Francium production and trapping at LNL Legnaro

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Physics with trapped atoms

- Precision spectroscopy to test relativistic many-body predictions
- Unique tests of the electroweak model via atomic parity nonconservation (APNC)
  - electron-nucleon: weak charge
  - nucleon-nucleon: anapole moments
- Limits on electric dipole moments (EDM) and time-reversal symmetry

Why Fr traps?

- Heaviest alkali metal: simple electronic structure and large nucleus ⇒ enhancement of APNC and EDM effects
- Several isotopes with lifetime > 1 min ⇒ isotope comparisons
- No stable isotopes, but traps partly compensate scarcity
- Magneto-optical trap (MOT) can feed other traps
- Temperature of MOT cloud ≈ mK ⇒ Doppler-free spectroscopy

Fr trapping experiments

SUNY Stony Brook

pioneered Fr trapping; spectroscopy

moving to TRIUMF

Gomez et al., Rep. Prog. Phys. 69, 79 (2006)

JILA Boulder

vapor cell; spectroscopy of ^{221}Fr

Lu et al., Phys. Rev. Lett. 79, 994 (1997)

LNL Legnaro

status in this talk

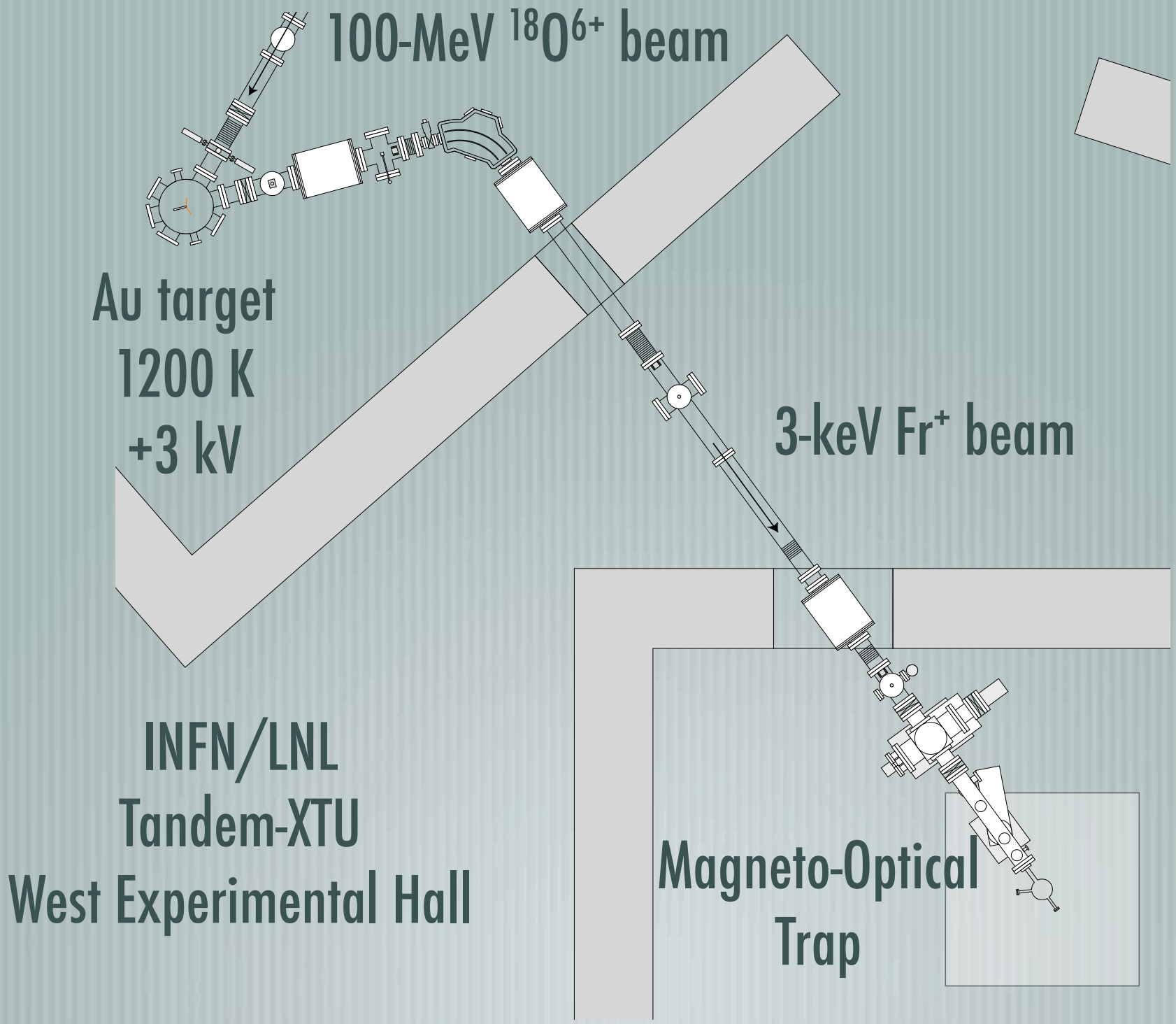
RCNP Osaka

feasibility tests for EDM

Sakemi, RCNP proposal 2005 (unpublished)

Collaboration

- **University and INFN Ferrara**: R. Calabrese, S. N. Atutov, G. Gattobigio, V. Guidi, G. Stancari, L. Tomassetti
- **INFN Laboratori Nazionali di Legnaro**: L. Corradi, A. Dainelli
- **University, INFM and INFN Pisa**: P. Minguzzi, S. Sanguinetti
- **University and INFM Siena**: L. Moi, V. Biancalana, A. Burchianti, C. de Mauro, A. Khanbekyan, C. Marinelli, E. Mariotti, S. Veronesi


100-MeV $^{18}O^{6+}$ beam
Au target
1200 K
+3 kV
3-keV Fr^{+} beam
INFN/LNL
Tandem-XTU
West Experimental Hall
Magneto-Optical
Trap

Primary beam

- 95–115 MeV $^{18}O^{6+}$ from Tandem-XTU
- Maximum intensity 2×10^{12} particles/s
- Average of 12 days of beam time per year since 2001

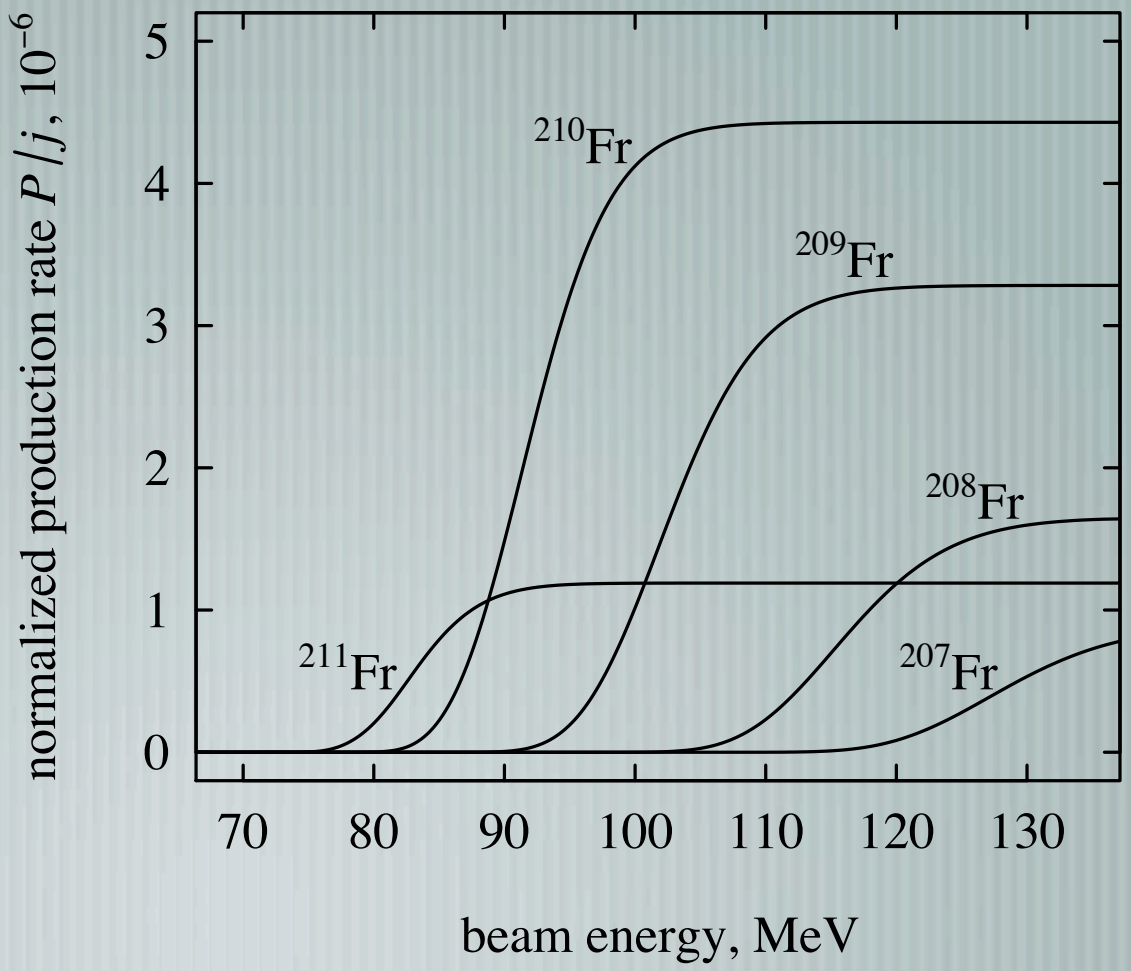
Production target

- ^{197}Au disk on W support rod
- 1200 K, +3 kV
- Fusion-evaporation:
  $^{197}Au(^{18}O,xn)^{215-x}Fr$
- ^{210}Fr yields @ flux 1.5×10^{12}:
  1×10^{6} (ave.), 3×10^{6} (max.)

Production estimates

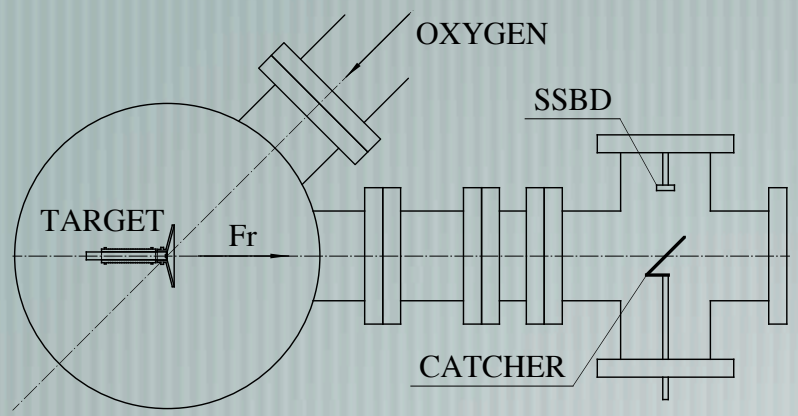
Data from Corradi et al., Phys. Rev. C 71, 014609 (2005)
+ HIVAP calculation

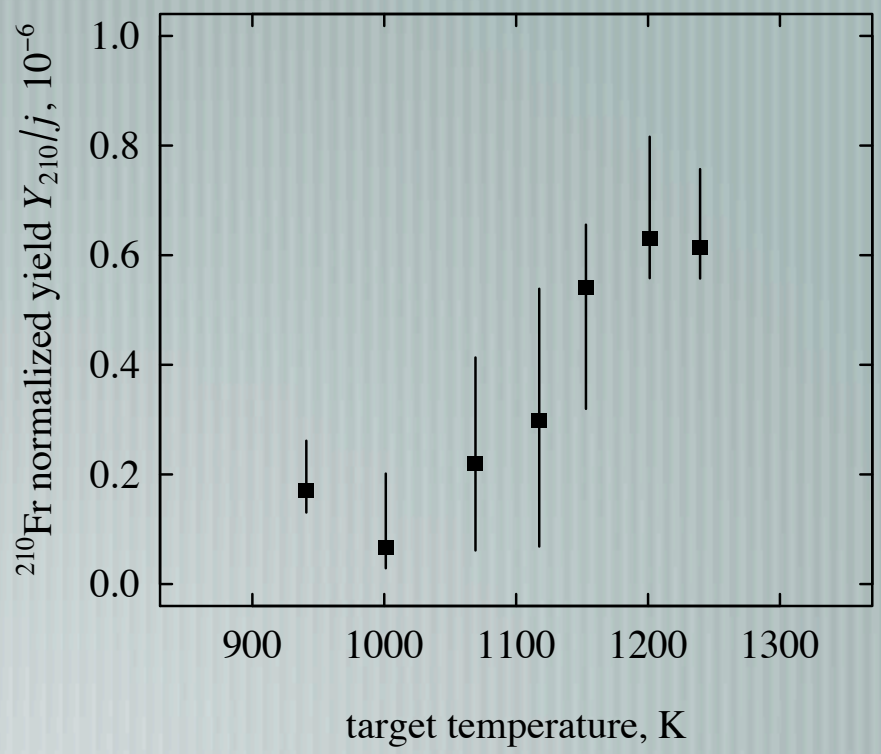
$$\frac{P}{j} = \int_0^{E_0} \frac{\sigma(E')}{\langle dE/dx \rangle} \frac{N_A}{M} dE'$$



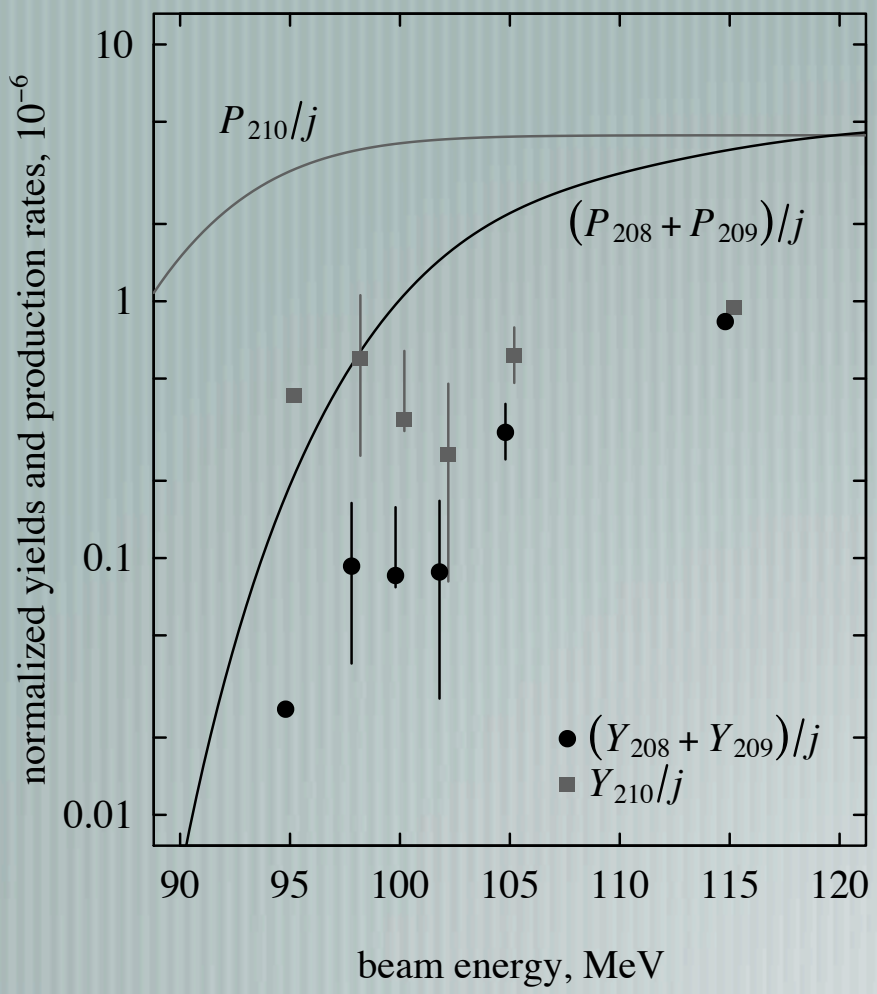
Yield measurements (1/2)

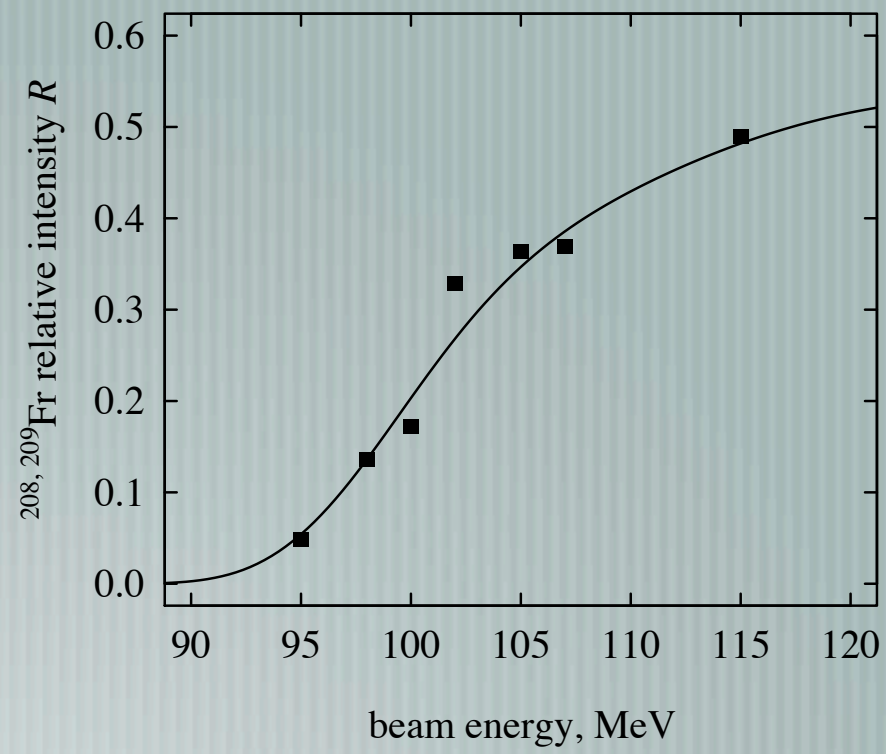
Stancari et al., Nucl. Instrum. Methods A 557, 390 (2006)





Yield measurements (2/2)

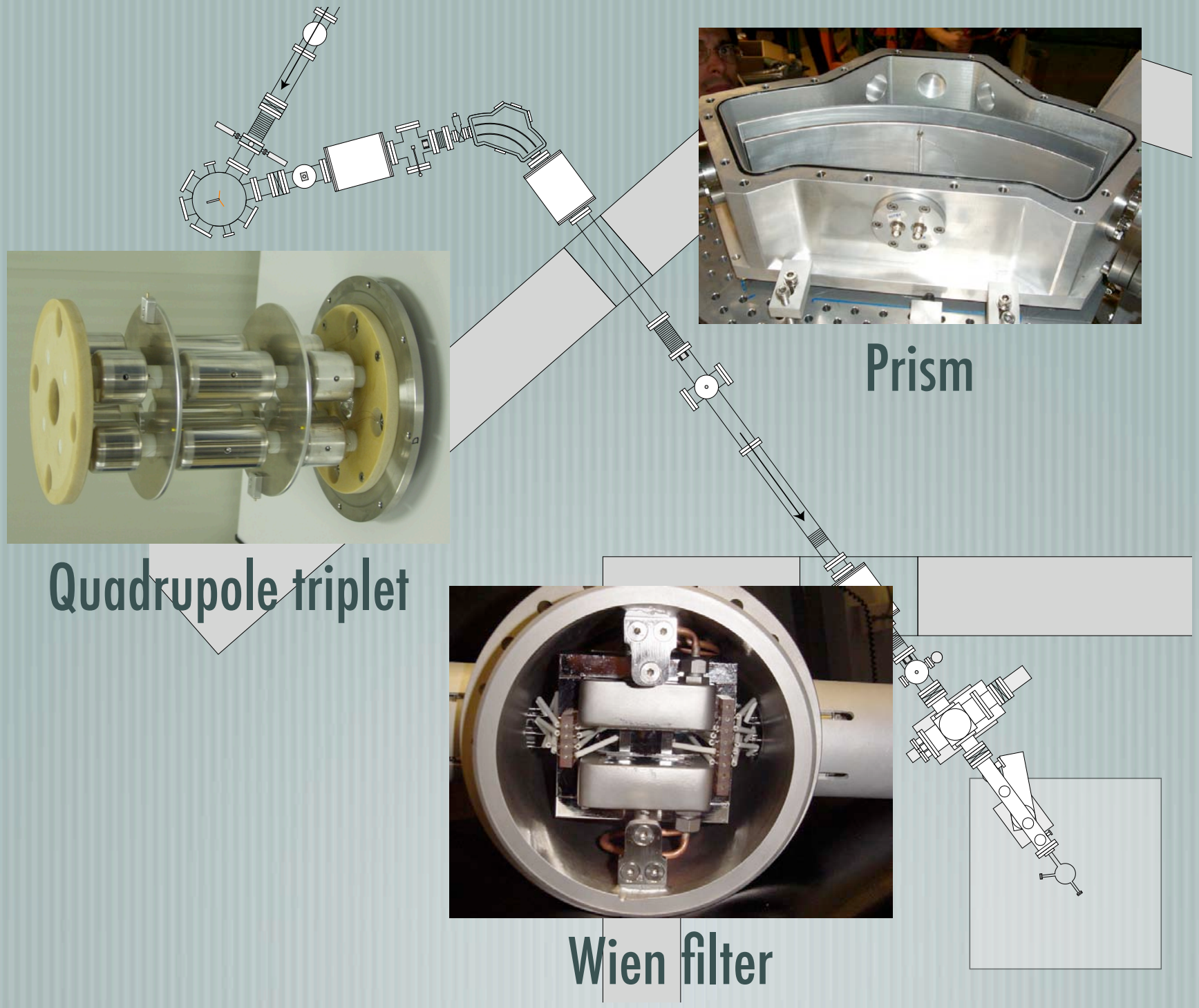




Diffusion process is efficient
Yields limited by surface desorption

Transport beamline

- Decouples MOT lab from target area (radiation + vacuum)
- Electrostatic, i.e. mass independent
- Mass selection with Wien filter


Prism
Quadrupole triplet
Wien filter

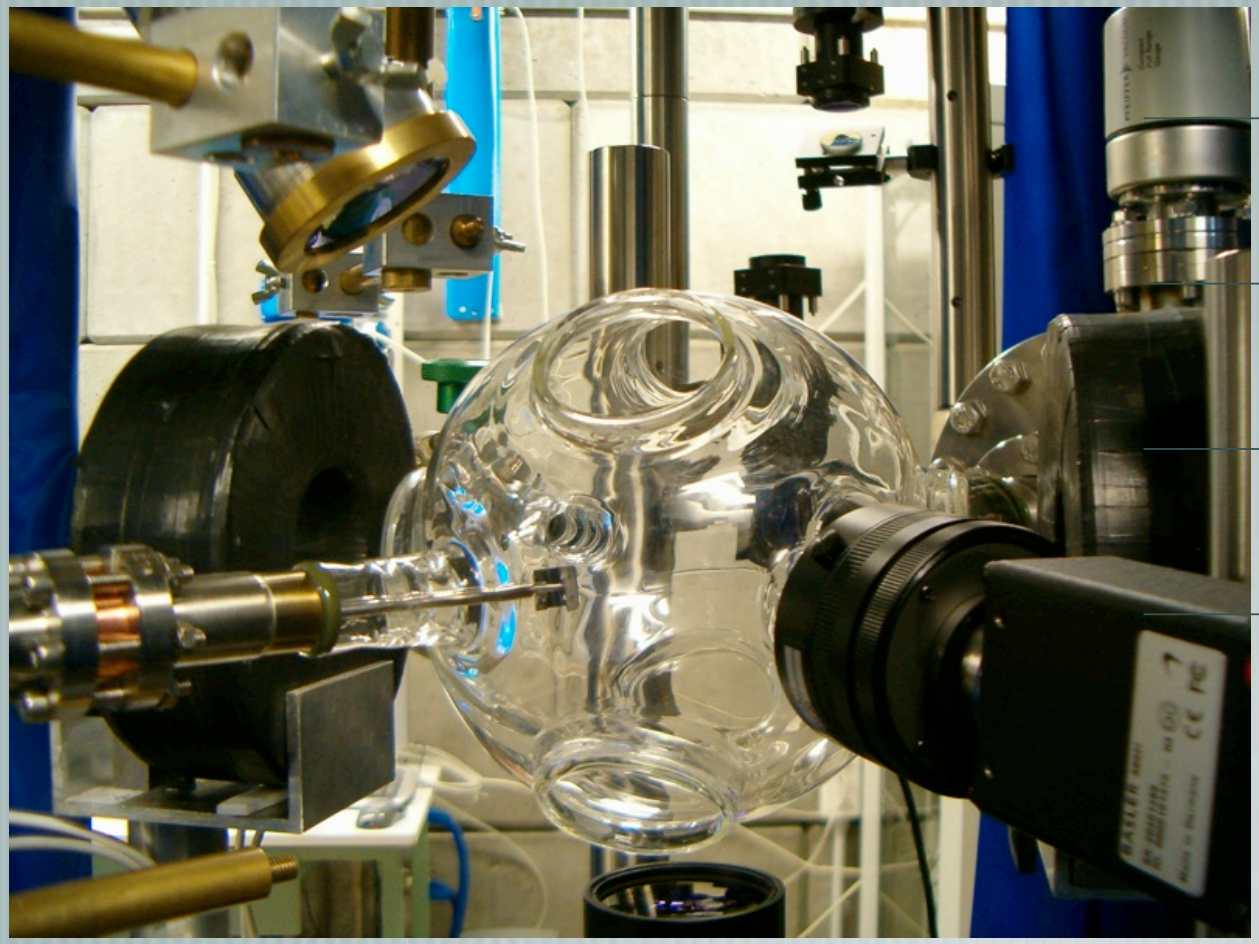
Laser Lab

Fr^+ → MOT area Laser systems

Neutralization

- Y or Zr plate inside MOT cell
- 900–1100 K for diffusion
- Test neutralizer on beamline
- Fr released in about 10 s

MOT features

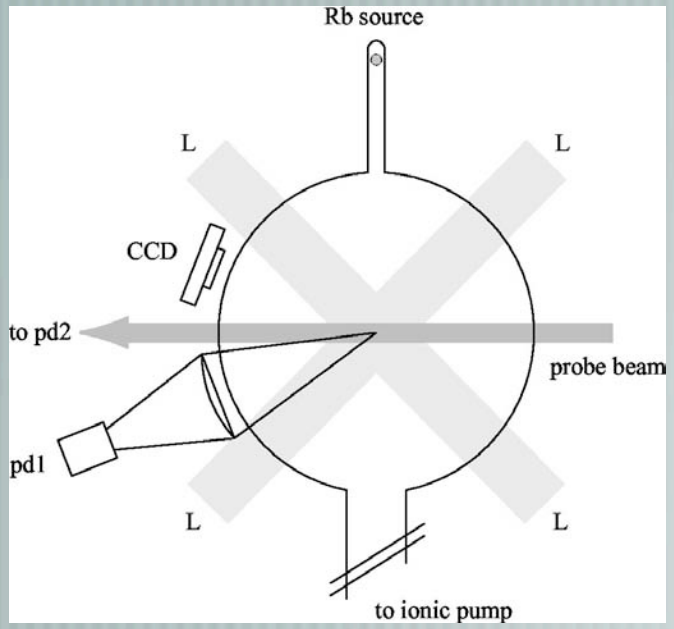


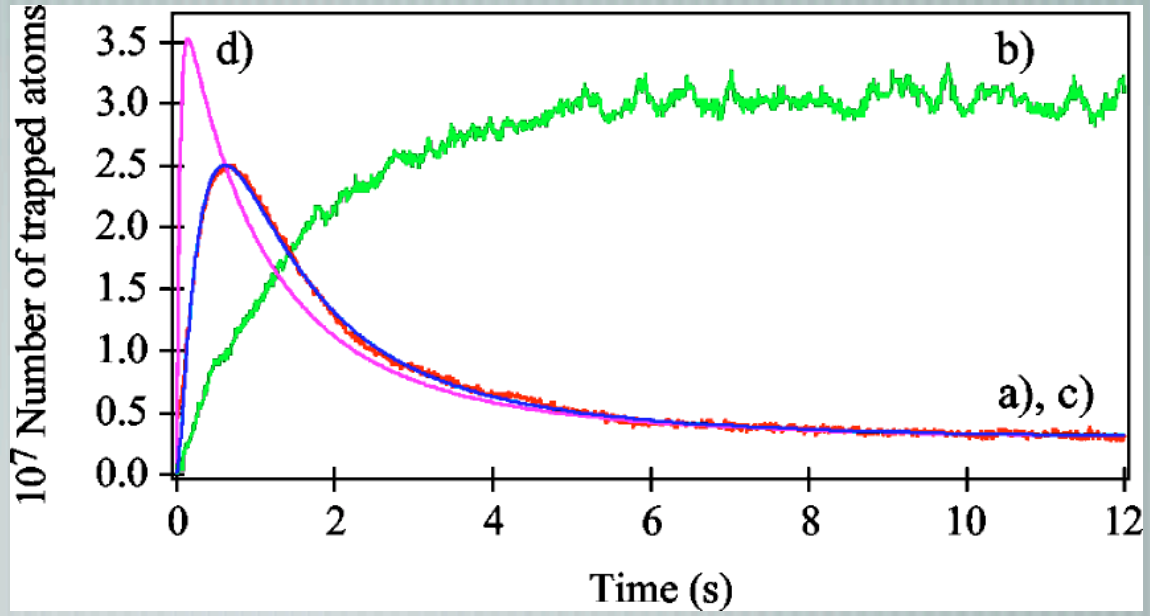
- Ti:Sa 718 nm
- Diode 817 nm
- Beam diameter 4 cm
- Pyrex cell with PDMS or Dryfilm coating

MOT improvements

Atutov et al., Phys. Rev. A 67, 053401 (2003)

- Achieved record loading rate of Rb MOT
- Exploits Light-Induced Atomic Desorption in PDMS coating

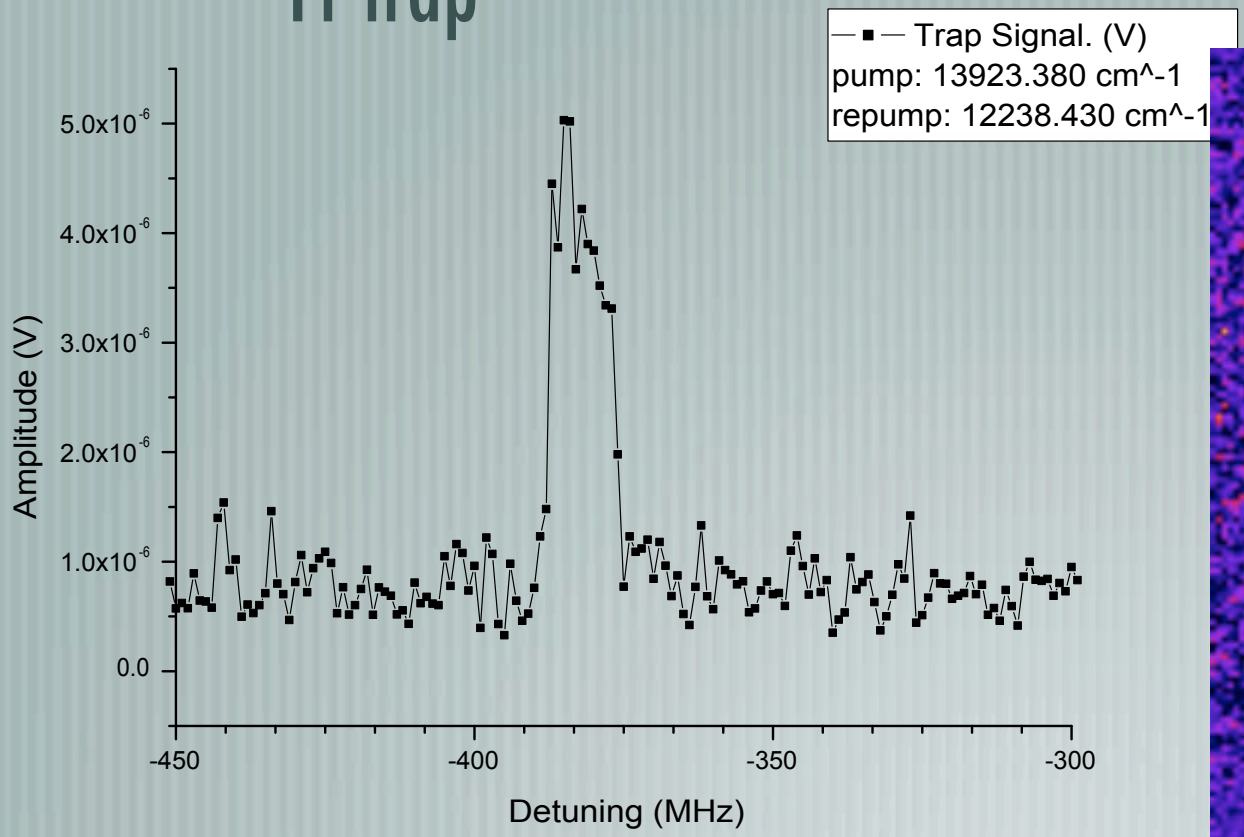




Light Detection

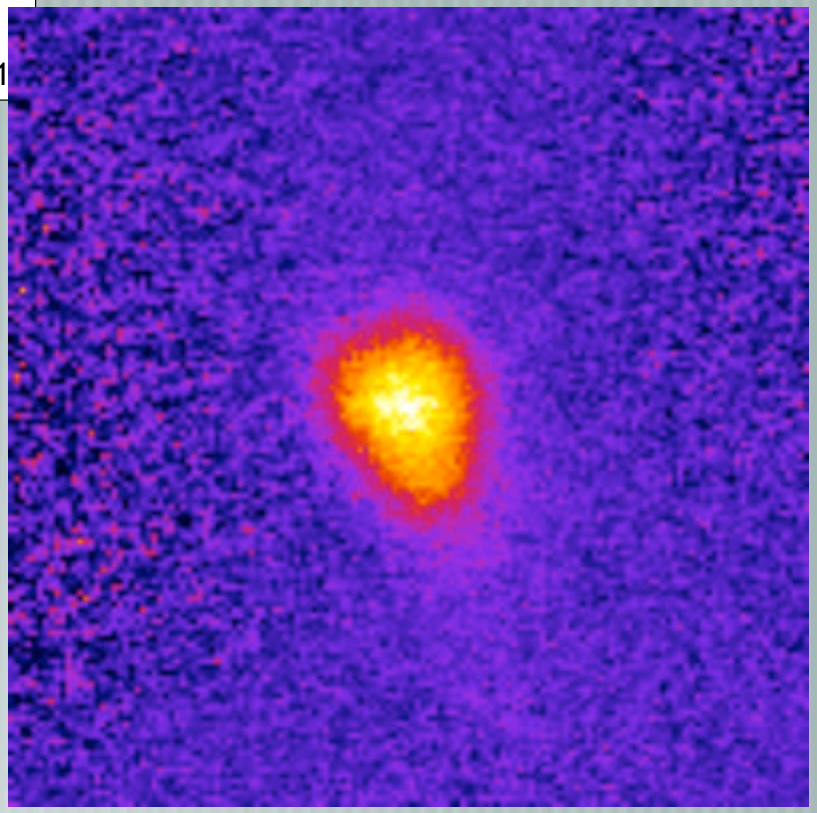
Atutov et al., Nucl. Phys. A 746, 421 (2004)

Fr trap



Photodiode and Lock-in

Rb trap



Cooled CCD Camera

Timeline

2001	– production target releases first Fr beam (June)
2002	– beamline completed; Fr^+ beam to MOT (July)
2003	– first Fr trap signals (April)
2004	– upgrades: Wien filter, Dryfilm coating, CCD camera
2005	– record Fr production (February)

Conclusions

- Built first European facility for Fr atomic traps
- Achieved record efficiency for Rb MOT
- Characterized Fr production via fusion-evaporation
- Rapid progress in spite of limited beam time
- Future experiments at ISOLDE?

Thanks for your attention