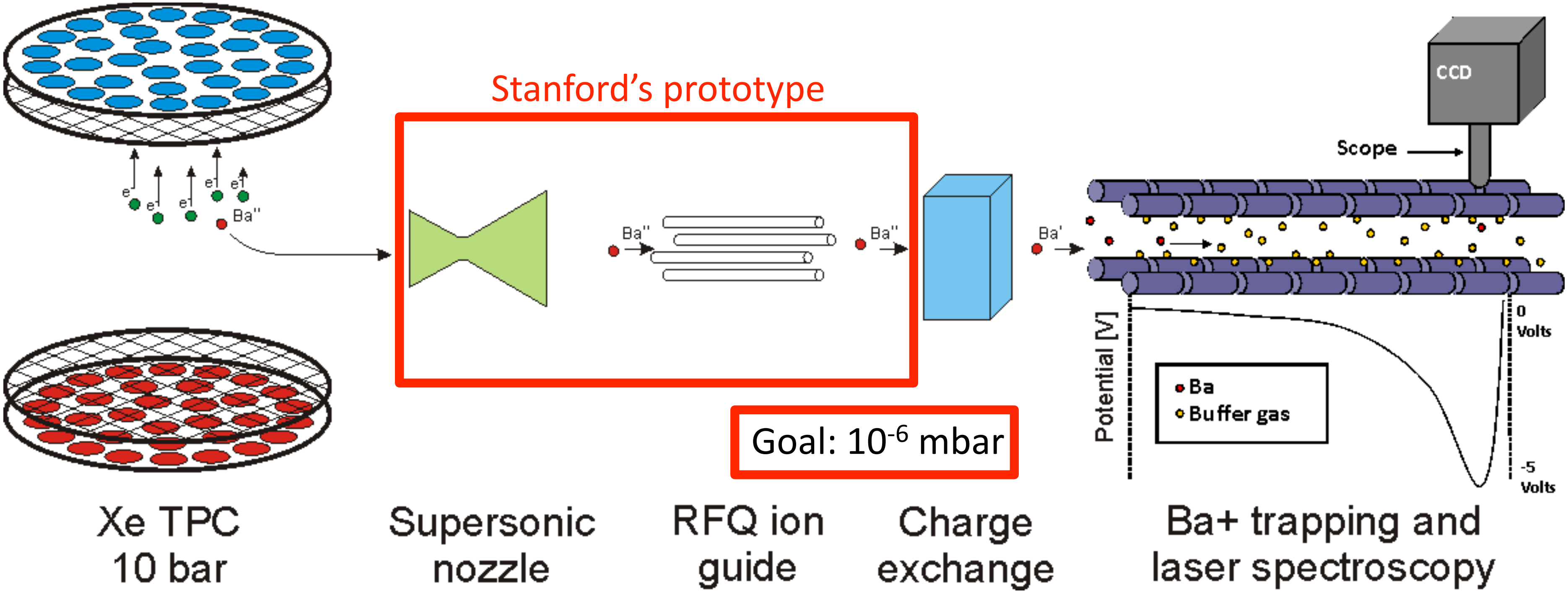
Ba Tagging in gXe at Stanford

EXO Week

Dec 10, 2013

Thomas Brunner, Dan Fudenberg
for the Gas Tagging Group

Tagging from Gas Xenon

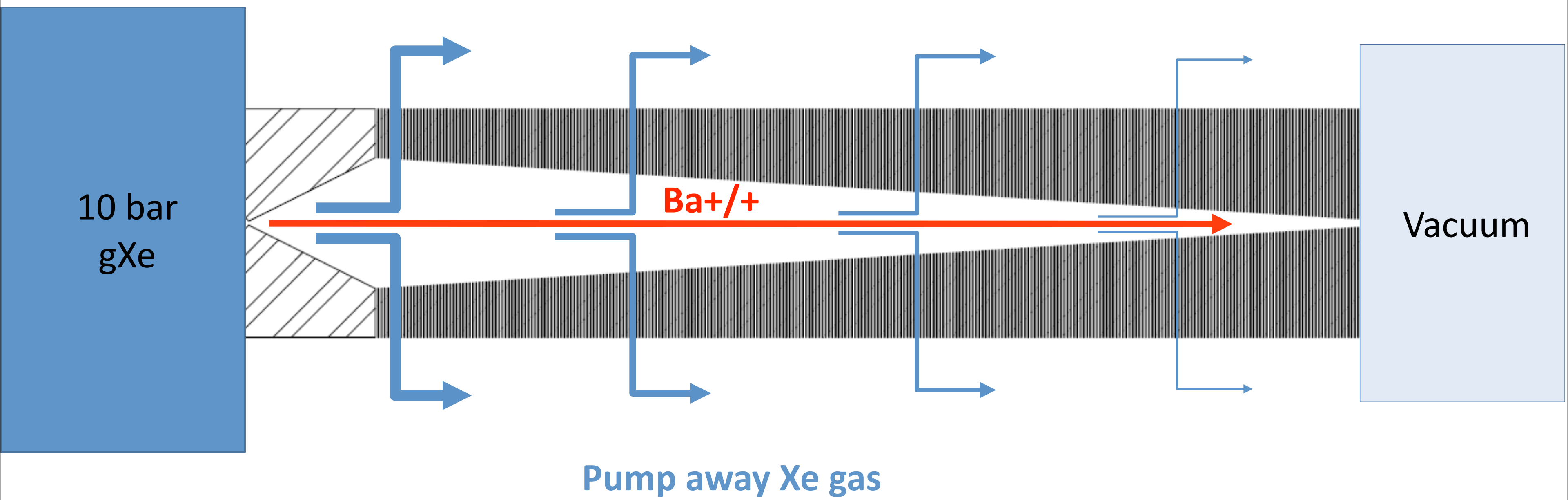


The Plan:

- Extract Ba^{++} from TPC by shaping E-field through a nozzle
- Guide into low pressure chamber then into a vacuum chamber
- Convert Ba^{++} to Ba^{+} [1]
- Identify via laser spectroscopy [2]

[1] J. of Phys.: Conf. Ser. 309(2011)12005 [2] Phys. Rev. A 76, 023404 (2007)

RF-funnel concept: V. Varentsov



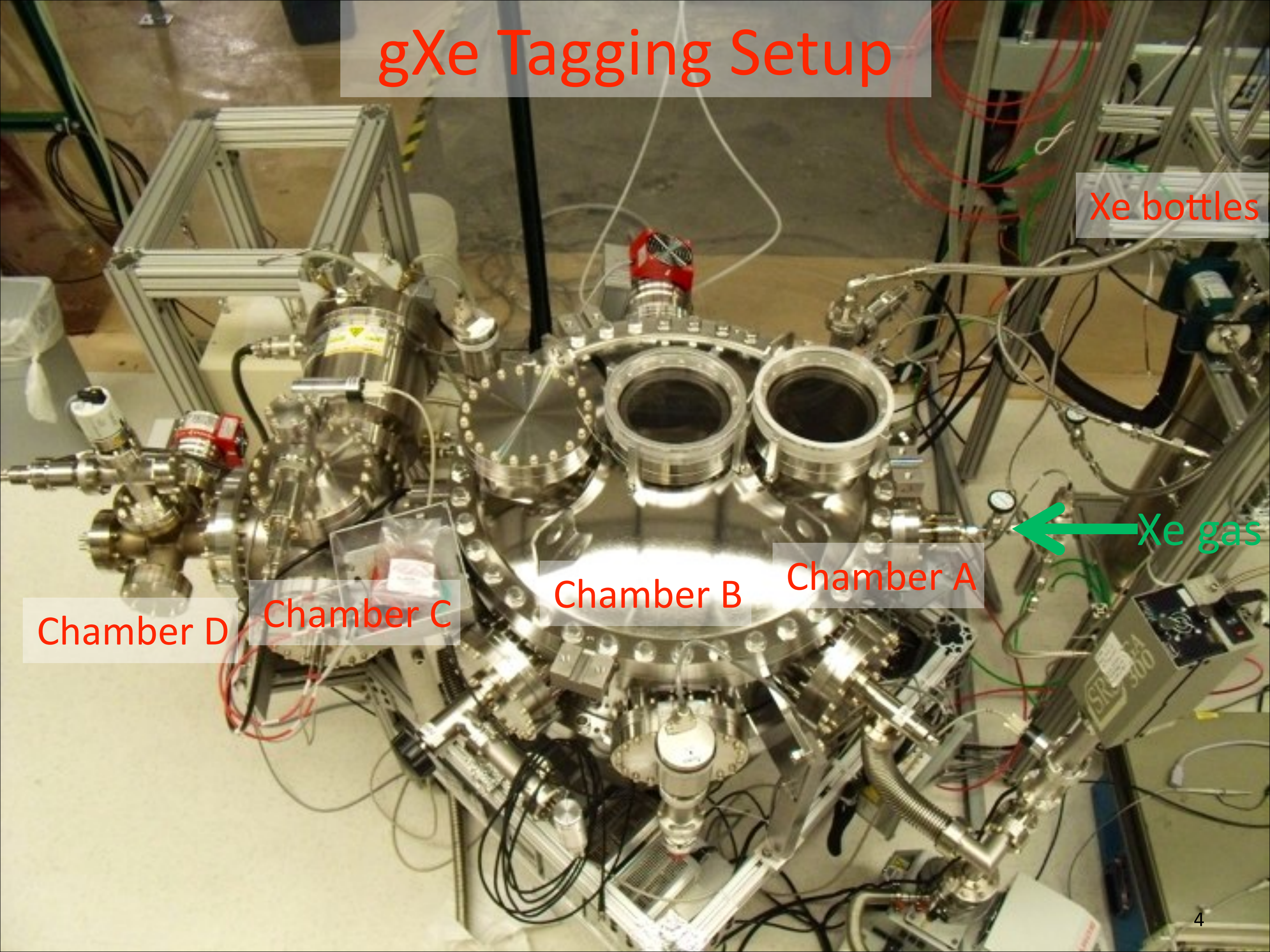
RF-funnel concept:

- Mounted on a converging-diverging nozzle with a 0.28 mm throat diameter
- 2 stacks totaling 301 electrodes with 0.010" spacing between adjacent electrodes
- RF-field applied to electrodes confines ions while gas flow pushes ions through
- P0 = 10 bar, Pa = 1 mbar

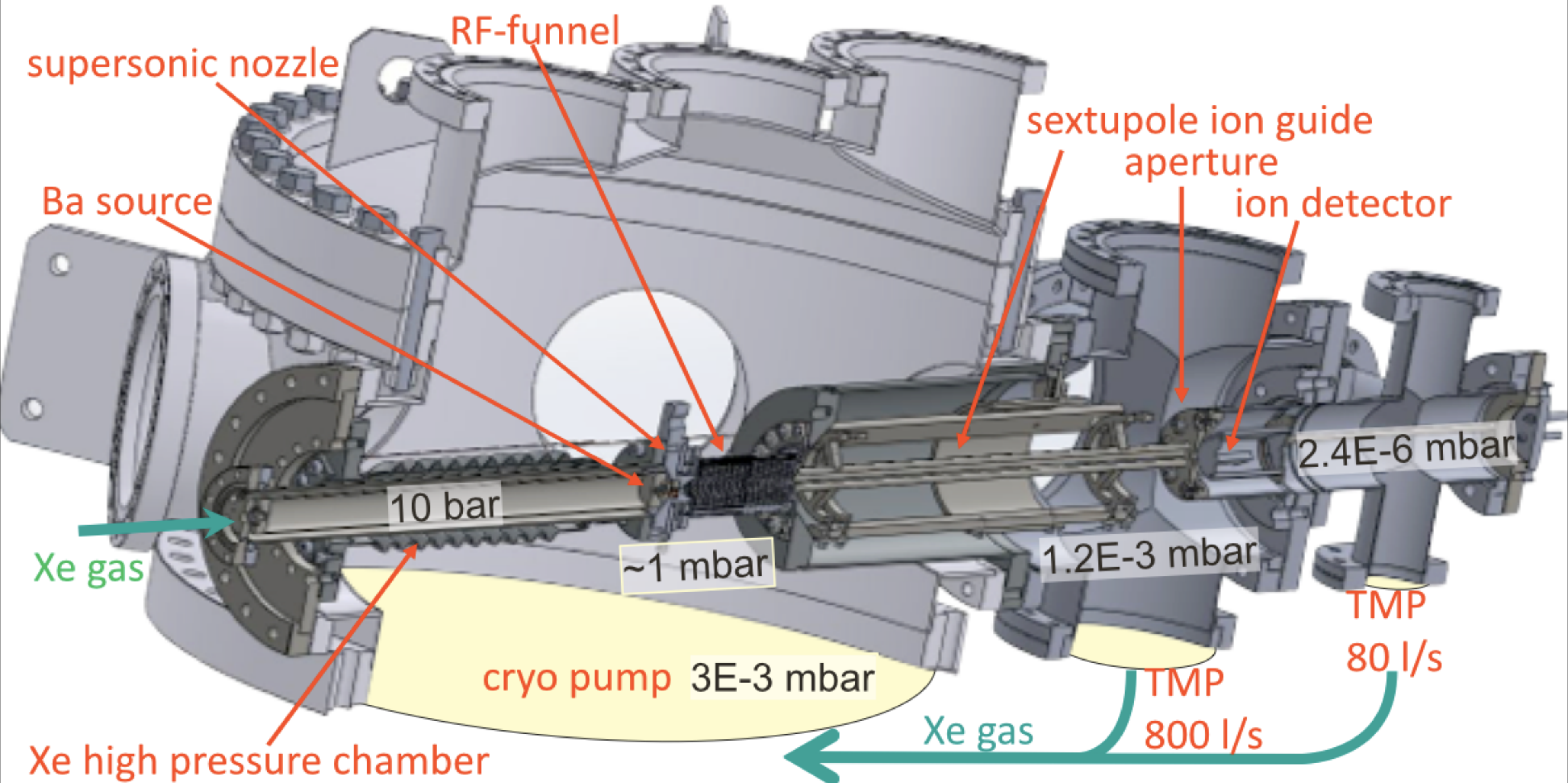
V_{RF} = 120 V
f = 10 MHz
Simulated Ba^+ transmission ~95%

V_{RF} = 25V
f = 2.6 MHz
Simulated Ba^+ transmission ~72%

gXe Tagging Setup



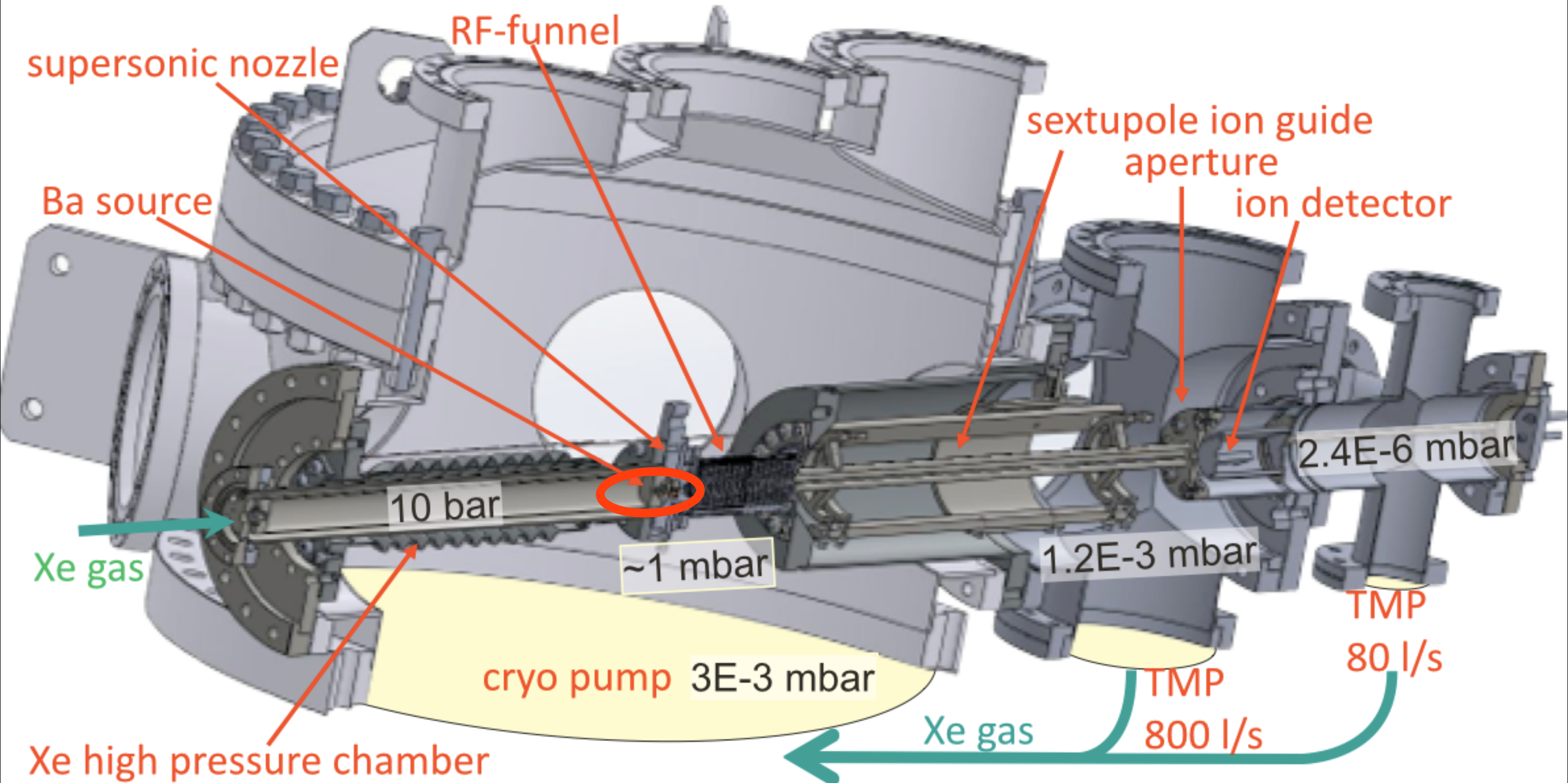
A Look Inside



Differential Pumping Stages

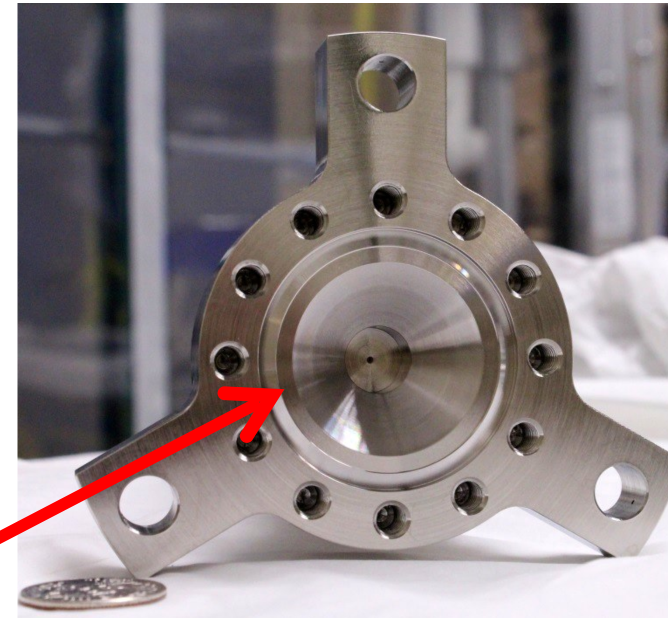
Chamber A	Funnel Interior	Chamber B	Chamber C	Chamber D
High pressure Xe	Funnel	Cryopump chamber	SPIG	Detection
10 bar	~1 mbar	3E-3 mbar	1.2E-3 mbar	2.4E-6 mbar

Ba Source and Holder



Source holder with dummy (non-plated) source or real source

- Electroplating of ^{148}Gd onto a 0.250” x 0.375” SS plate
- Evaporate BaF (~10 nm) onto ^{148}Gd source
- ^{148}Gd activity before BaF coating ~250 Bq
- Source holder to source gap of ~0.03”

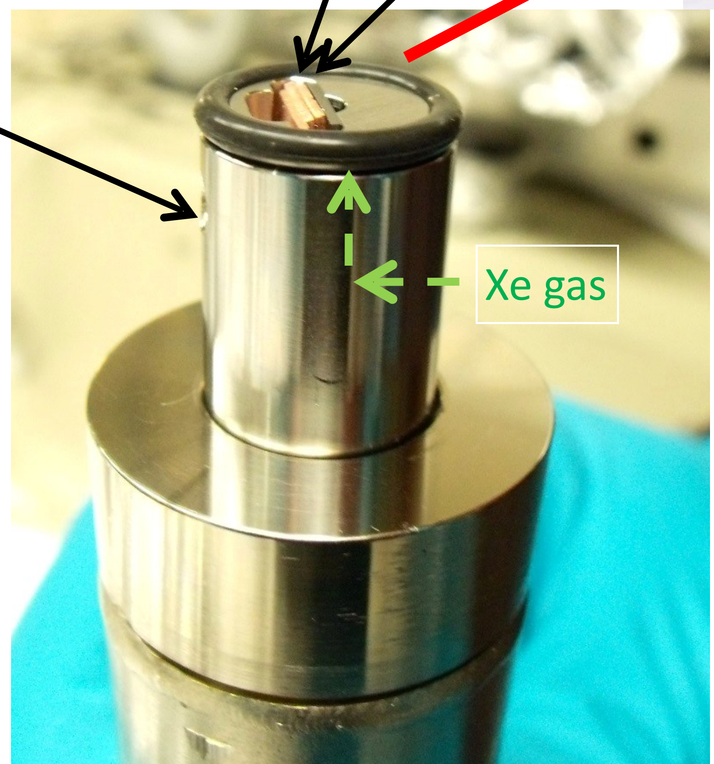


Rev. Sci. Inst. **81** 113301 (2010)

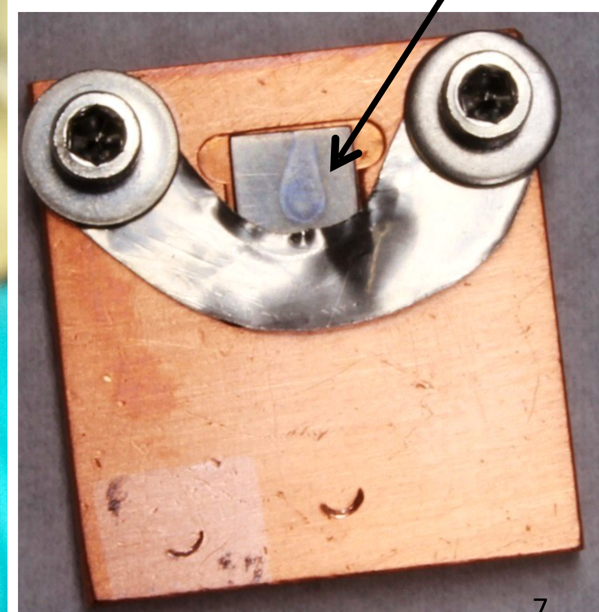
Cu plate

SS wafer

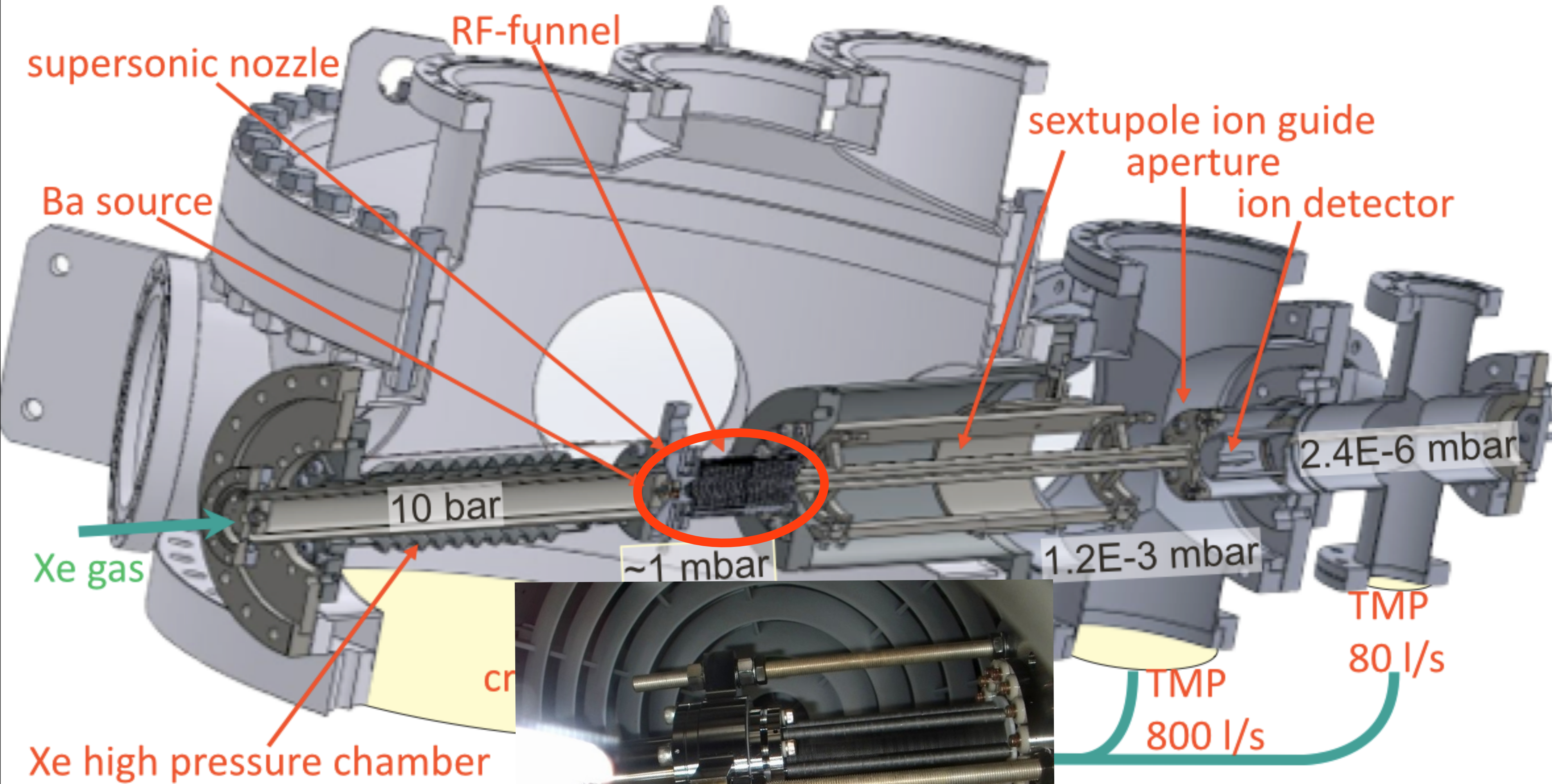
Set screw



Source

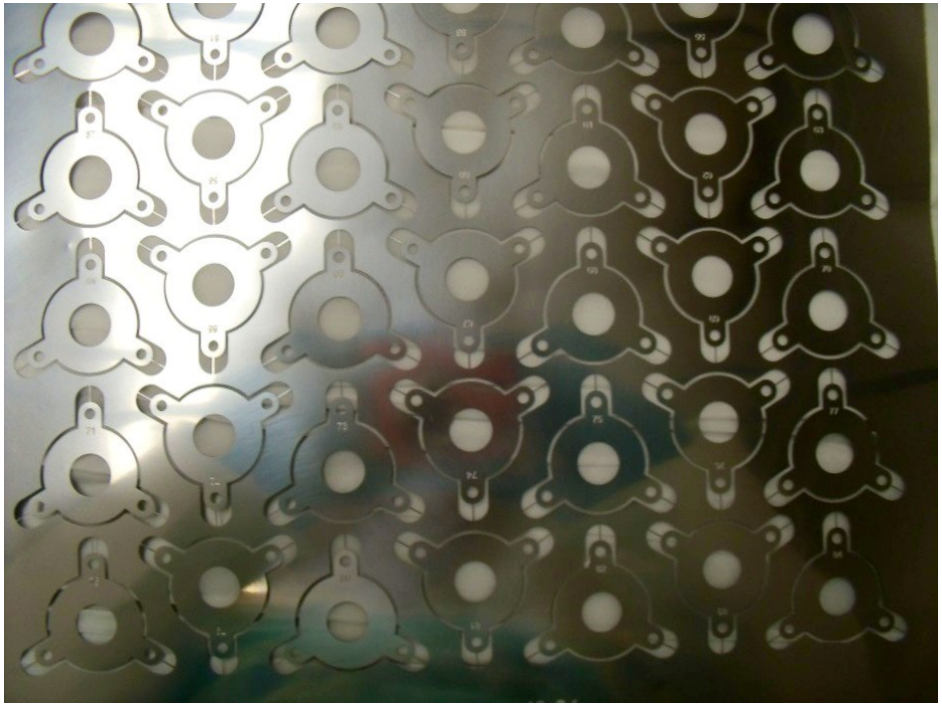


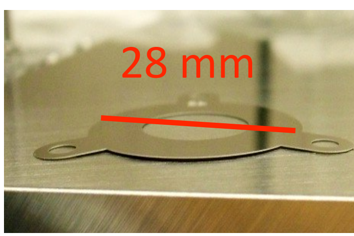
RF-funnel

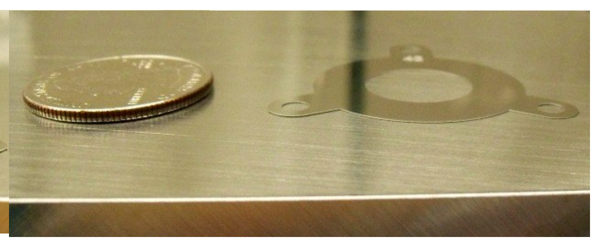


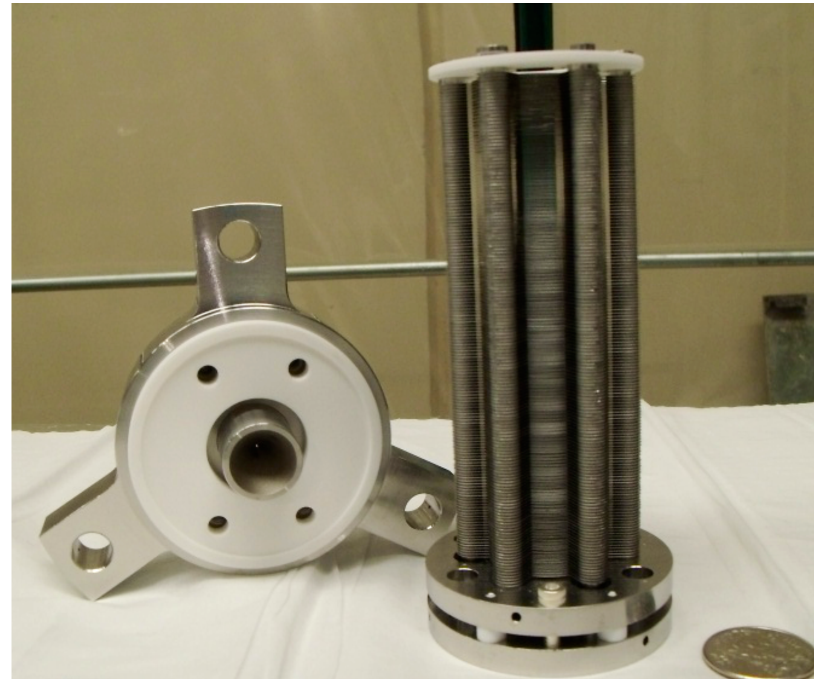
RF-funnel and
Xe ice on cryopump

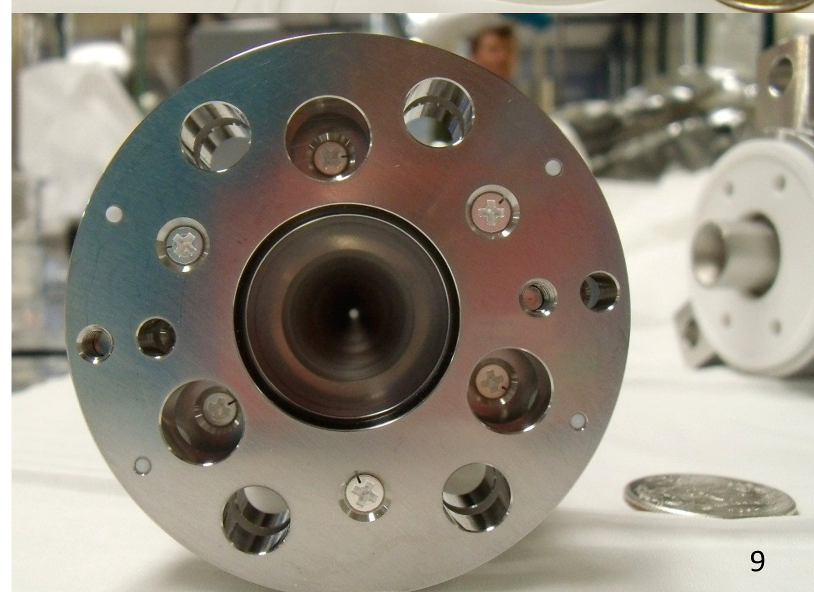
RF-funnel Assembly





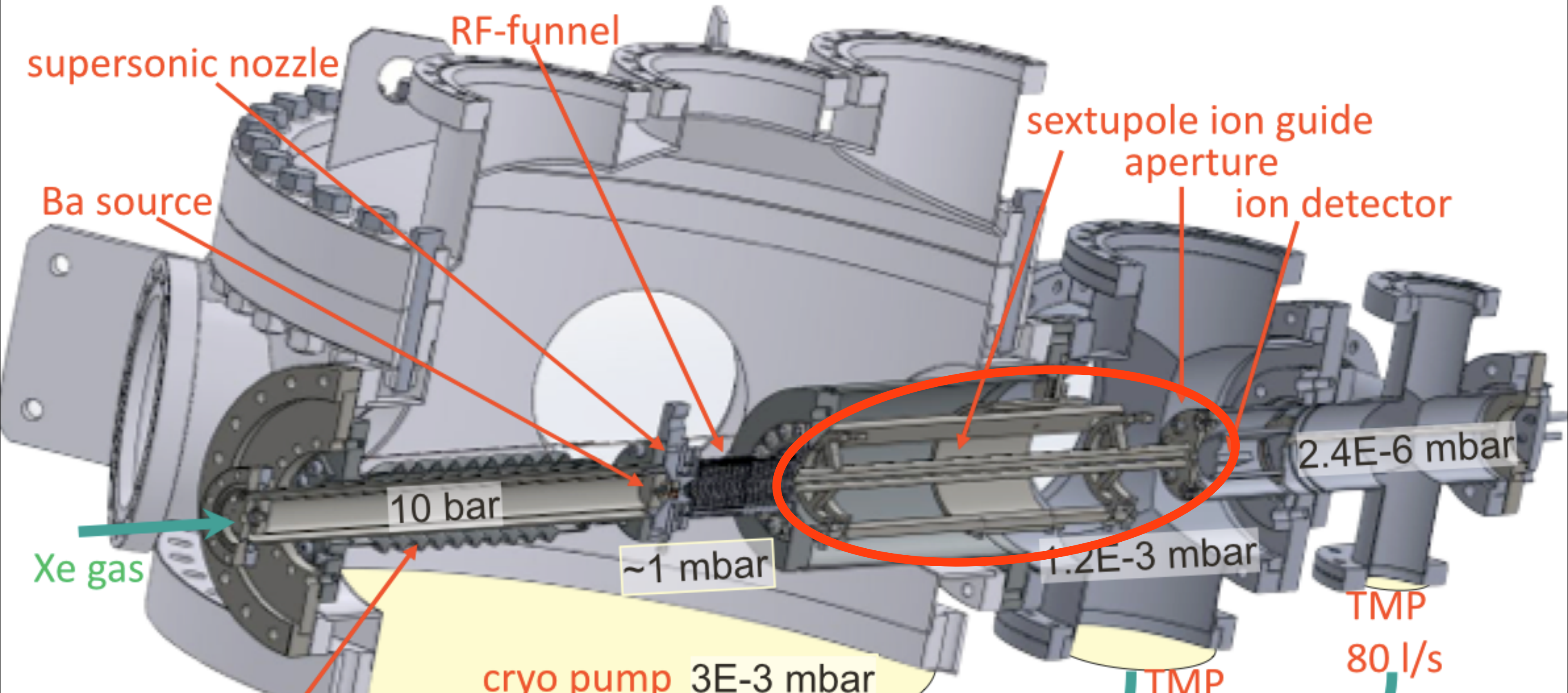




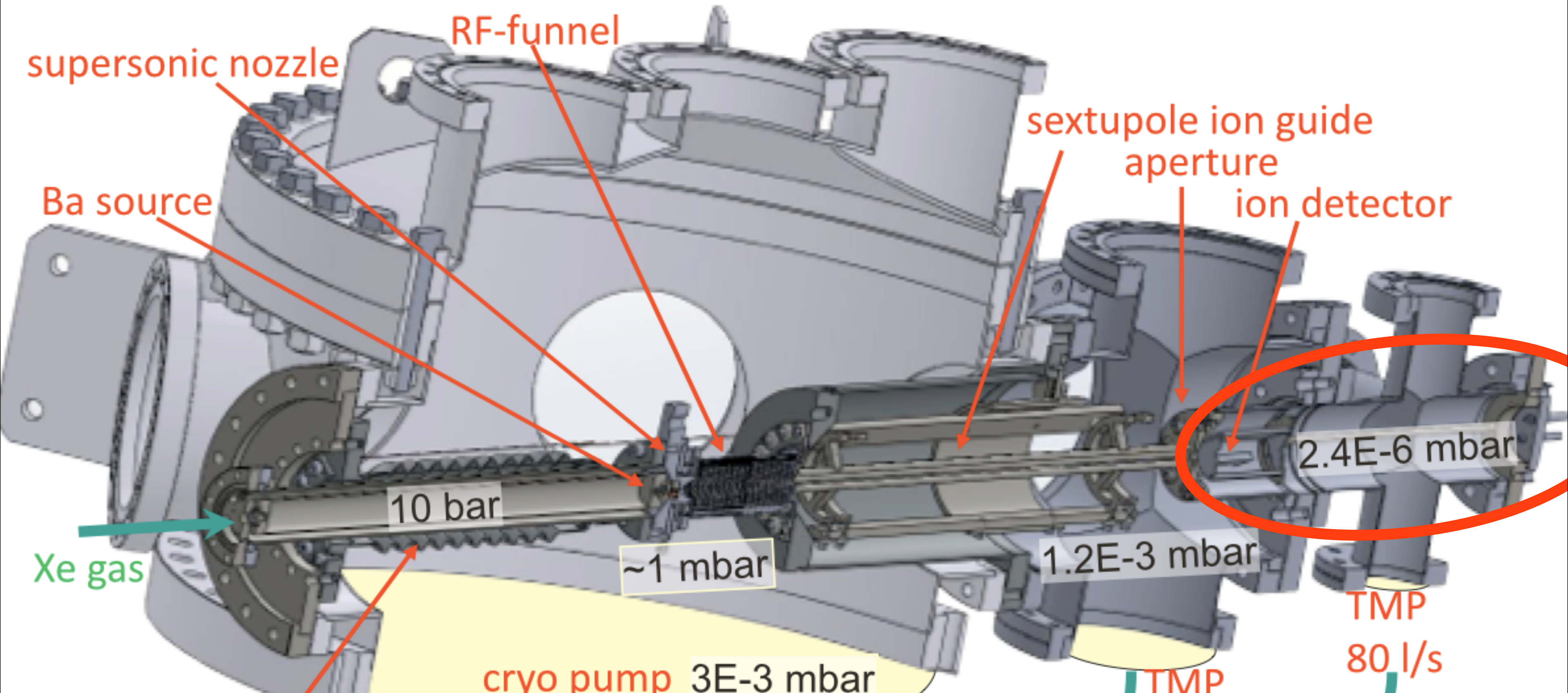


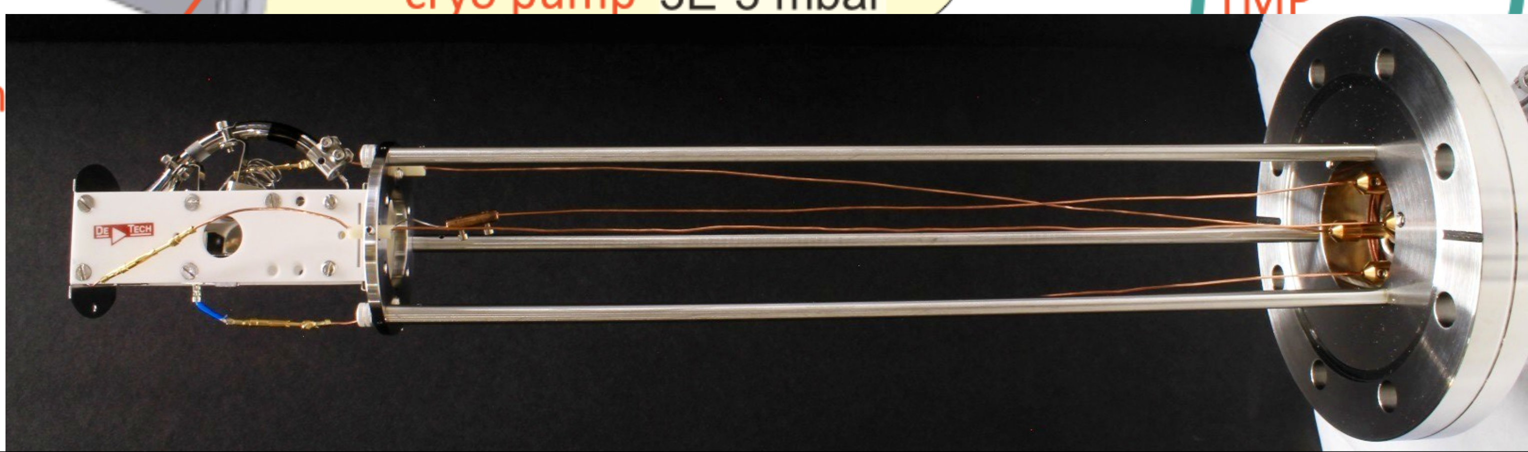
- 336 (301 + spares) photo-etched electrodes by Newcut
- 6x7 electrodes/sheet @ 8 sheets
- Metal sheet: 0.1016 mm (±0.00254 mm)

Downstream Ion Optics

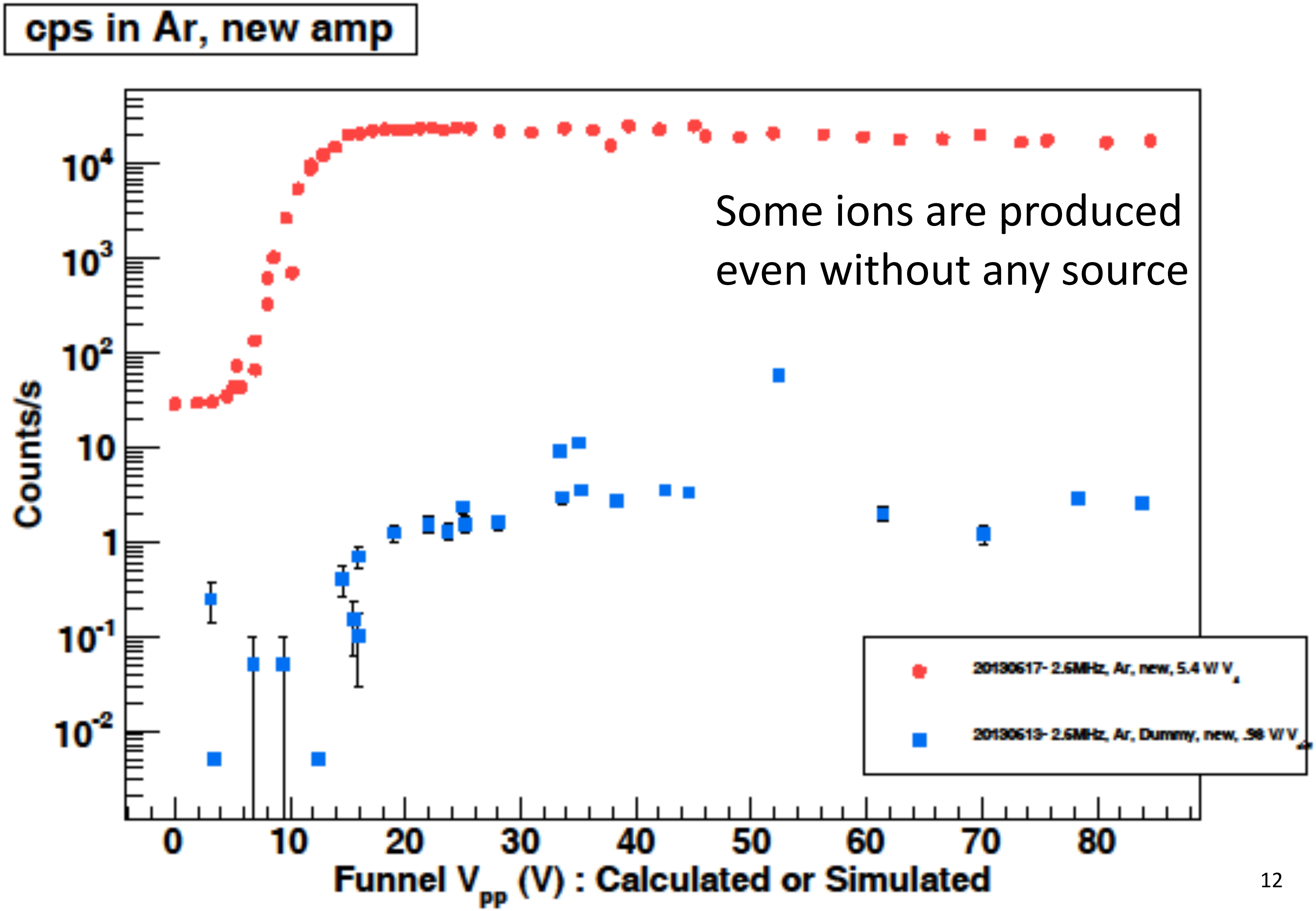


Ion Detection

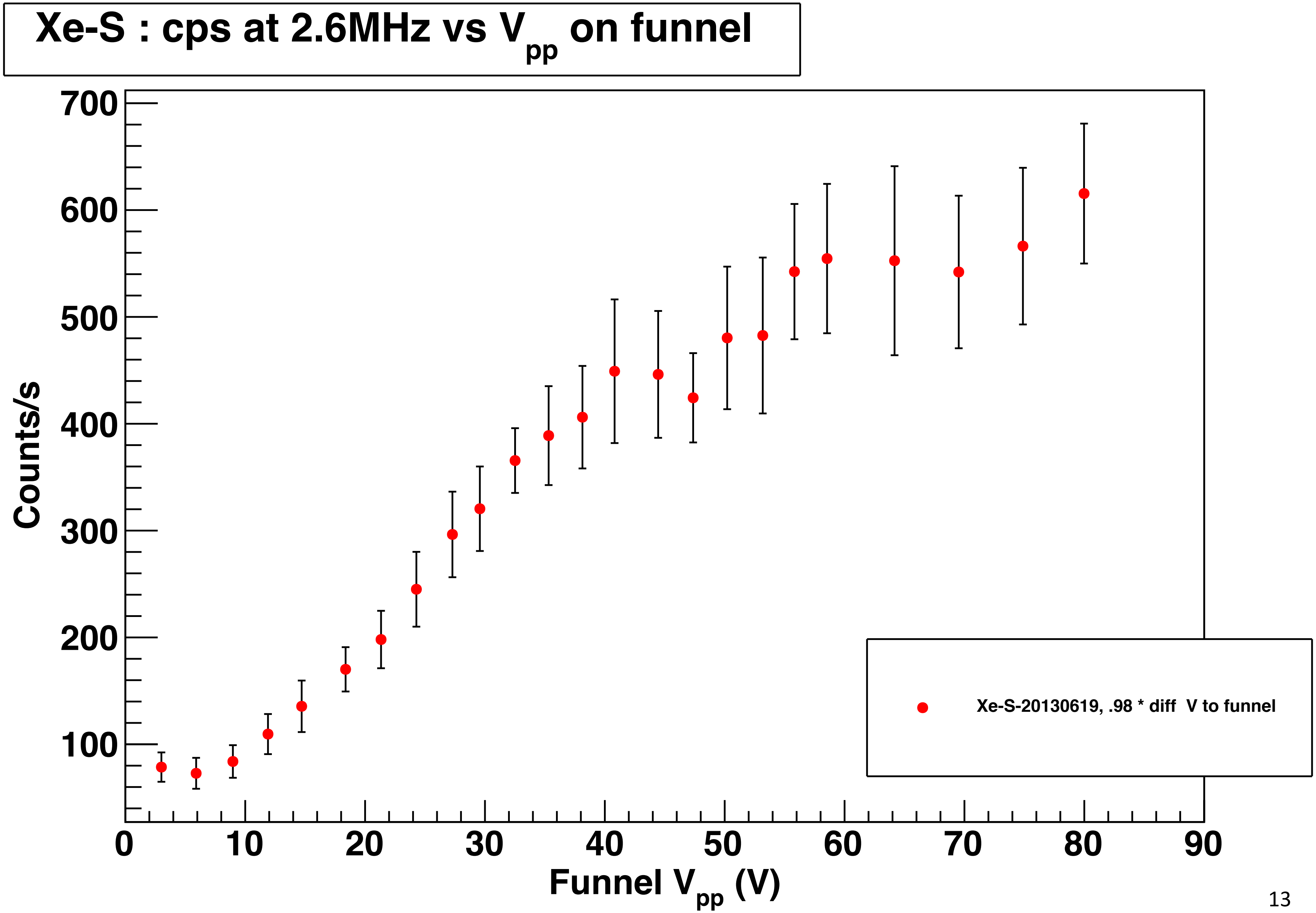




Dummy source vs. Ba^+ source in Ar



Xe gas operation



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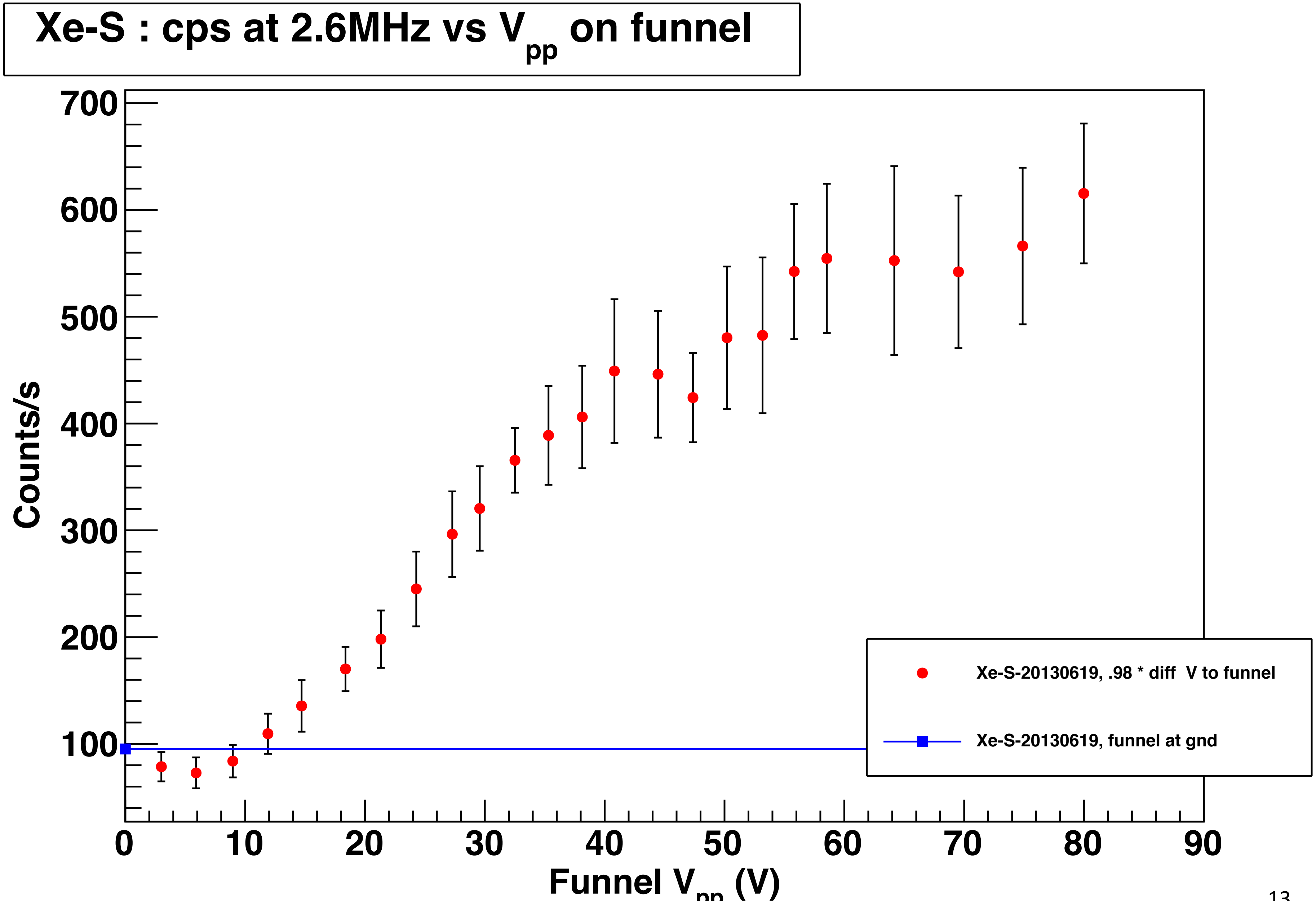

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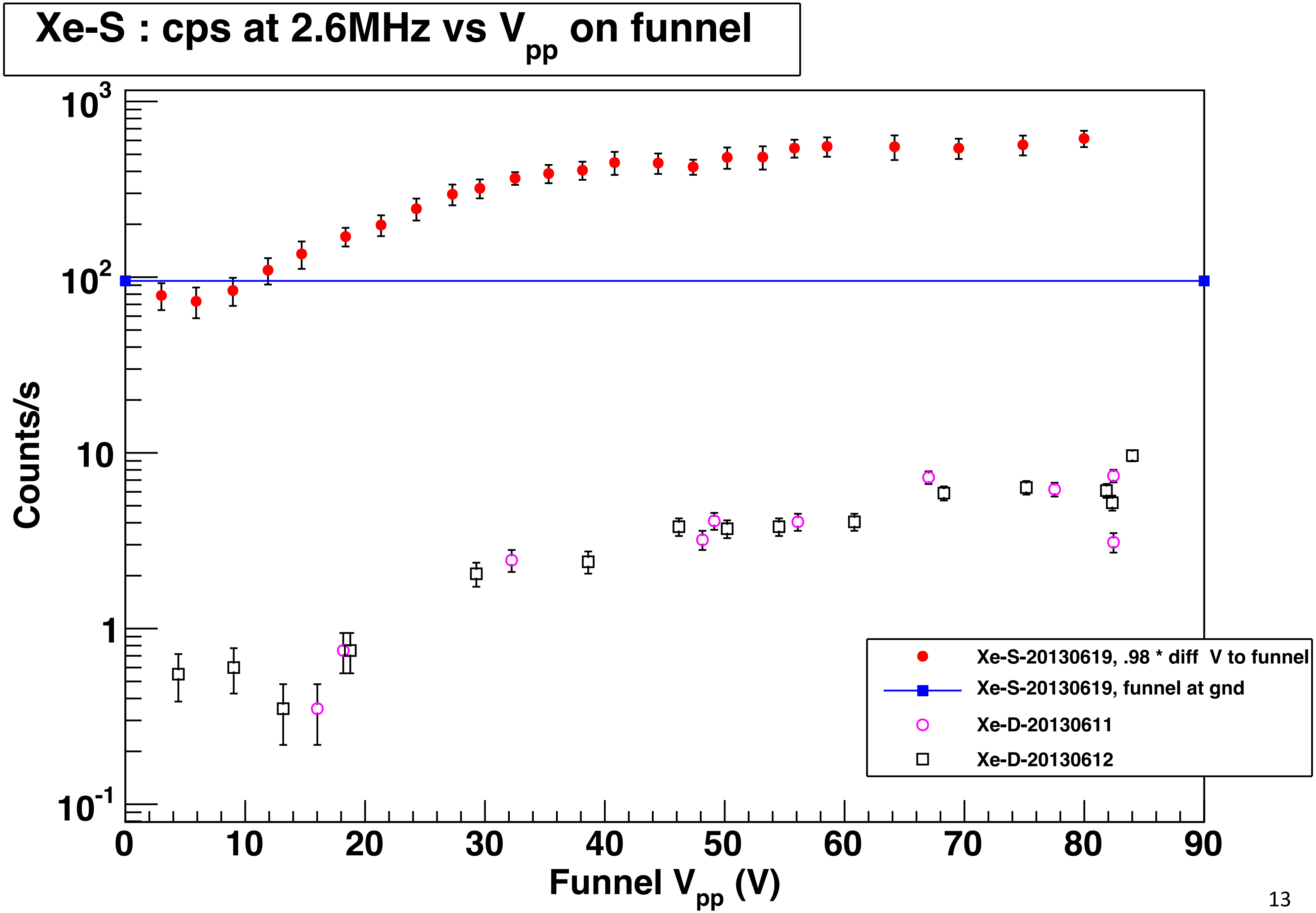
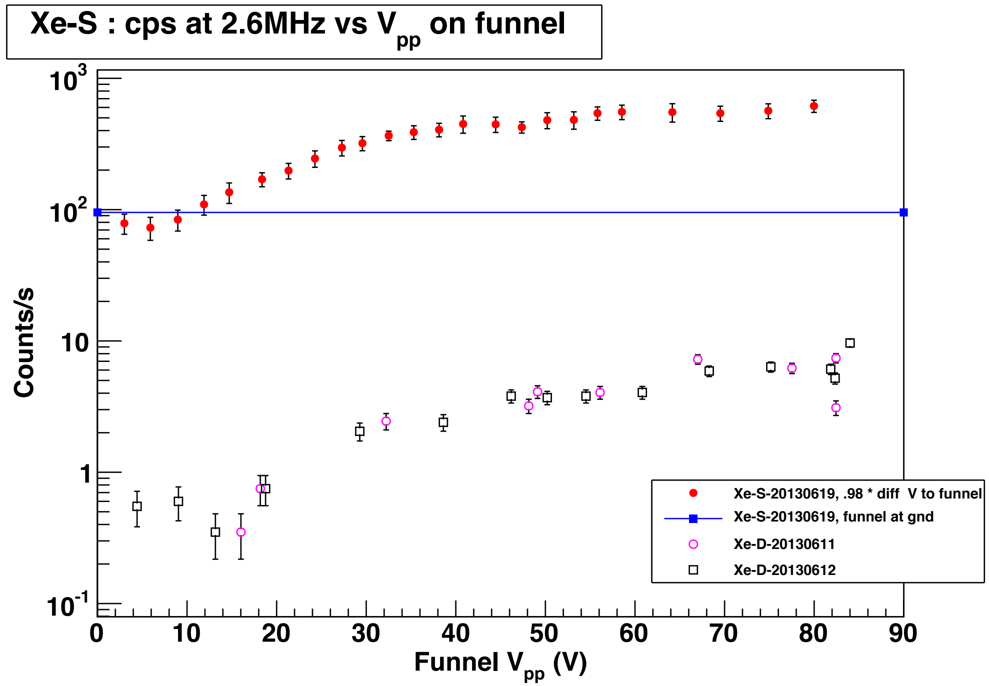


What are we seeing?

- Ions are produced in the gas jet (w/o source)
- Gas jet produced ions respond to RF on funnel the same as ions from source
- w/o RF on funnel, the gas still transports ions
- SPIG guides ions through the differential pumping stage (off -> no counts)
- Ions can be trapped in SPIG



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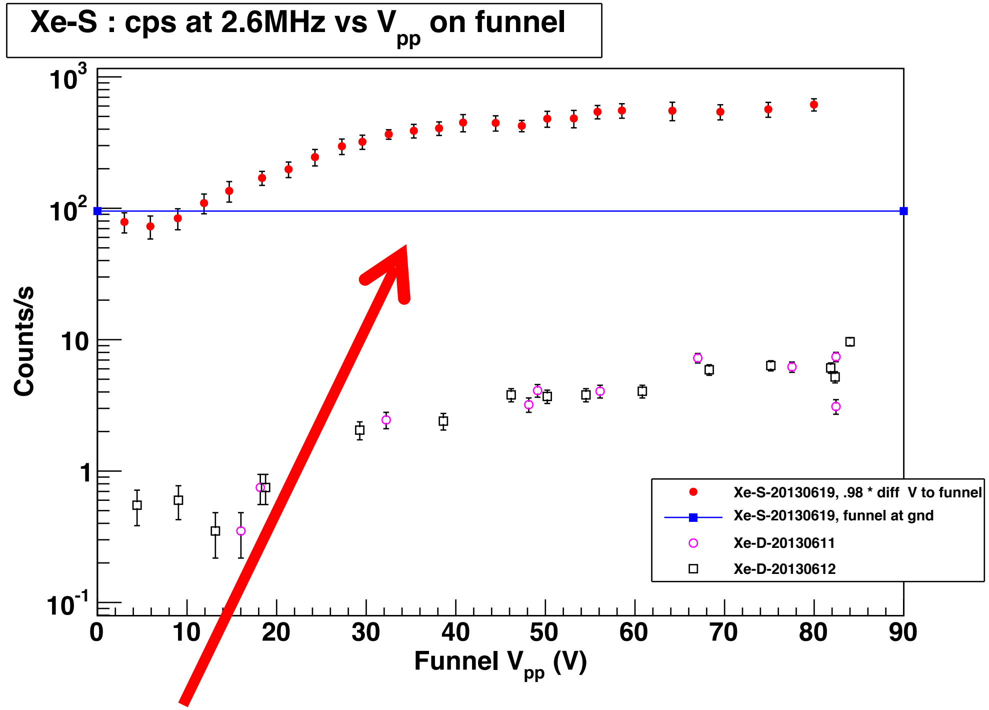

Gedankenexperiment:
With no RF, neutral & ion transport should be the same, measured ~90cps on CEM.
Assuming a gas flow reduction factor of ~120 into C over B, this required about 10800 ions in the jet (neglecting SPIG and detection efficiency)
Assuming 60% efficiency -> 18k-ions/s in funnel with Ba^{+} source

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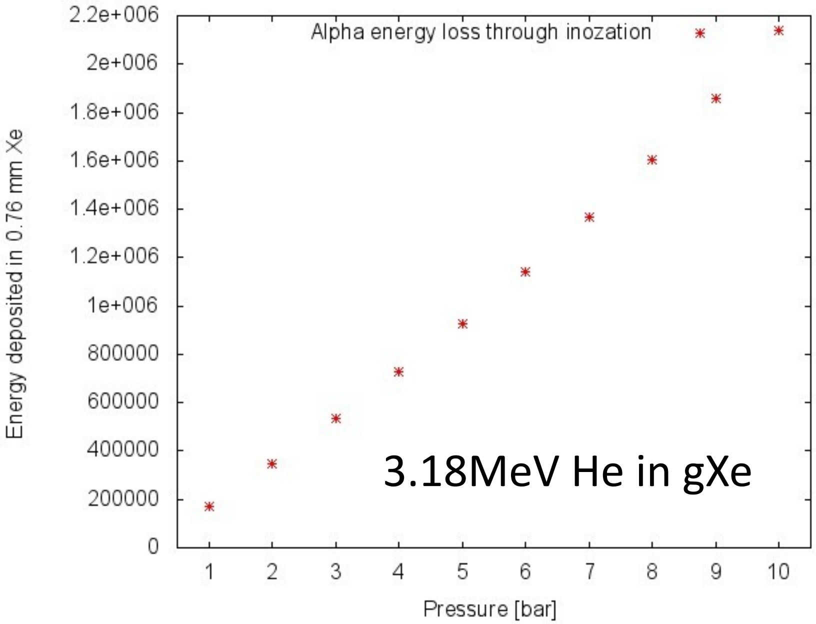

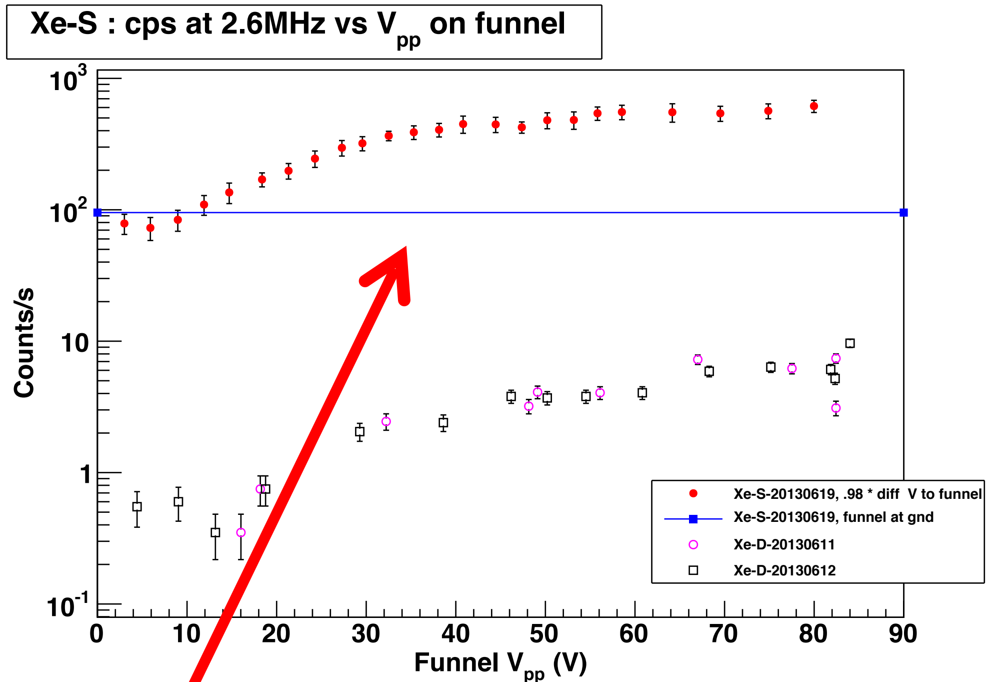

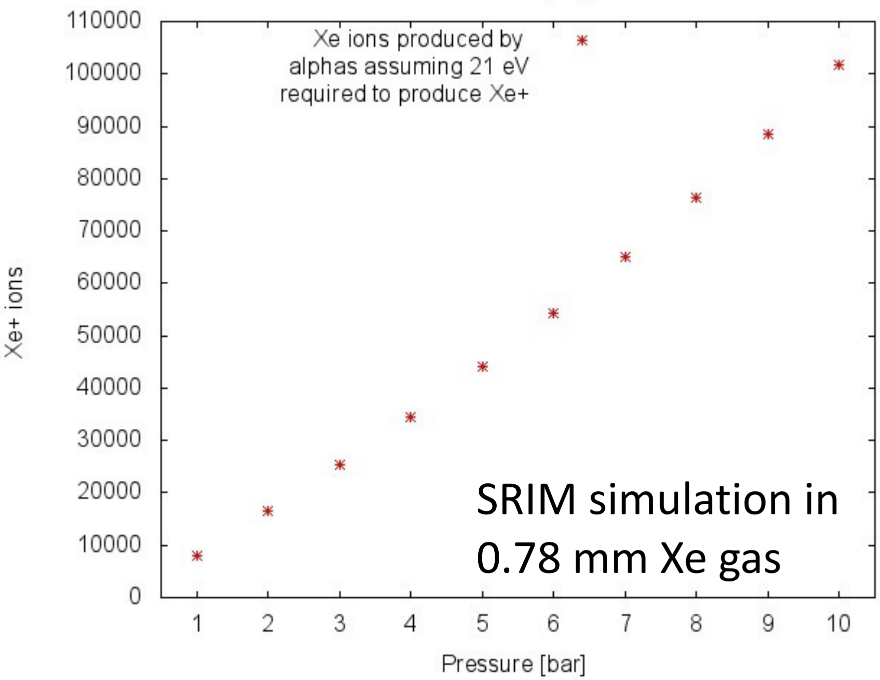

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Preliminary

Another Gedankenexperiment

- Xe flow is about 0.34 g/s -> 1.5 x 10^{21} atoms/s
- Extraction of 600 ions/s is a reduction of 18oom
- Assuming 2 Ba^+ ions out of these 600

  -> only a reduction of 300 left ;-)

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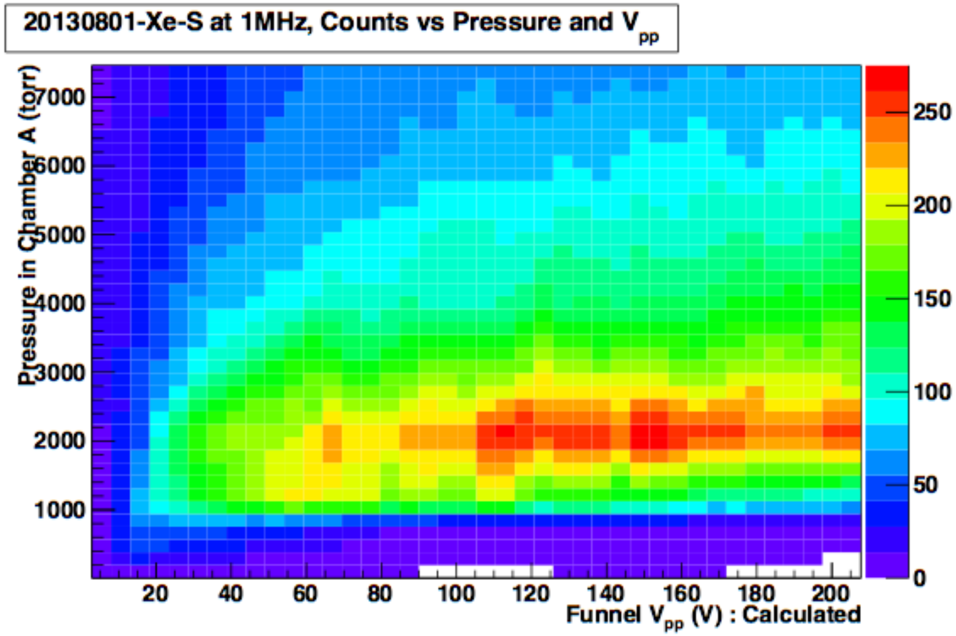
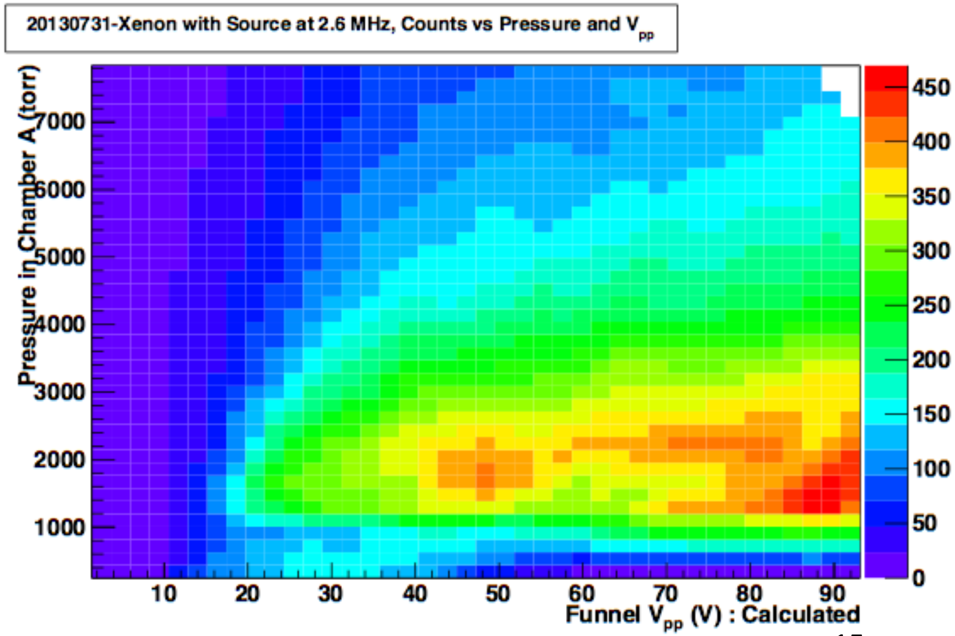


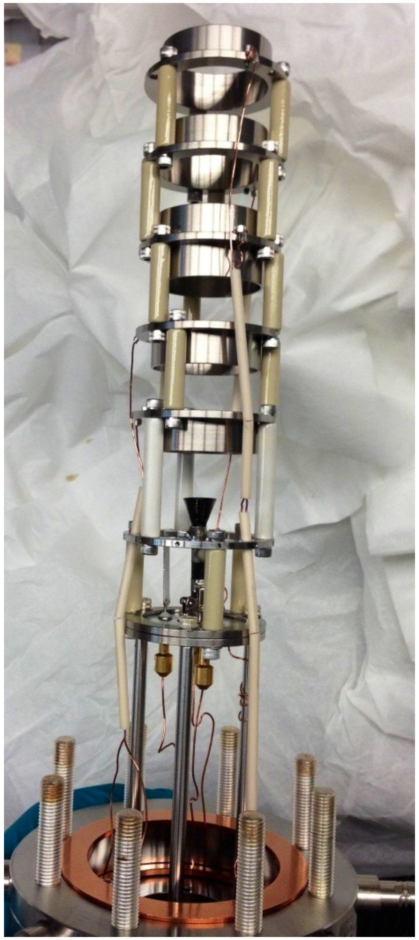


Ion identification - RGA

Idea: Inject ion bean into a commercial RGA unit & scan

Channeltron

Channeltron with lenses



MKS MicroVision 2
RGA with lenses

Signal:

- Detect ions directly
- Focus ions with lens system
- Steer ions with split Einzel lens through an aperture

No signal:

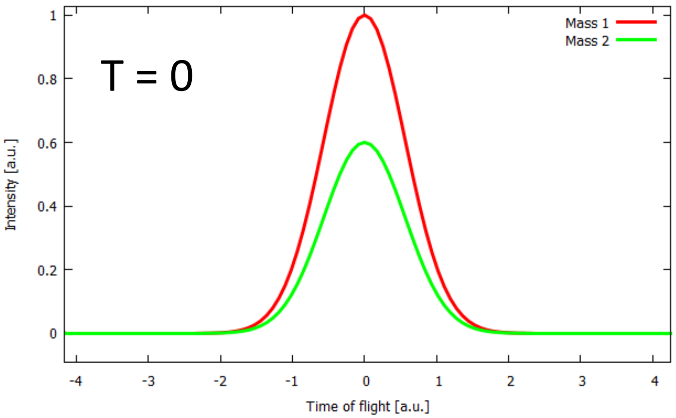
- Ions injected into MV2

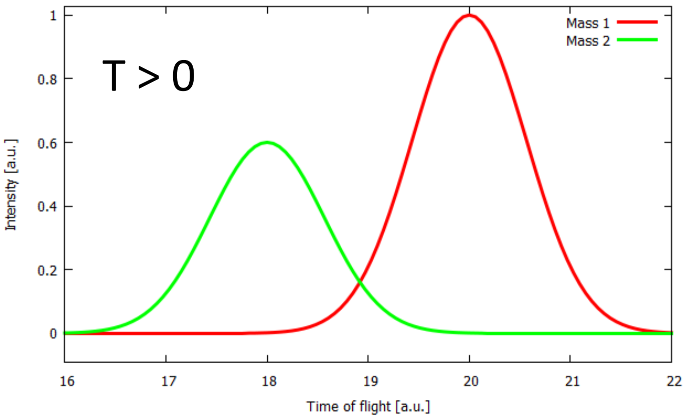
Thanks to MKS for lending us a MV2 unit

Ion identification – ToF mass spectrometry

$E_{kin} = \frac{1}{2} m v^2$ -> all ions start with same E_{kin}

-> m/q determination by ToF

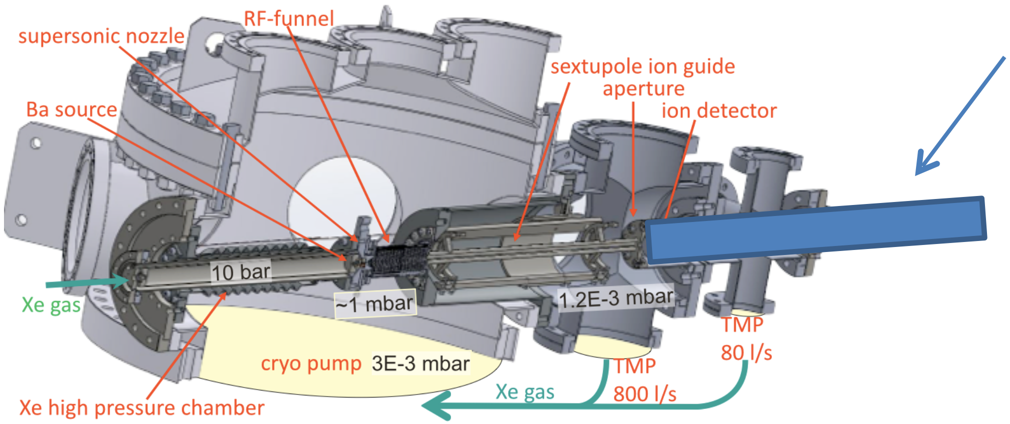




ToF MS in ES3 for Ba tagging

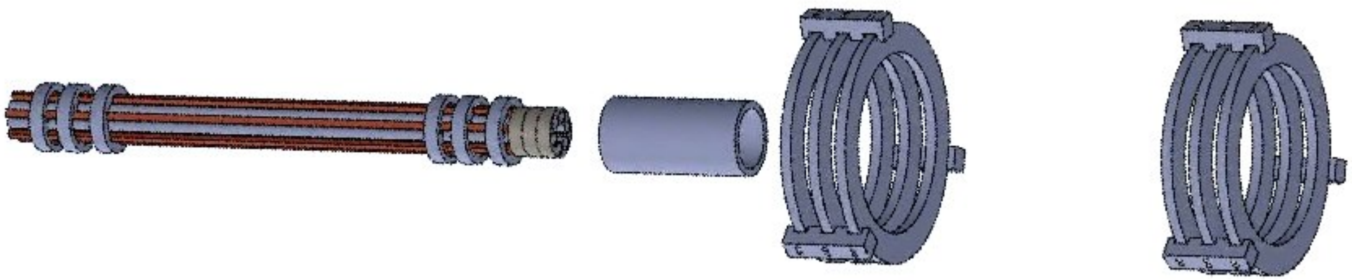
1. Capture DC ion beam and cool ions (in linear Paul trap)
2. Extract a short ion bunch
3. Adjust kinetic energy of ions inside the bunch
4. Find m/q of ions in bunch by recording time of flight to an ion detector

MR TOF MS

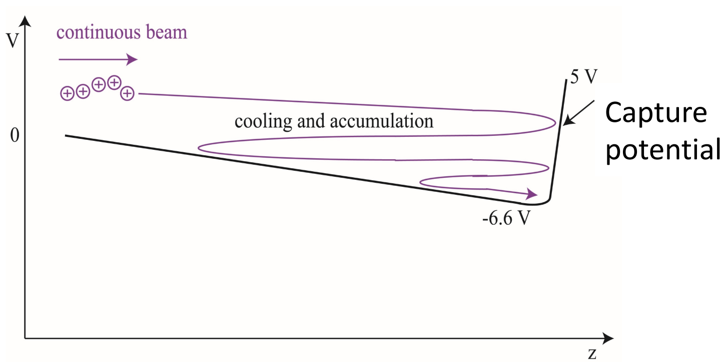


m/q identification

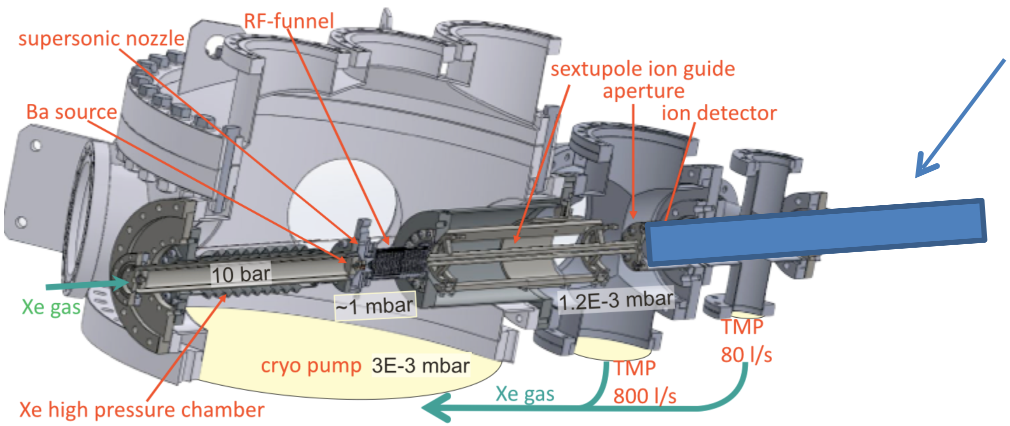
- SPIG with coupled DC electrodes
- He buffer gas ion cooling
- Pulsed drift tube (PDT) to adjust energy
- Electrostatic mirrors for ToF



Linear Paul trap PDT Switchable electrostatic mirrors



MR TOF MS



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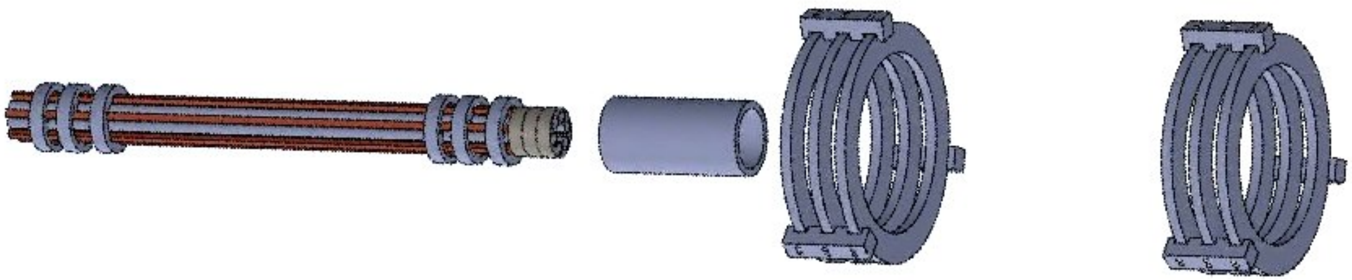

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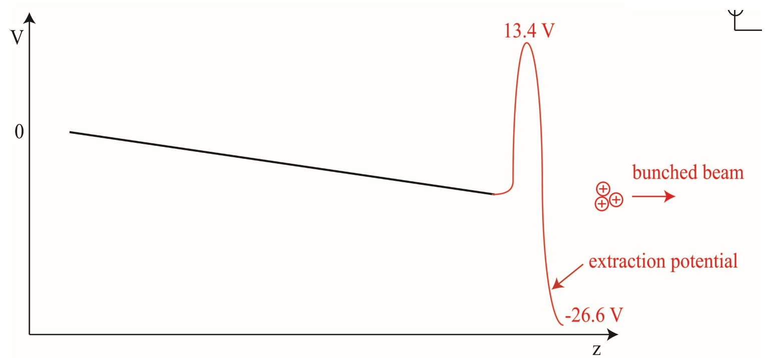

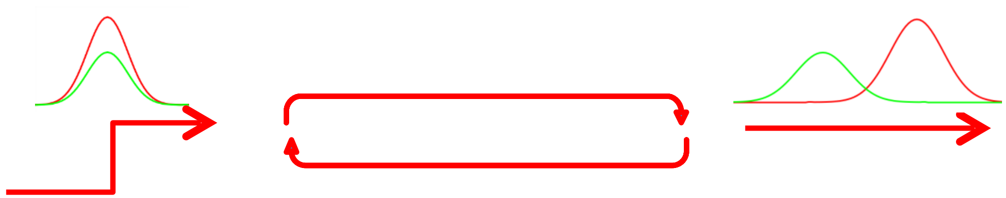

Adjust ion energy　　Separate ions by m/q　　Extract and detect ion's TOF

Next Steps – Stay Tuned

Fabricate ion source with new ion source design (0.010” gap)

Determine means to identify ions by q/m -> design a multi-reflection TOF mass spectrometer

Determine the possibilities to measure Ba^{++} source activity

Determine efficiency of funnel

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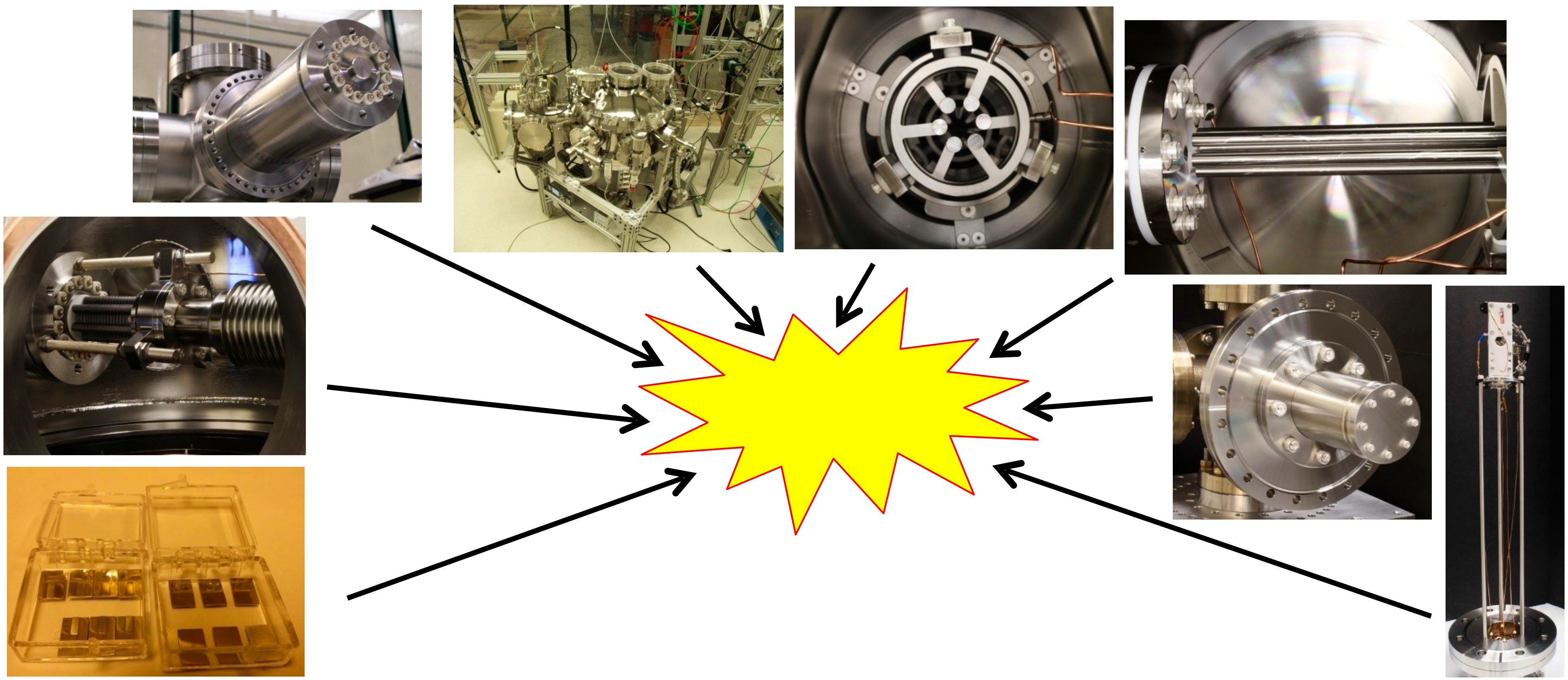

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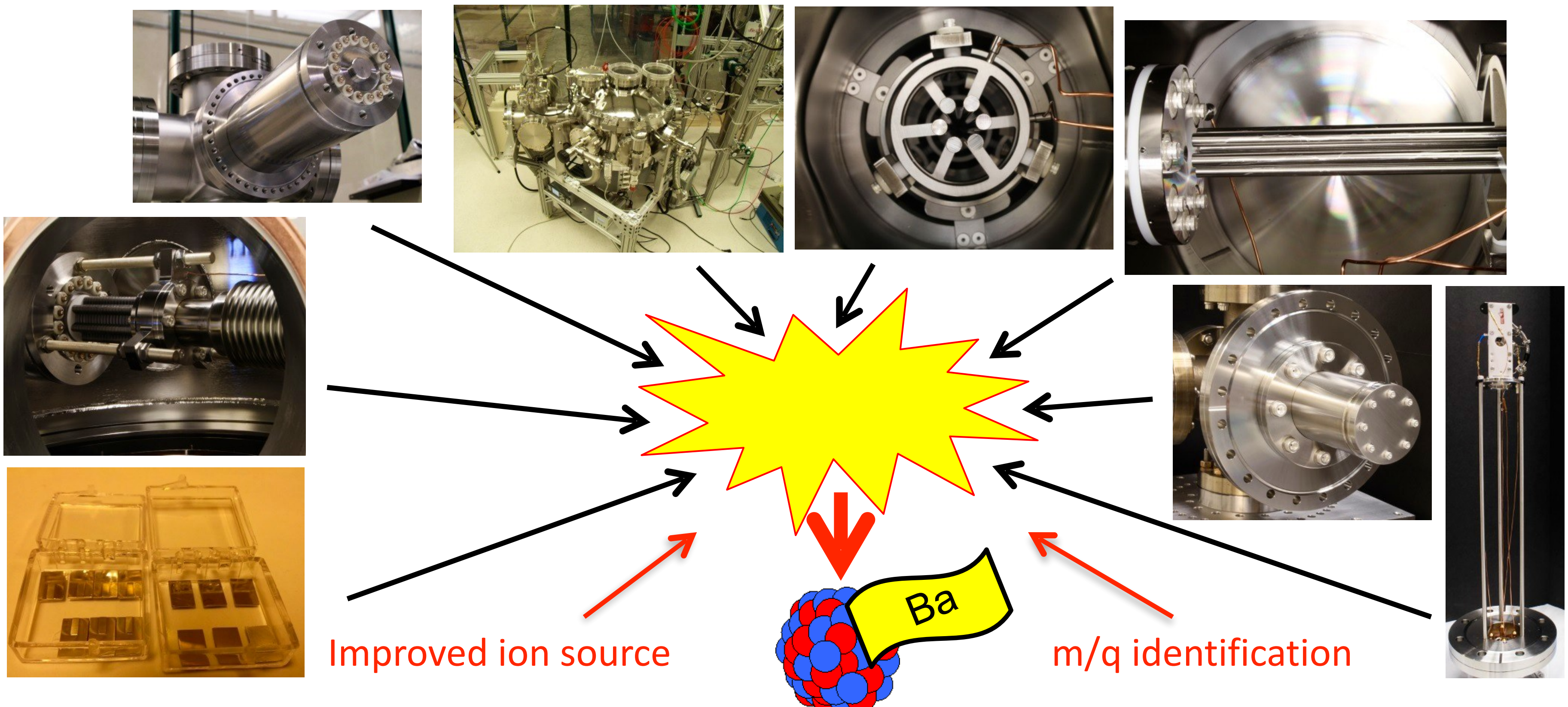
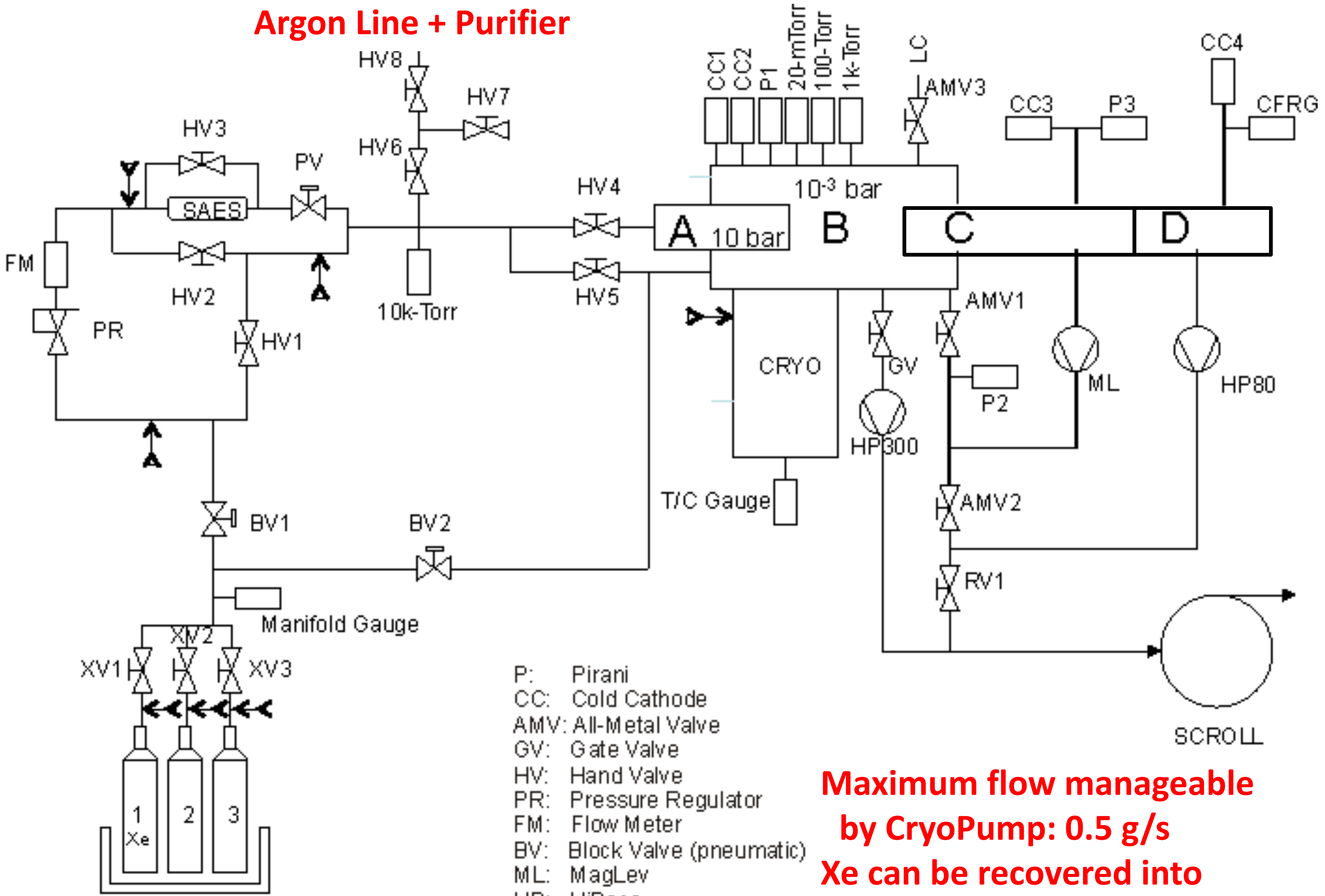


Backup slides

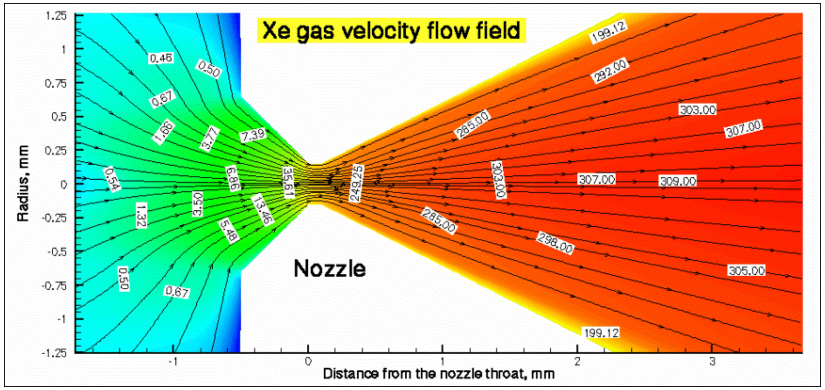
Argon Line + Purifier

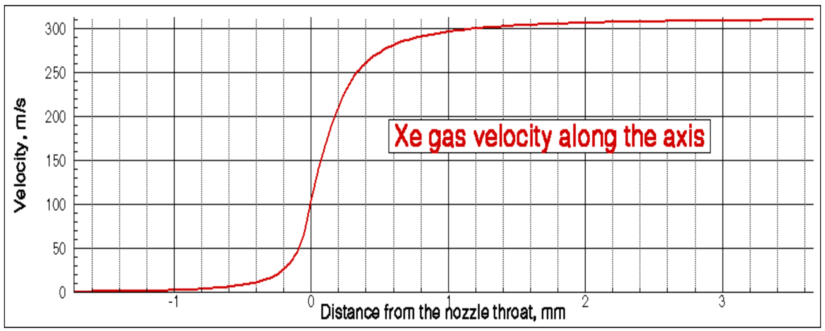


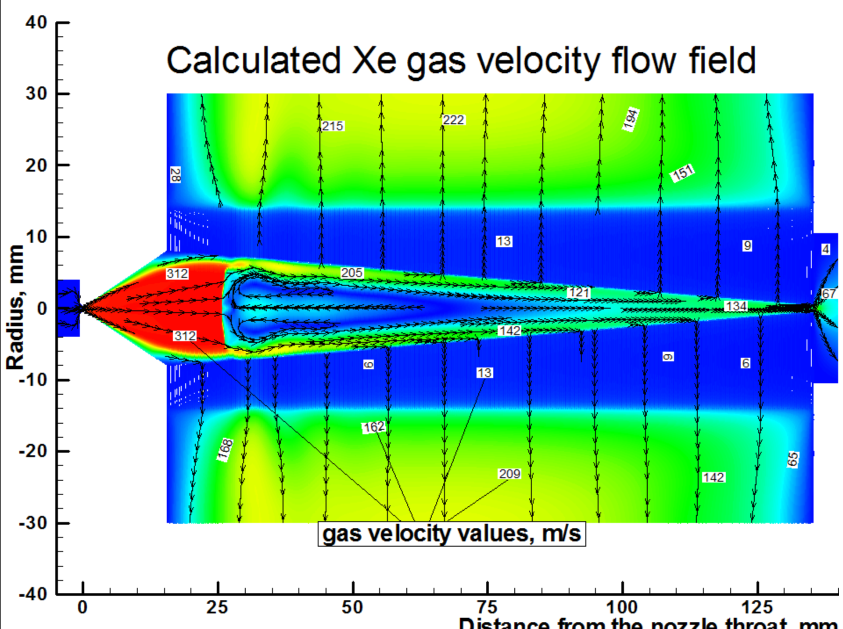
P: Pirani
CC: Cold Cathode
AMV: All-Metal Valve
GV: Gate Valve
HV: Hand Valve
PR: Pressure Regulator
FM: Flow Meter
BV: Block Valve (pneumatic)
ML: MagLev
HP: HiPace
RV: Roughing Valve
LC: Leak Check
CFRG: Compact Full Range Gauge

Maximum flow manageable by CryoPump: 0.5 g/s
Xe can be recovered into the gas bottles

Funnel Parameters







<u>Converging-diverging nozzle</u>

Half-angle of subsonic cone	45^o
Half-angle of supersonic cone	26.6^o
Throat diameter	0.28 mm
Mass Flow	0.33 g/s
Exit diameter	16.0 mm
Subsonic part length	0.5 mm
Supersonic part length	15.5 mm

<u>RF-funnel electrodes</u>	CU
Entrance aperture diameter	0.6299”
Exit aperture diameter	0.0394”
Ring electrode diameter	1.1024”
Change in aperture diam./el.	0.0020”
Ring electrode thickness	0.0040”
(design)	0.0001”
Gap between electrodes	0.0100”
Total number of electrodes	301

Simulated Efficiencies

Victor's funnel @ 2.6 MHz	72.0%
Sextupole ion guide	91.2%
Aperture to CEM	83%
CEM efficiency	80%
TOTAL	44%