Experiments with stored ions at ISOLDE: TSR@HIE-ISOLDE proposal

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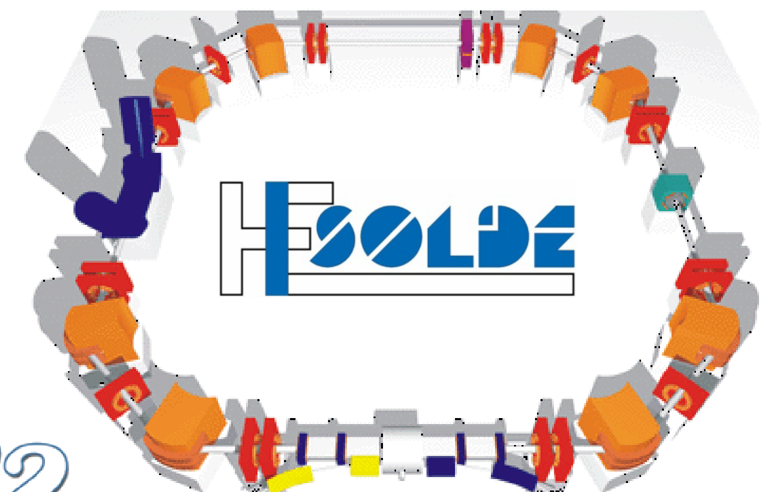
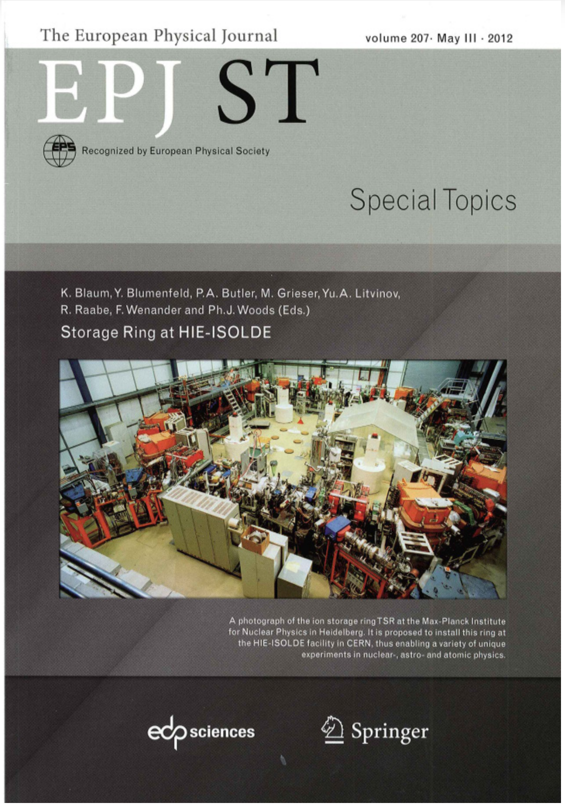
Yu.A. Litvinov (Univ. Heidelberg and GSI), R. Raabe (KU Leuven),
F. Wenander (CERN), Ph.J. Woods (Univ. Edinburgh) (eds.)





Collaboration: 129 scientists from 47 institutions in 19 countries

M. Aliotta[1], A. Andreyev[2], A. Artemyev[3], D. Atanasov[4], T. Aumann[5,6], D. Balabanski[8], A. Barzakh[9], L. Batist[9], A.-P. Bernardes[10], D. Bernhardt[11], J. Billowes[12], S. Bishop[13], K. Blaum[14], Y. Blumenfeld[10], M. Borge[15], I. Borzov[16], F. Bosch[6]A. Boston[17], C. Brandau[18,6], P.A. Butler[17], W. Catford[19], R. Catherall[10], J. Cederkäll[10,20], D. Cullen[12], T. Davinson[1], I. Dillmann[21,6], C. Dimopoulou[6], G. Dracoulis[22] C. Düllmann[23], P. Egelhof[6], A. Estrade[6], D. Fischer[14], K. Flanagan[10,12], M. Fraser[10], S. Freeman[12], H. Geissel[21,6], J. Gerl[5,6], P. Greenlees[7,47], M. Grieser[14], R.E. Grisenti[24,6], R. von Hahn[14], S. Hagmann[24], M. Hausmann[25], J.J. He[26], M. Heil[6], M. Huyse[27], D. Jenkins[28], A. Jokinen[7,47], J. Jolie[29], B. Jonson[30], D. Joss[17], Y. Kadi[10], N. Kalantar-Nayestanaki[31], B. Kay[28], H.-J. Kluge[6], M. Kowalska[10], C. Kozhuharov[6], S. Kreim[10,14], T. Kröll[5], R. Krücken[13,32], J. Kurcewicz[10], M. Labiche[33], R.C. Lemmon[33], M. Lestinsky[6], Yu.A. Litvinov[3,6], G. Lotay[1], X.W. Ma[26], J. Meng[45], D. Mücher[13], I. Mukha[6], A. Müller[11], A. Murphy[1], G. Neyens[27], T. Nilsson[30], C. Nociforo[6], W. Nörtershäuser[23], R. Page[17], M. Pasini[10], N. Petridis[24], N. Pietralla[5], M. Pfützner[44], Zs. Podolyák[19], R. Raabe[27], P. Regan[19], M.W. Reed[19], R. Reifarth[24], P. Reiter[29], R. Repnow[14], K. Riisager[34], B. Rubio[35], M.S. Sanjari[24], D.W. Savin[36], C. Scheidenberger[21,6], S. Schippers[11], D. Schneider[37], R. Schuch[38], D. Schwalm[14,39], L. Schweikhard[46], D. Shubina[14], E. Siesling[10], H. Simon[6], J. Simpson[33], J. Smith[2], K. Sonnabend[24], M. Steck[6], T. Stora[10], T. Stöhlker[3,43,6], B. Sun[45], A. Surzhykov[3], F. Suzaki[40], O. Tarasov[25], S. Trotsenko[43], X.L. Tu[26], P. Van Duppen[27], C. Volpe[41], D. Voulot[10], P.M. Walker[19], F. Wenander[10], E. Wildner[10], N. Winckler[14], D.F.A. Winters[6], A. Wolf[14], P. Woods[1], H.S. Xu[26], A. Yakushev[6], T. Yamaguchi[40], Y.J. Yuan[26], Y.H. Zhang[26], K. Zuber[42]

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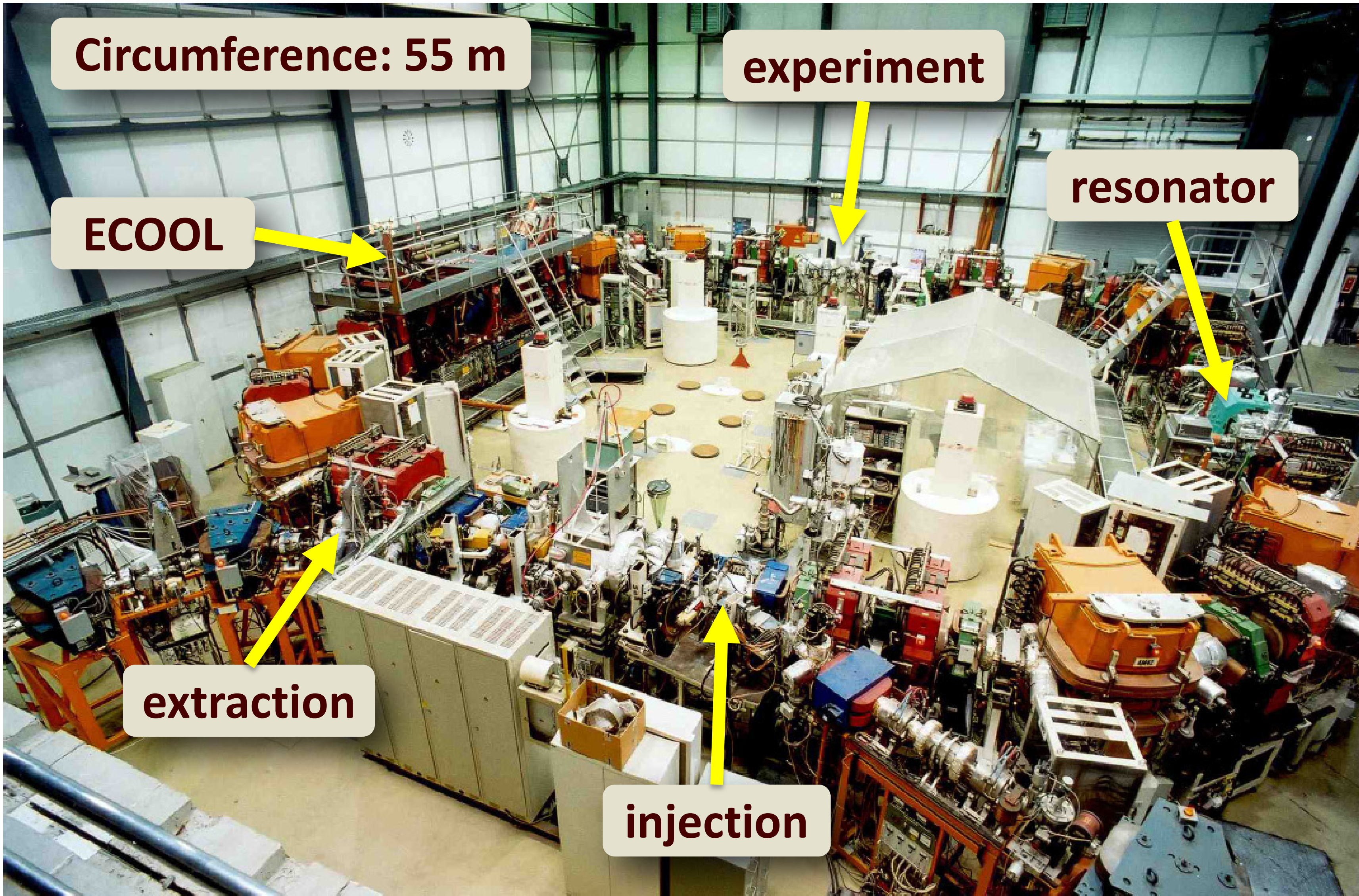
The Test Storage Ring at Heidelberg



A storage ring at an ISOL facility

Advantages

With respect to in-flight storage rings

- High intensity
- Cooler beams

With respect to "direct" beams

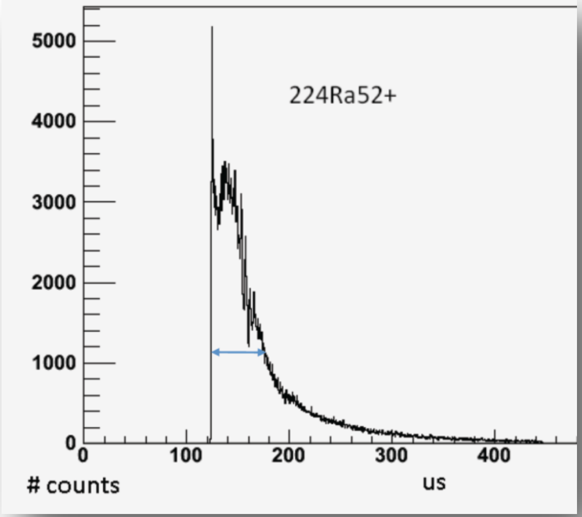
- Less background (target, beam dump)
- Improved resolution
- CW beam

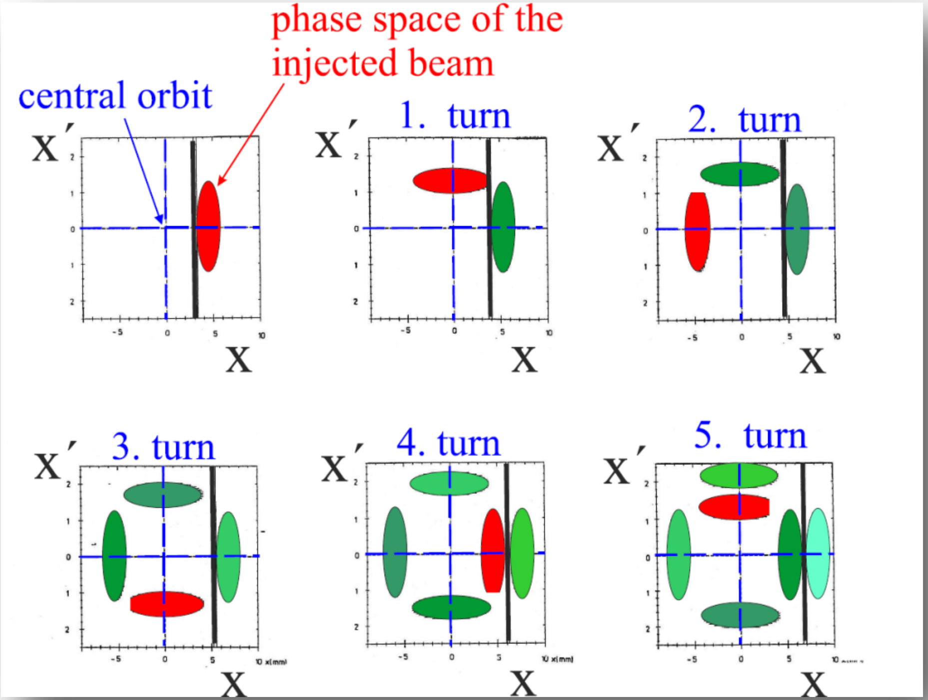
Physics programme

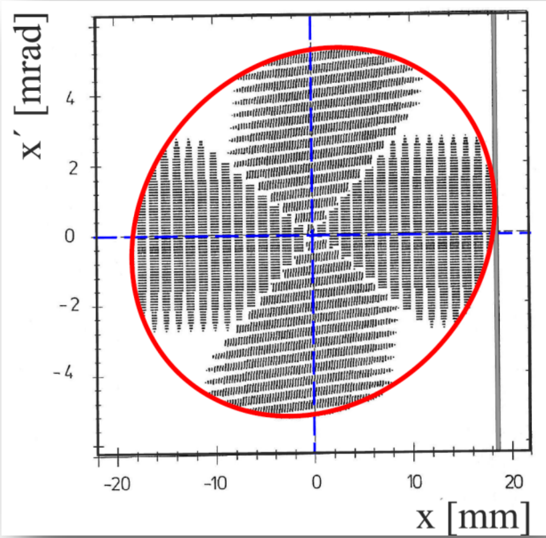
- Astrophysics
  Capture, transfer reactions
  ^{7}Be half life
- Atomic physics
  Effects on half lives
  Di-electronic recombination
- Nuclear physics
  Reaction studies
  Isomeric states
  Decay of halo states
  Laser spectroscopy
- Neutrino physics

Coupling the TSR to HIE-ISOLDE

- Good matching of timing properties: multi-turn injection
  → an EBIS pulse can be fully injected

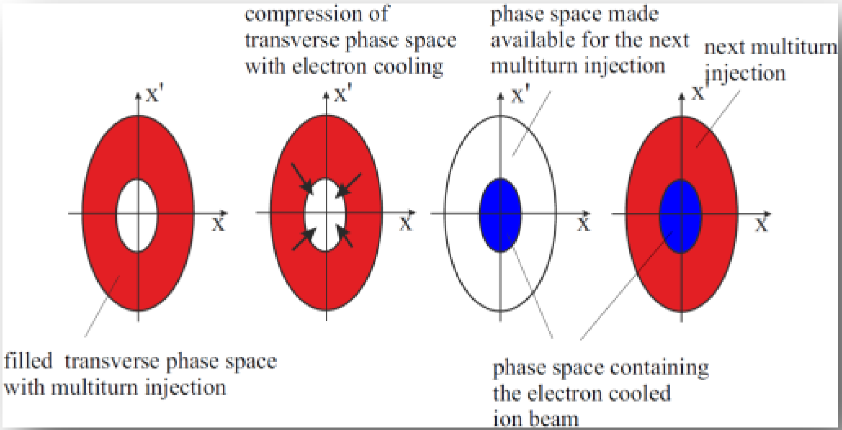


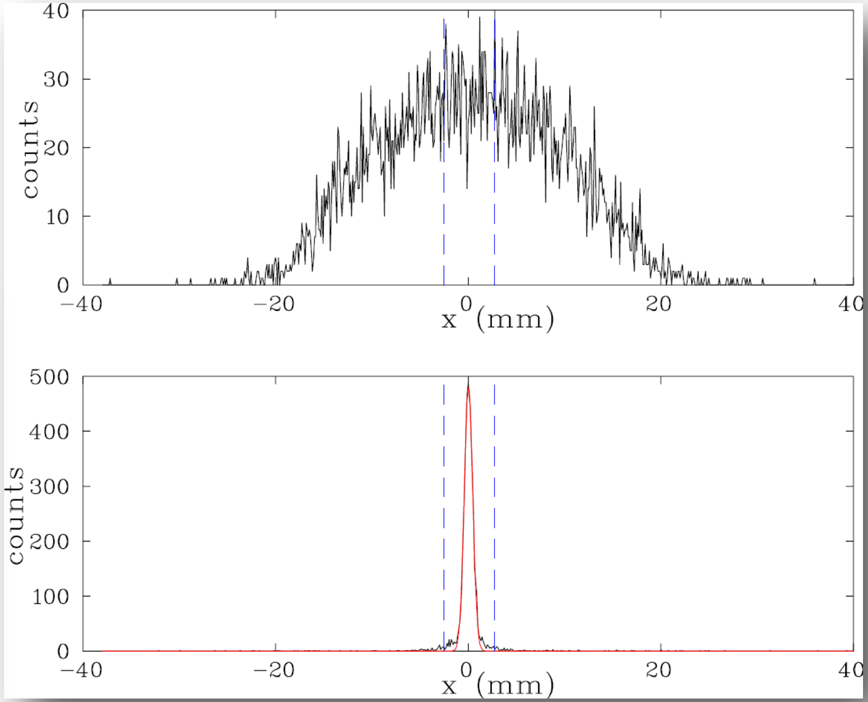




Coupling the TSR to HIE-ISOLDE

- Good matching of timing properties: multi-turn injection
  → an EBIS pulse can be fully injected
- Cooling during the time between EBIS pulses



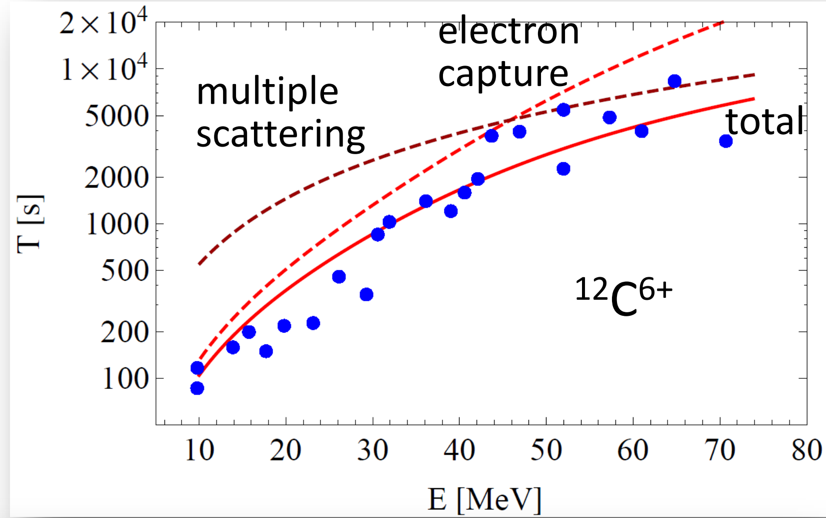


M. Beutelspacher, Diploma thesis, University Heidelberg, 1997

Coupling the TSR to HIE-ISOLDE

- Good matching of timing properties: multi-turn injection
  → an EBIS pulse can be fully injected
- Cooling during the time between EBIS pulses
- Intensities only limited by lifetimes
  $I_{ring} = I_{inj}\, \varepsilon\, f\, \tau$
  → gains around 10^6

S. Artikova, University Heidelberg, Ph.D. thesis



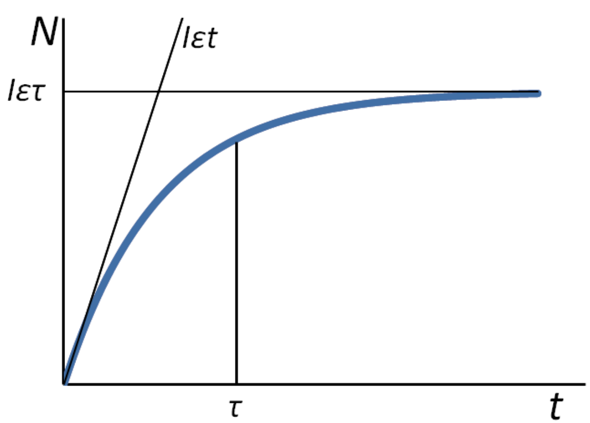


Table 1: Parameters of beams circulating in the TSR. See text for details.

Ion	Nuclear lifetime	Energy (MeV/u)	Cooling time	Beam lifetime in residual gas	H_2 target (atoms/cm^2)	Beam lifetime in target	Eff. target thickness (μg/cm^2)
^{7}Be 3+	(53 d)	10	2.3 s	370 s			
^{18}F 9+	100 m	10	0.7 s	280 s	1×10^{14}	236 s	31000
^{26m}Al 13+	6.3 s	10	0.5 s	137 s	5×10^{14}	23 s	4200
^{52}Ca 20+	4.6 s	10	0.4 s	58 s	5×10^{14}	9.6 s	3000
^{70}Ni 28+	6.0 s	10	0.25 s	30 s	2×10^{14}	12 s	1600
^{70}Ni 25+	6.0 s	10	0.3 s	26 s	2×10^{13}	2.1 s	60
^{132}Sn 30+	40 s	4	0.4 s	1.5 s	1×10^{12}	1.4 s	1.2
^{132}Sn 45+	40 s	4	0.2 s	1.4 s	5×10^{12}	1.6 s	7
^{132}Sn 39+	40 s	10	0.25 s	7.4 s	2×10^{12}	3.6 s	9.5
^{132}Sn 45+	40 s	10	0.2 s	10 s	5×10^{13}	1.3 s	90
^{186}Pb 46+	4.8 s	10	0.25 s	4 s	2×10^{12}	1.5 s	4
^{186}Pb 64+	4.8 s	10	0.13 s	5 s	1×10^{13}	1.7 s	20

Physics programme

Advantages

With respect to in-flight storage rings

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With respect to “direct” beams

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- Improved resolution
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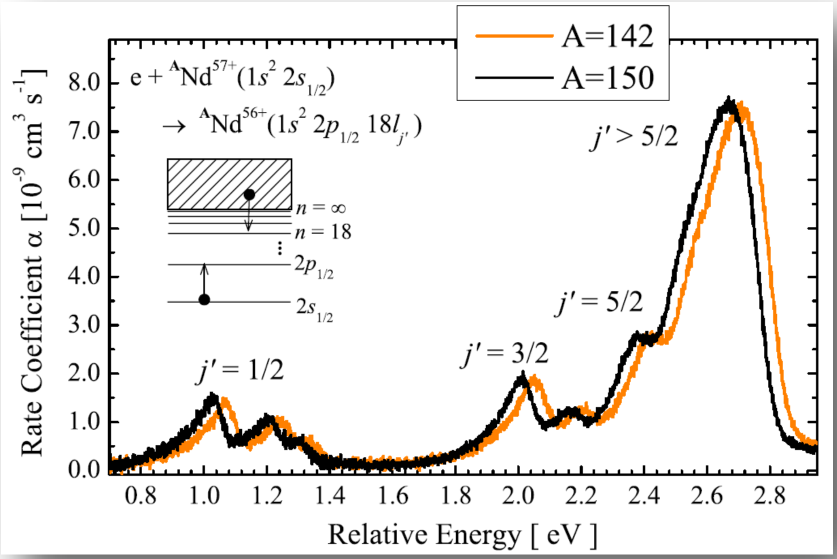
  ^{7}Be half life
- Atomic physics
  Effects on half lives
  Di-electronic recombination
- Nuclear physics
  Reaction studies
  Isomeric states
  Decay of halo states
  Laser spectroscopy
- Neutrino physics

Atomic methods and physics

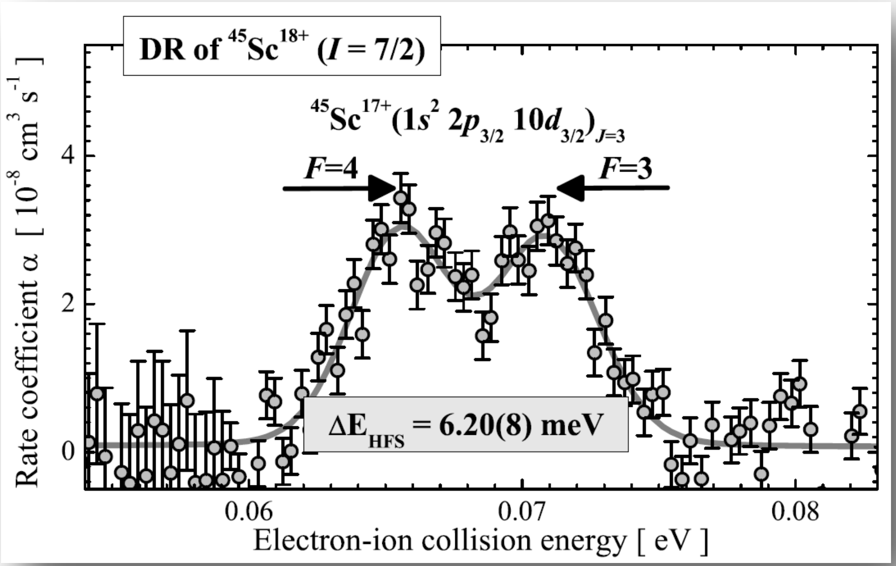
F. Bosch, C. Brandau, Yu. Litvinov,
D.W. Savin, S. Schippers

- Study of atomic shells using dielectronic recombination
  → deduce nuclear properties

- Atomic data for astrophysics, fusion energy



C. Brandau, et al., Phys. Rev. Lett. 100, 073201 (2008)



M. Lestinsky, et al., Phys. Rev. Lett. 100, 033001 (2008)

Atomic methods and physics

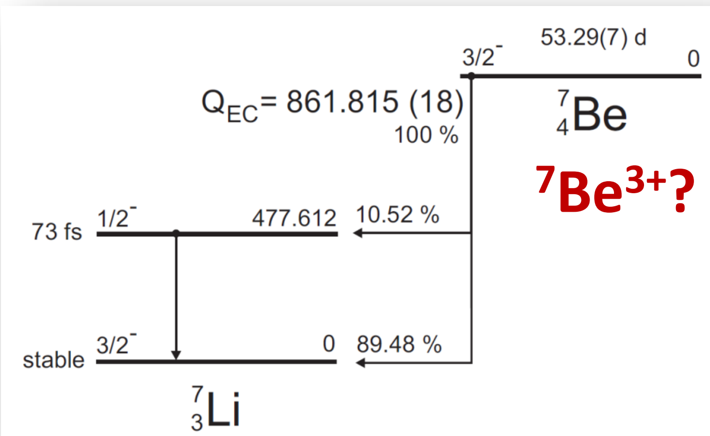
F. Bosch, C. Brandau, Yu. Litvinov,
D.W. Savin, S. Schippers

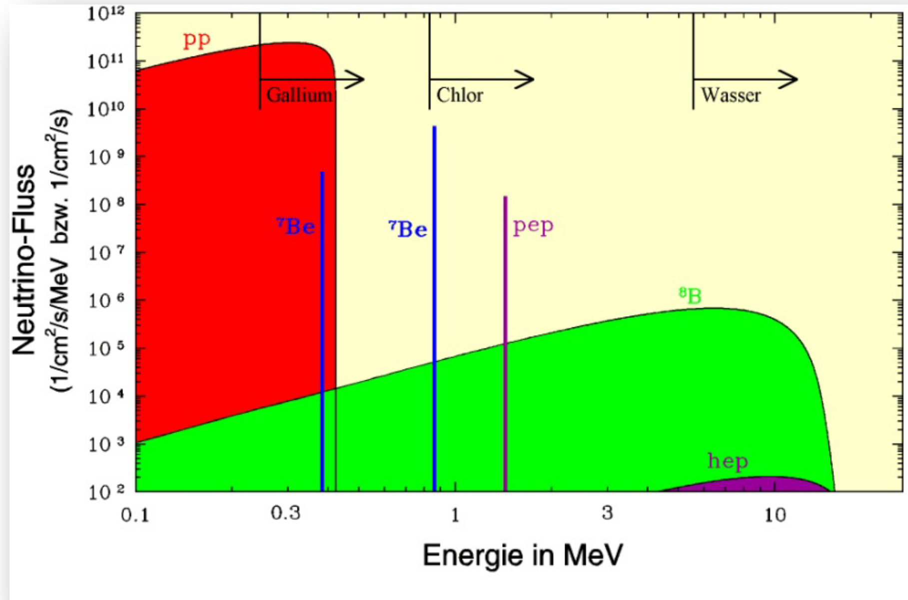
- Study of atomic shells using dielectronic recombination
  → deduce nuclear properties
- Atomic data for astrophysics, fusion energy
- Nuclear effects on atomic half-lives
  Study in function of the magnetic moment
- Atomic effects on nuclear half-lives
  (counting experiments, need large number of nuclei)

Half life of H-like ^{7}Be

K. Blaum, F. Bosch,
Yu. Litvinov, K. Zuber

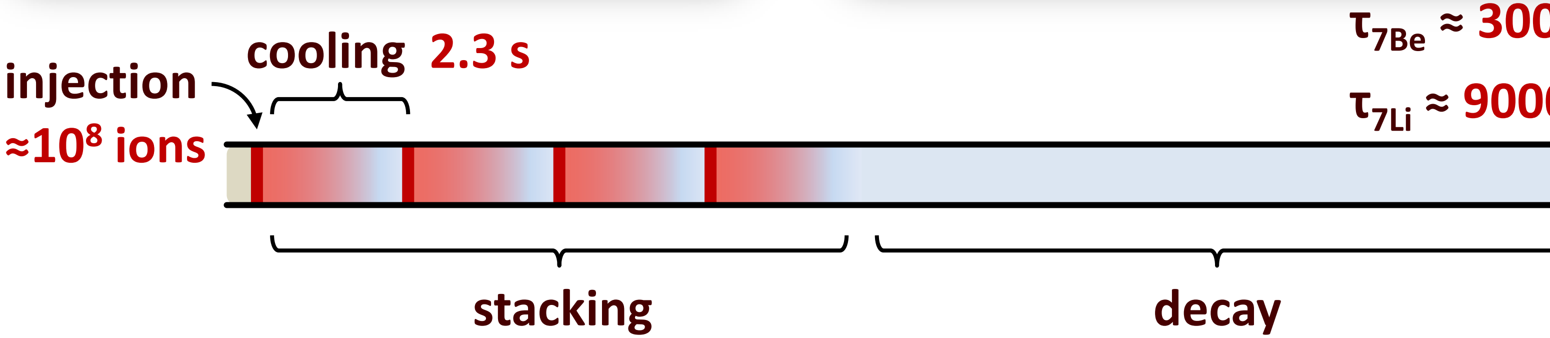
- Half life of ^{7}Be in the Sun
- Produced ν_e rates
- Electron screening test case





$\tau_{7Be} \approx$ 300 s

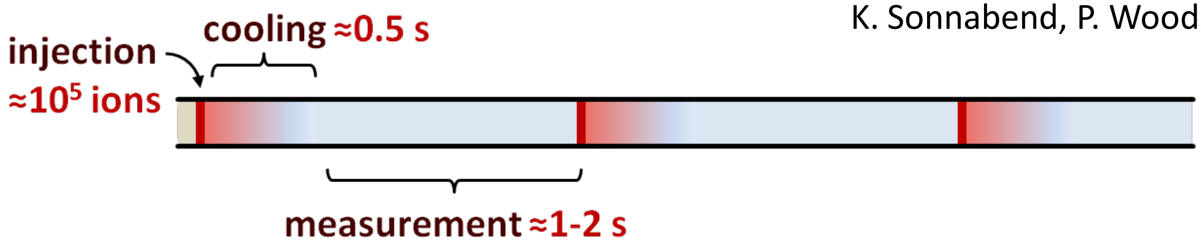
$\tau_{7Li} \approx$ 9000 s

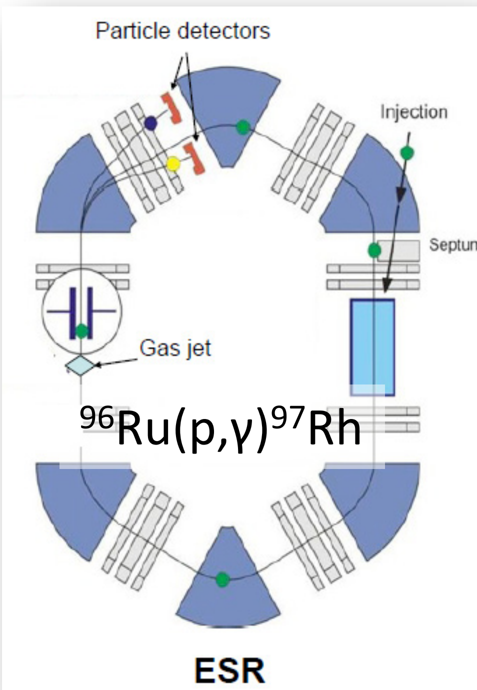


Reaction measurements

P. Butler, M. Heil, R.R., R. Reifarth, K. Sonnabend, P. Woods

- Proton capture (astrophysics)
- Transfer reactions



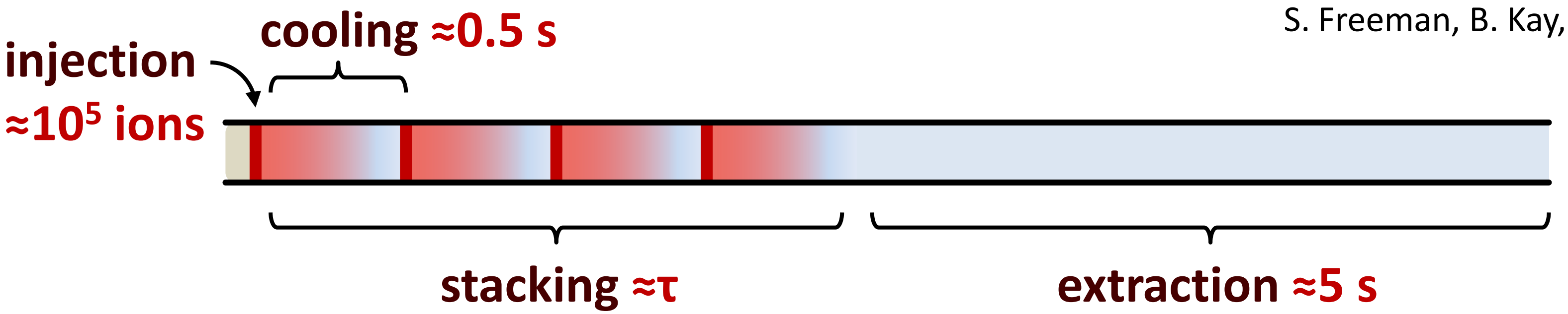


Q. Zhong, Journal of Physics: Conference Series 202 (2010) 012011

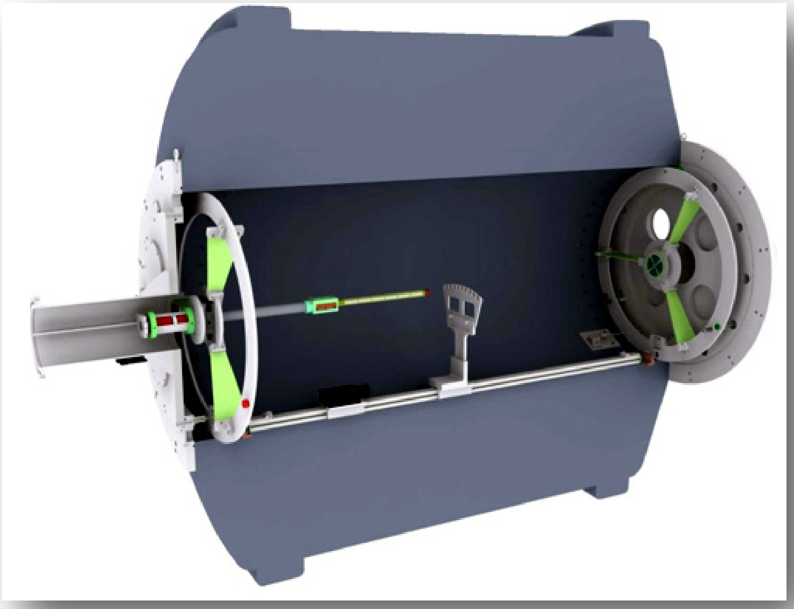
- EXL collaboration

Extracted beams

P. Butler, W. Catford, J. Cederkäll,
S. Freeman, B. Kay, R. Page, R.R.



- Cooled beams
  in HELIOS-type spectrometer
- Very good energy resolution
  for reactions at low beam
  intensity



J. C. Lighthall et al, NIM A 622, 97 (2010)

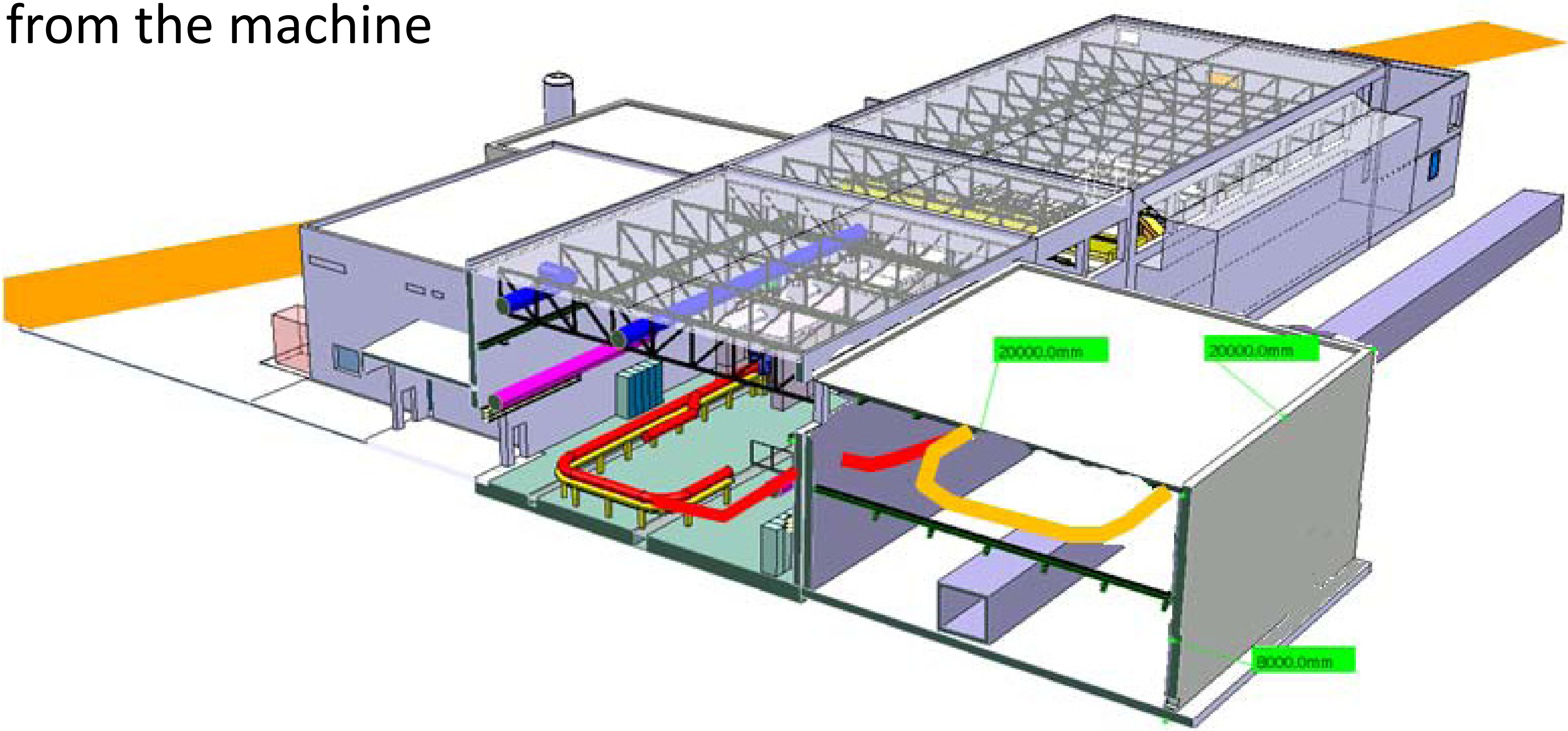
Neutrino physics

T. Stora, C. Volpe, E. Wildner

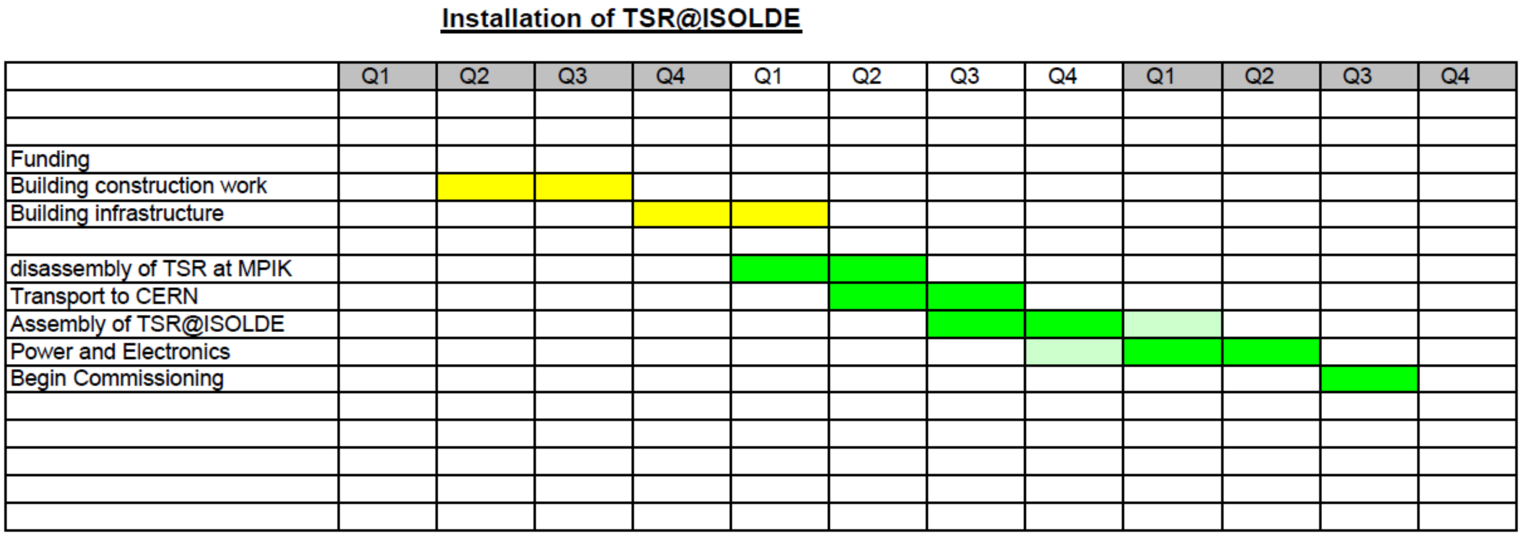
- Production and storage of beta-decaying nuclei which are suitable for beta-beam project (^{6}He, ^{18}Ne, ^{8}Li, ^{8}B)
- Development of the secondary beams, injection, cooling, accumulation, decay losses
- Ideal test facility for the accumulation and storage of ^{6}He
- In-ring production, e.g. ^{6}Li(^{3}He,n)^{8}B
  (B is not available as ISOL beam)
  (resonances at low energies – TSR is an ideal instrument)
- Development of d, ^{3}He targets

The TSR@HIE-ISOLDE

- Possible TSR installation above the CERN cable-tunnel
- Tilted beam line coming up from the machine



Planning



- Estimates made for disassembly, transportation, reassembly
- Building (≈ 3 MCHF) to be requested from CERN
- Hardware: working groups the Collaboration seeks funding
- Running costs and manpower provided by the Collaboration

Working Group	Participating Institutions
Electron Cooler / Electron Target	MPIK / Uni Giessen / CERN
Gas Target	MPIK / Uni Frankfurt / UK Universities
Diagnostics	MPIK / GSI
Setup & Commissioning	MPIK / CERN
Control System	CERN
Particle Detectors	TU Darmstadt / TU Munich / GSI / KU Leuven / UK Universities
EBIT/S & Injection / Extraction	MPIK / CERN

Summary

- A storage ring at an ISOL facility: a unique instrument
- TSR matches HIE-ISOLDE characteristics
- Possibilities in atomic, nuclear, astro- and neutrino physics
- TSR at ISOLDE: favourably received by CERN authorities

At HIE-ISOLDE by the second shutdown?