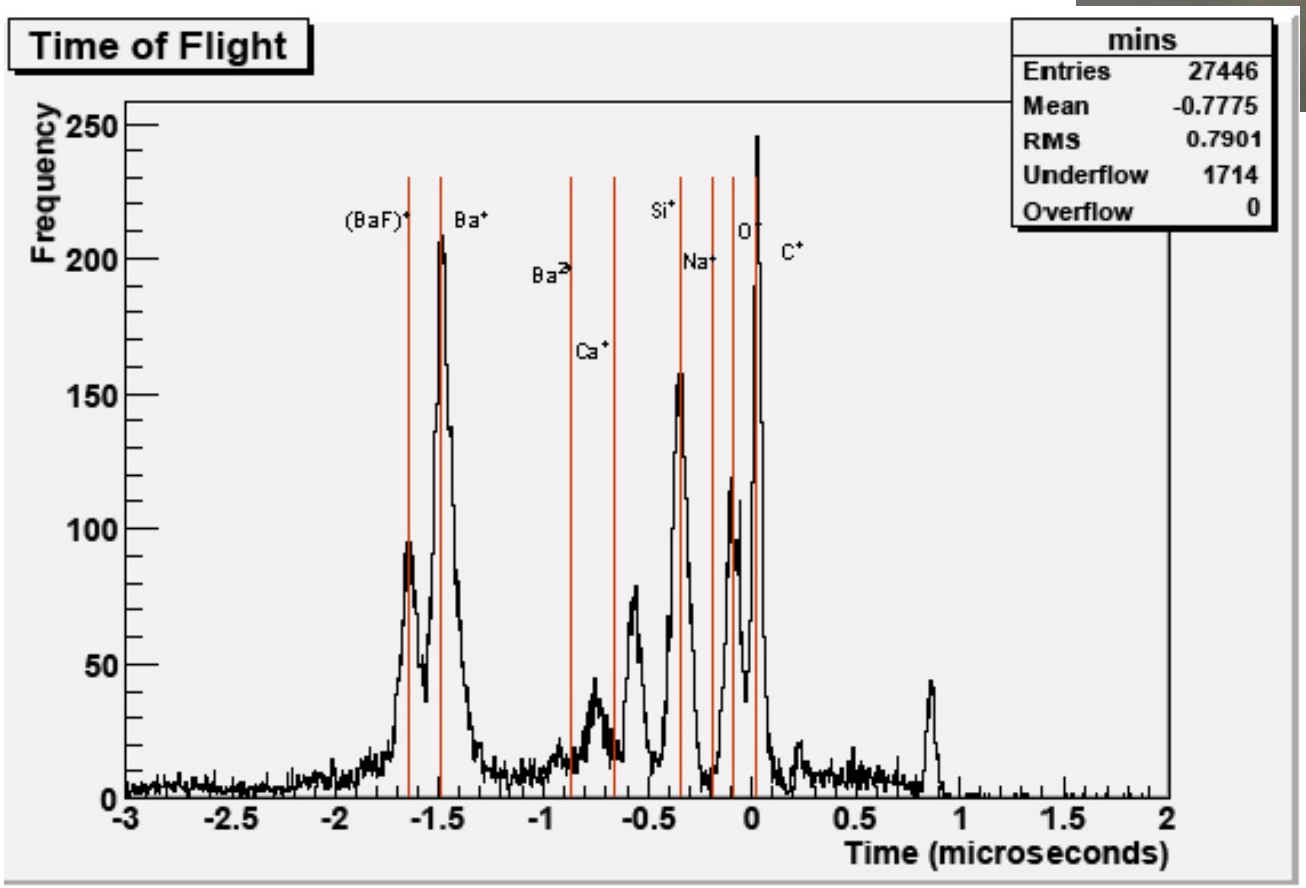


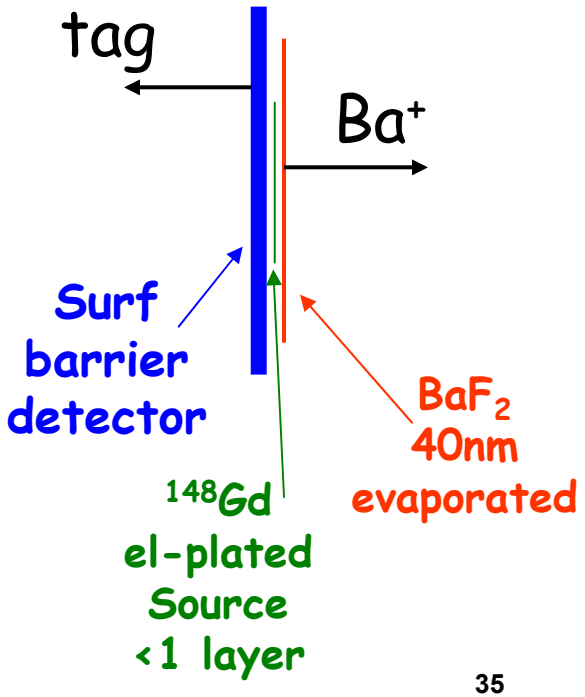


Needs a tagged single Ba^+ source to measure efficiency

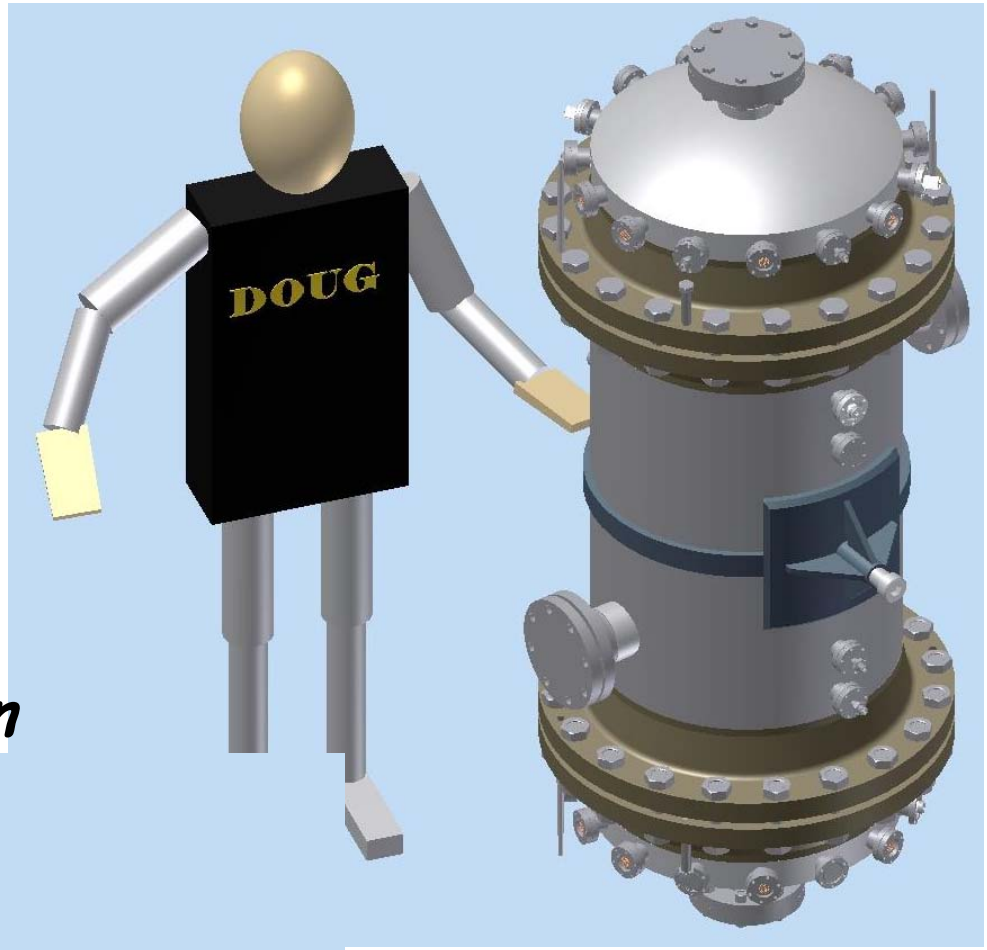
Simple tagged Ba^+ capable of operation in different media



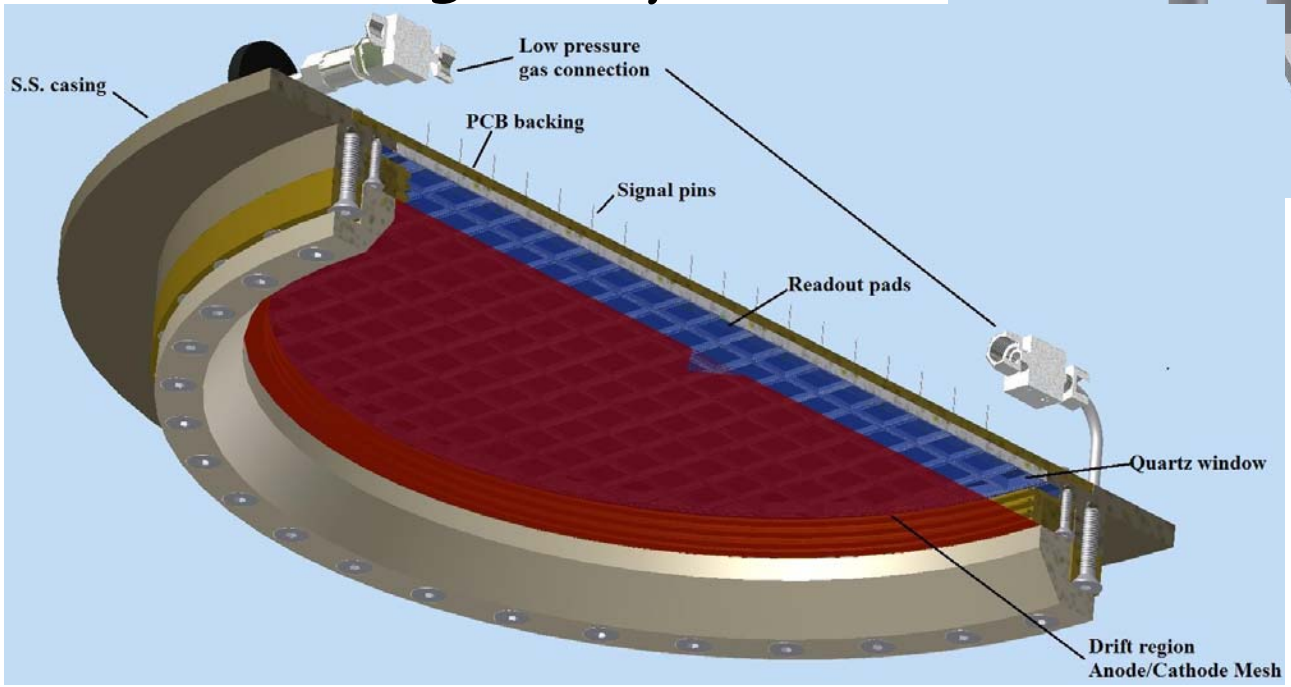




Mature design of a non-low-background high-pressure GXe test-bed detector

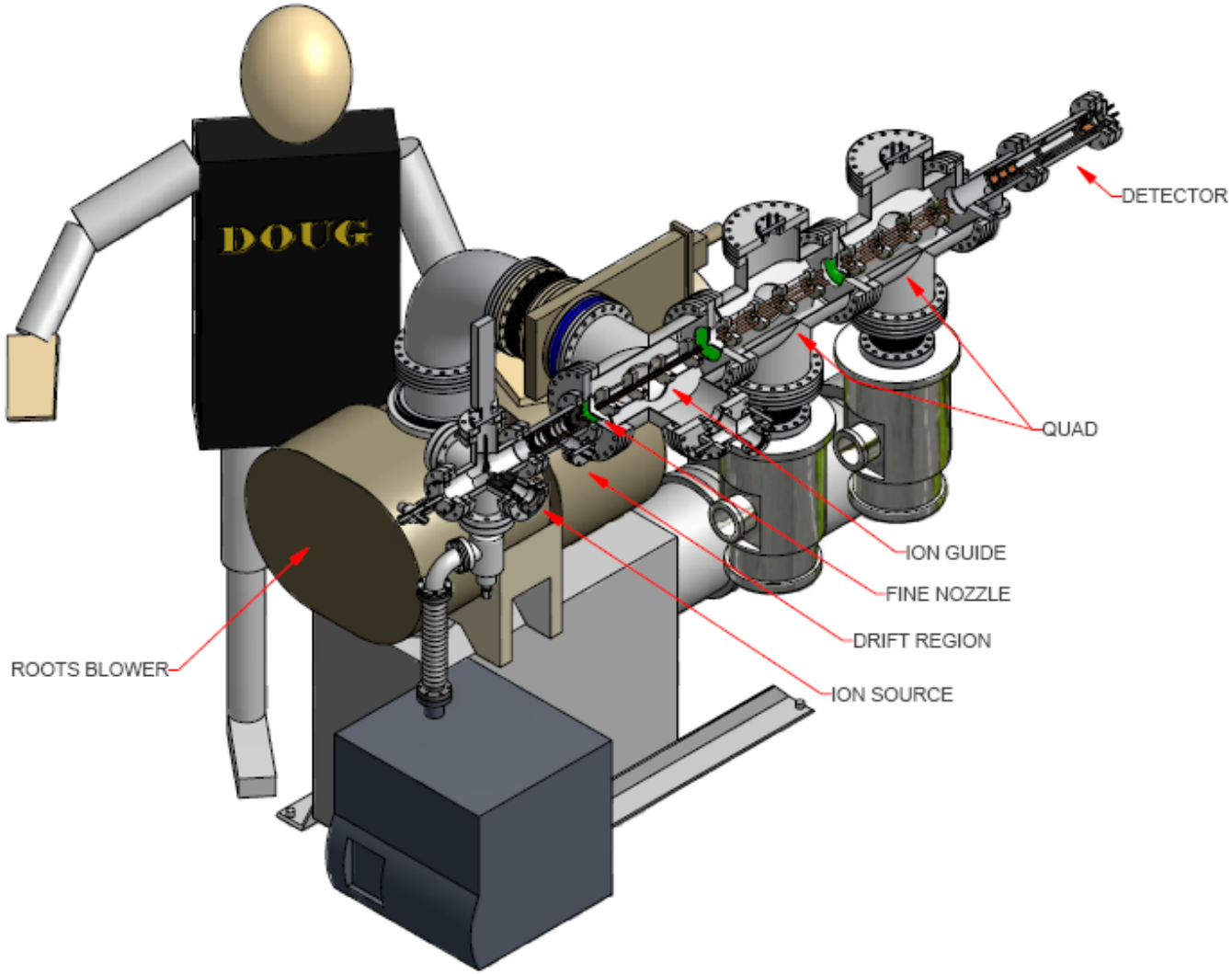


Choice of electroluminescence light readout with photocathodes and electron gas amplification



Conceptual design of the setup for extrating and tagging Ba ions from 10 bar GXe chamber

This activity is ramping up really fast and is receiving lots of input from the online isotope production/ separation community



SMI-10

International Workshop on Stopping and Manipulation of Ions
Stanford University March 21-24, 2010

The International Workshop on Stopping and Manipulation of Ions and related topics (SMI-10) will be held at Stanford University, Stanford, CA , on March 21-24, 2010.

The Workshop continues the series of meetings begun in 1986 in Konnevesi, Finland. The scope of these meetings has followed the evolution and expansion of the techniques related to the stopping of energetic ions in noble gases and the use of noble gases to manipulate ions and atoms, mostly in research involving unstable nuclides. In addition SMI 10 will cover topics of interest for the extraction and identification of ions produced in rare nuclear decays, such as would be desirable for ultra-low background double-beta decay experiments. The many new developments since the last workshop in this series in 2006 in Groningen warrant the organization of this meeting. The SMI-10 Workshop aims at providing a status of the field as well as guidance for future developments.

Committee:
Peter Dendooven, KVI/University of Groningen
Jens Dilling, TRIUMP/UBC
Giorgio Gratta, Stanford University
Marcia Keating, Stanford University

Registration Deadline: TBD
www.stanford.edu/SMI-10 TBD

SMI-10, c/o Marcia Keating
Physics Department, Rm # 148
Stanford University
382 Via Pueblo Mall
Stanford, CA 94305, USA
Phone: +1 650 725-2344
FAX: +1 650 725-6544
email: mkeating@stanford.edu


Enriched Xenon Observatory
EXO
for double beta decay