MATS and LaSpec: Status and first experiments

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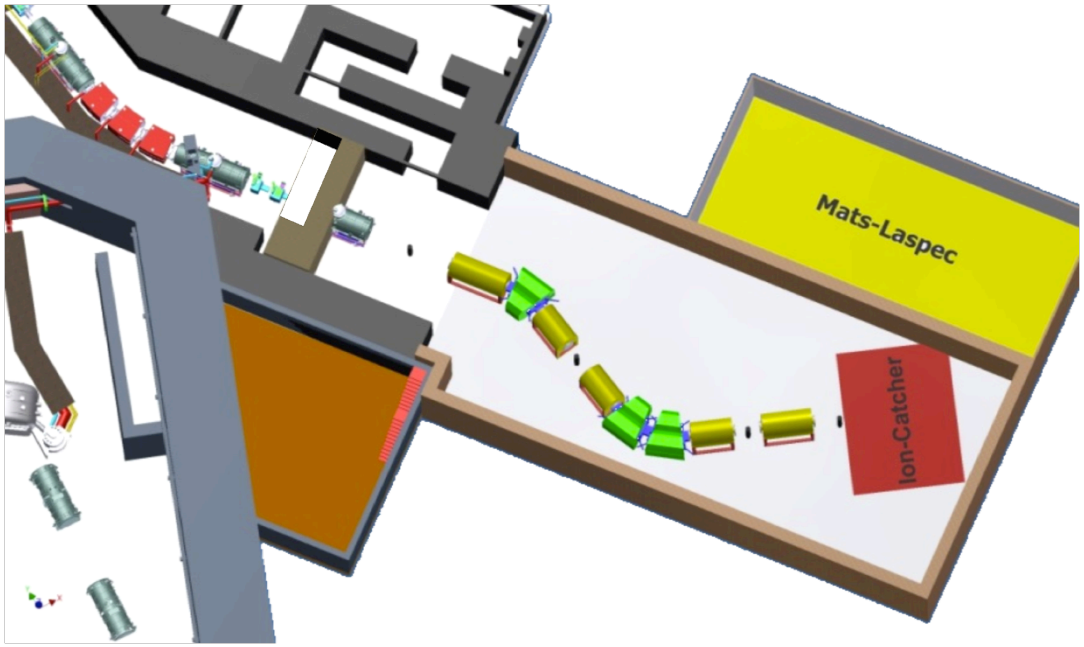
MATS and LaSpec
Precision experiments at low energy

Precise **M**easurements on **very short-lived** nuclei using an
Advanced **T**rapping **S**ystem

Laser **Spec**troscopy on **very short-lived** nuclei

in **NUSTAR**

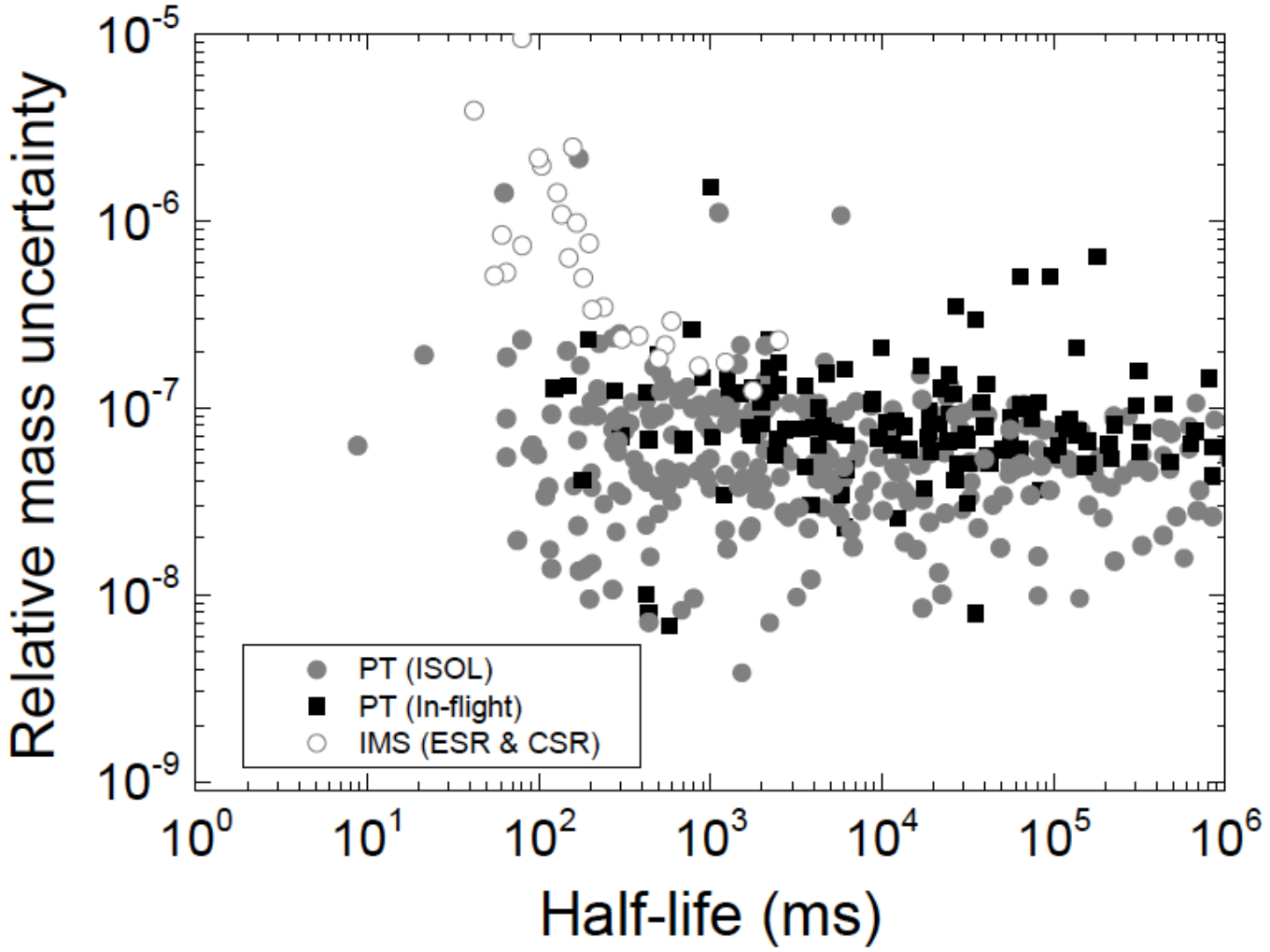


at the end of the **L**ow
Energy **B**ranch (LEB)
of the Super-FRS

Outline

- Physics motivation
- The collaborations and the facilities
- Staging at FAIR
- Developments with prospects for MATS and LaSpec
- Summary & outlook

Motivation for MATS at FAIR
Precise mass measurements on short-lived isotopes



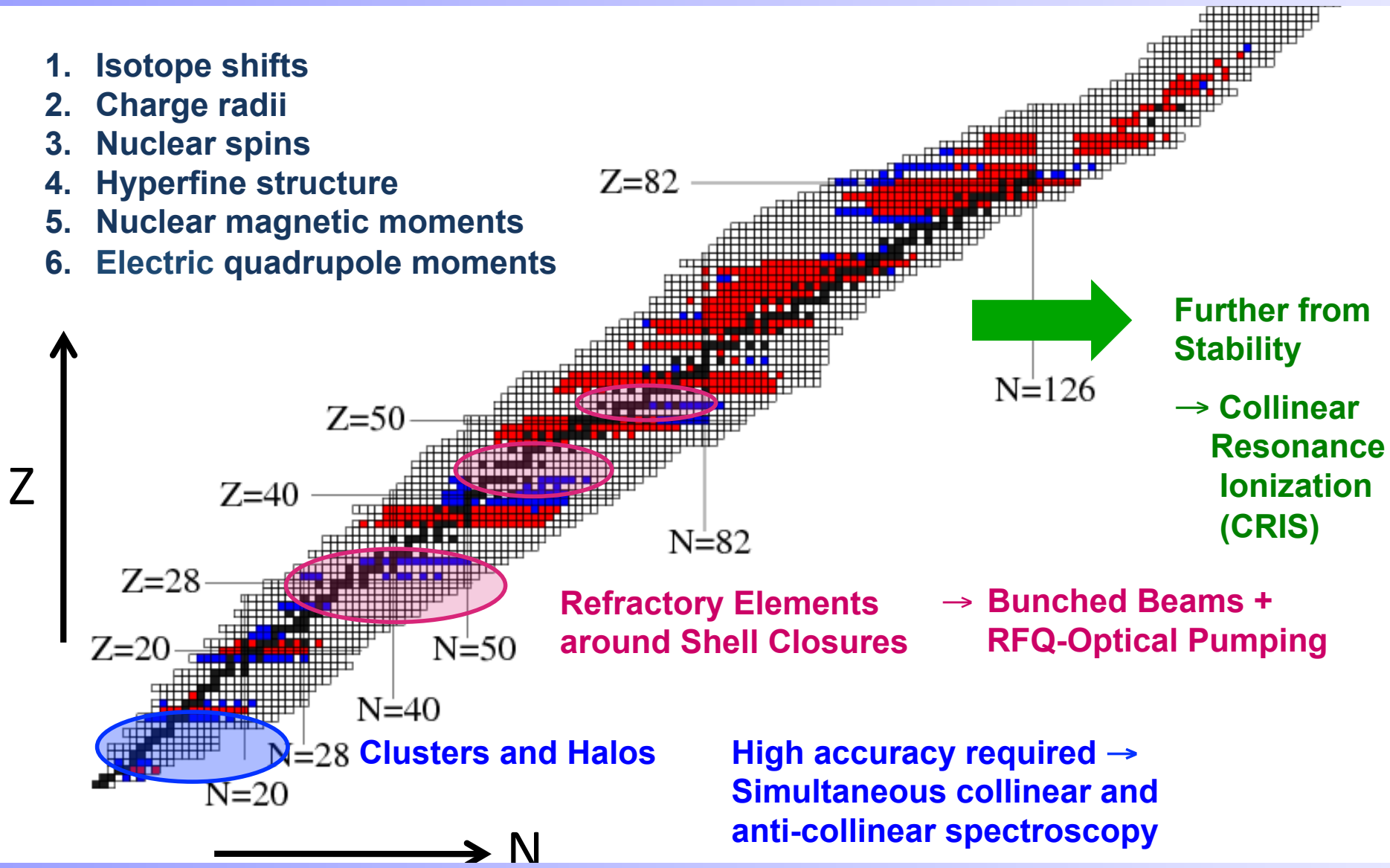
IJMS 349-350 (2013) 255

(talk by K. Blaum)

1. Nuclear structure
2. SHE
3. Halo nuclei
4. Astrophysics
5. Fundamental interactions
6. Neutrino physics
7. Discovery of new isotopes
8. In-trap decay spectroscopy
9. Trap-assisted spectroscopy
10. Spectroscopy on HCI
11. Laser-spec on HCI with LaSpec

Motivation for LaSpec at FAIR
Laser Spectroscopy on short-lived isotopes

1. Isotope shifts
2. Charge radii
3. Nuclear spins
4. Hyperfine structure
5. Nuclear magnetic moments
6. Electric quadrupole moments



Further from Stability

→ Collinear Resonance Ionization (CRIS)

Refractory Elements around Shell Closures → Bunched Beams + RFQ-Optical Pumping

Clusters and Halos

High accuracy required → Simultaneous collinear and anti-collinear spectroscopy

Motivation for MATS & LaSpec at FAIR

Complementarity of MATS & LaSpec with other facilities

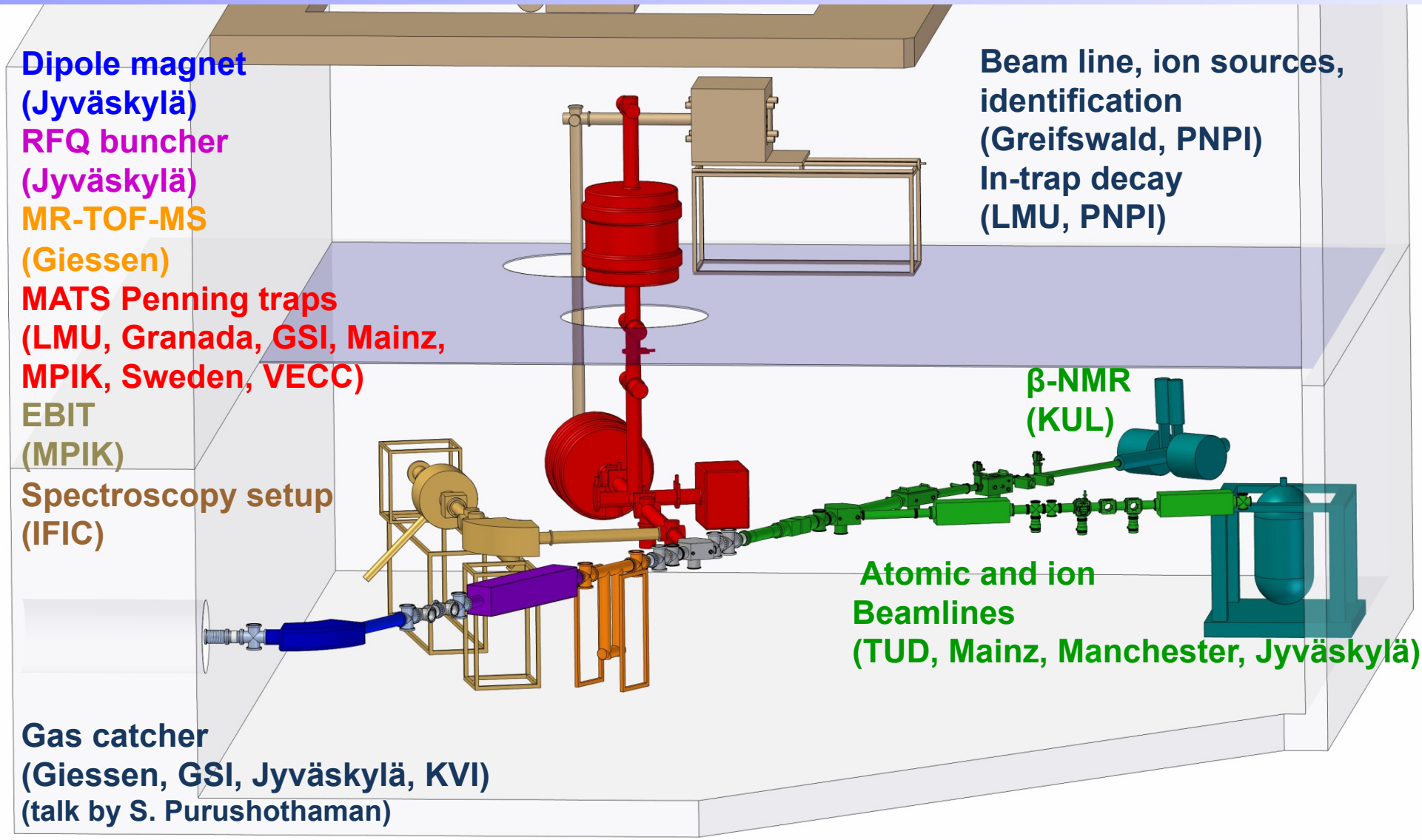
ISOL	Fusion	IGISOL	Neutron Induced fission	Spontaneous fission	Photo-induced fission	Fragmentation
ISOLTRAP COLLAPS (CERN)	SHIP TRAP Laser Spec (GSI)	JYFL TRAP Laser Spec (JYFL)	TRIGA-TRAP TRIGA-SPEC (Mainz)	CARIBU Laser Spec (ANL)	ALTO (Orsay)	LEBIT Laser Spec (MSU)
TITAN Laser Spec (TRIUMF)	CPT (ANL)					FRIB
MLLTRAP LUMIERE (SPIRAL2)						MATS LaSpec (FAIR)

The MATS and LaSpec collaborations
12 countries, 37 institutes, ~ 110 members

Belgium		Universite Bruxelles, KUL
Canada		TRIUMF
Finland		JYFL, UH
France		CSNSM-IN2P3, CNRS, CENBG, US
Germany		EMAU, FAIR, FAU, GSI, TUD, JGU, MPIK, JLU, LMU, PTB
Great Britain		UL, UM
India		VECC, RGC
Russia		PNPI, PSU
Spain		UHU, UGR, IFIC
Sweden		SU, UU
Switzerland		ISOLDE/CERN, PSI
USA		LLNL, MSU, LSU

http://www.fair-center.eu/for-users/experiments/nustar/experiments/mats.html
http://www.fair-center.eu/for-users/experiments/nustar/experiments/laspec.html

The MATS and LaSpec facilities
TDR approved in 2010



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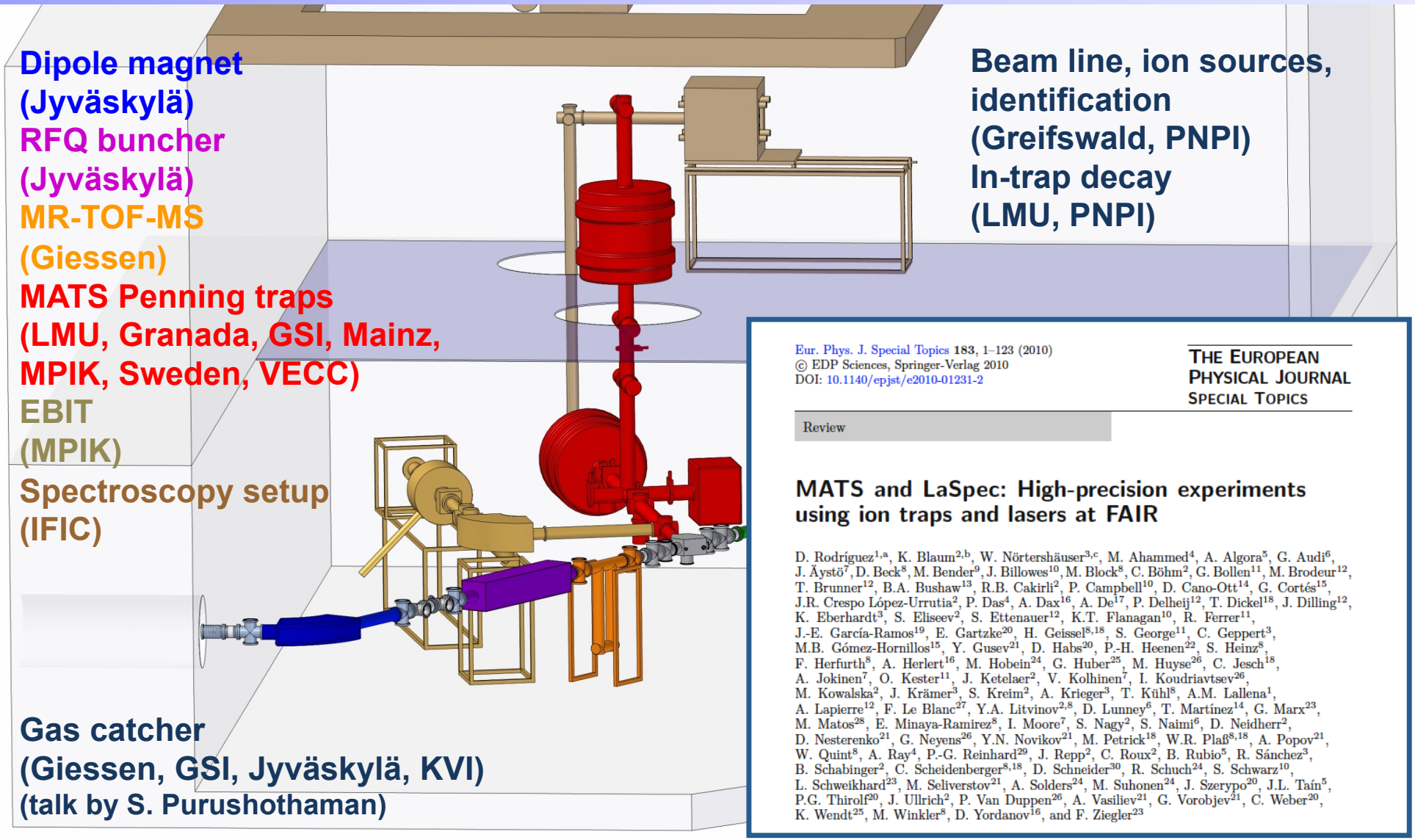

Dipole magnet (Jyväskylä)
RFQ buncher (Jyväskylä)
MR-TOF-MS (Giessen)
MATS Penning traps (LMU, Granada, GSI, Mainz, MPIK, Sweden, VECC)
EBIT (MPIK)
Spectroscopy setup (IFIC)

Beam line, ion sources, identification (Greifswald, PNPI)
In-trap decay (LMU, PNPI)

Gas catcher (Giessen, GSI, Jyväskylä, KVI)
(talk by S. Purushothaman)

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THE EUROPEAN PHYSICAL JOURNAL SPECIAL TOPICS

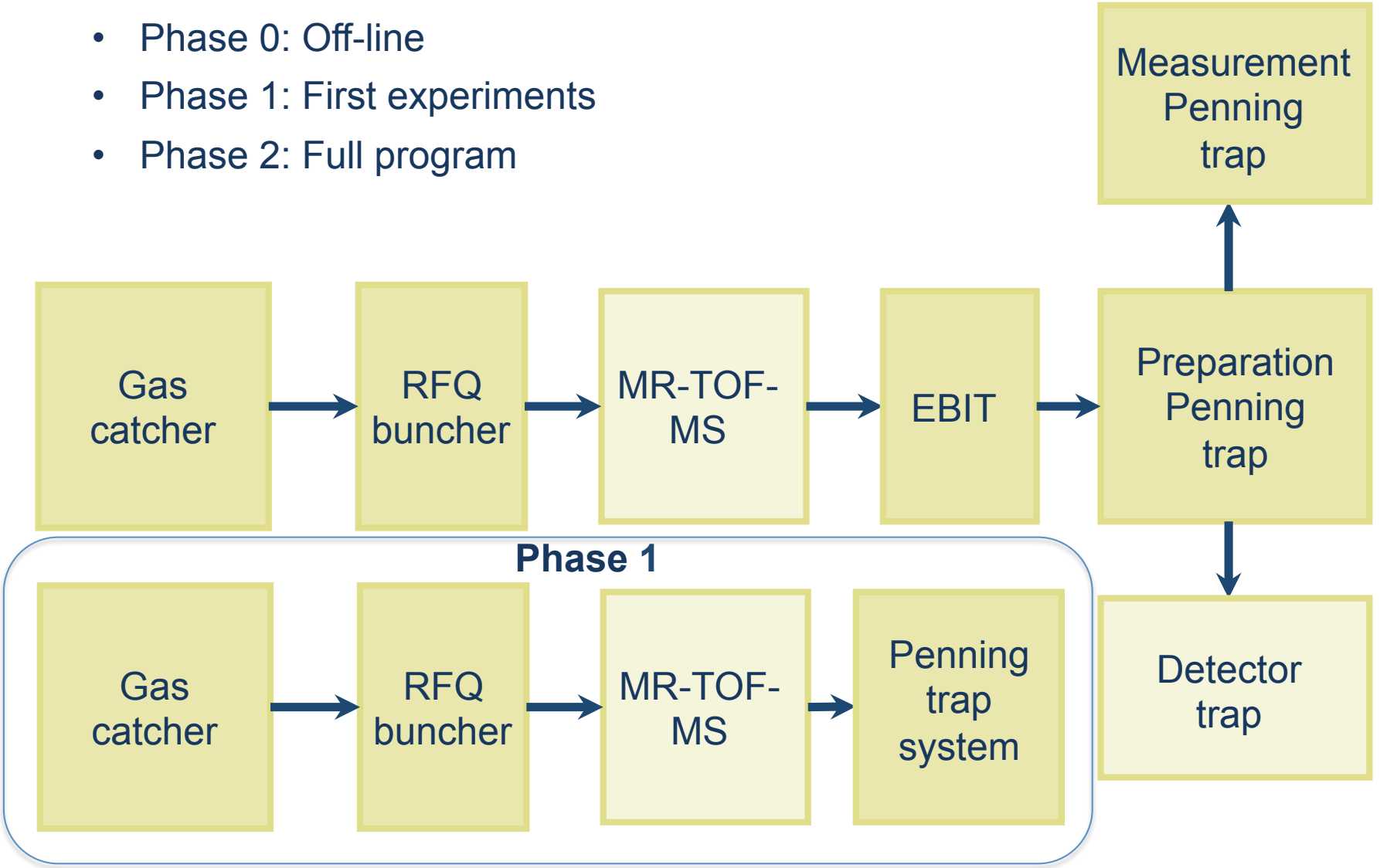
Review

MATS and LaSpec: High-precision experiments using ion traps and lasers at FAIR

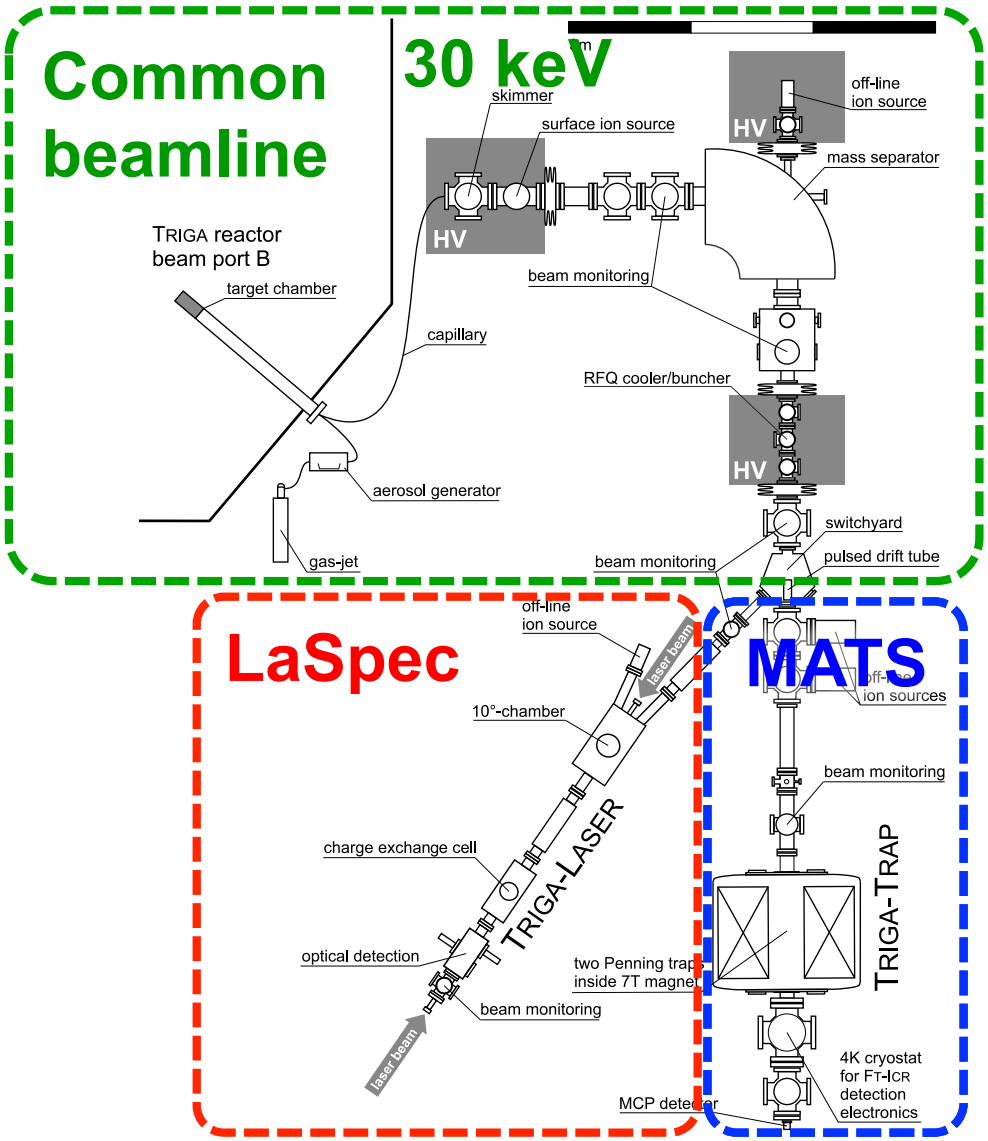
D. Rodríguez[1,a], K. Blaum[2,b], W. Nörtershäuser[3,c], M. Ahammed[4], A. Algora[5], G. Audi[6], J. Äystö[7], D. Beck[8], M. Bender[9], J. Billowes[10], M. Block[8], C. Böhm[2], G. Bollen[11], M. Brodeur[12], T. Brunner[12], B.A. Bushaw[13], R.B. Cakirli[2], P. Campbell[10], D. Cano-Ott[14], G. Cortés[15], J.R. Crespo López-Urrutia[2], P. Das[4], A. Dax[16], A. De[17], P. Delheij[12], T. Dickel[18], J. Dilling[12], K. Eberhardt[3], S. Eliseev[2], S. Ettenauer[12], K.T. Flanagan[10], R. Ferrer[11], J.-E. García-Ramos[19], E. Gartzke[20], H. Geissel[8,18], S. George[11], C. Geppert[3], M.B. Gómez-Hornillos[15], Y. Gusev[21], D. Habs[20], P.-H. Heenen[22], S. Heinz[8], F. Herfurth[8], A. Herlert[16], M. Hobein[24], G. Huber[25], M. Huyse[26], C. Jesch[18], A. Jokinen[7], O. Kester[11], J. Ketelaer[2], V. Kolhinen[7], I. Koudriavtsev[26], M. Kowalska[2], J. Krämer[3], S. Kreim[2], A. Krieger[3], T. Kühl[8], A.M. Lallena[1], A. Lapierre[12], F. Le Blanc[27], Y.A. Litvinov[2,8], D. Lunney[6], T. Martínez[14], G. Marx[23], M. Matos[28], E. Minaya-Ramirez[8], I. Moore[7], S. Nagy[2], S. Naimi[6], D. Neidherr[2], D. Nesterenko[21], G. Neyens[26], Y.N. Novikov[21], M. Petrick[18], W.R. Plaß[8,18], A. Popov[21], W. Quint[8], A. Ray[4], P.-G. Reinhard[29], J. Repp[2], C. Roux[2], B. Rubio[5], R. Sánchez[3], B. Schabinger[2], C. Scheidenberger[8,18], D. Schneider[30], R. Schuch[24], S. Schwarz[10], L. Schweikhard[23], M. Seliverstov[21], A. Solders[24], M. Suhonen[24], J. Szerypo[20], J.L. Taín[5], P.G. Thirolf[20], J. Ullrich[2], P. Van Duppen[26], A. Vasiliev[21], G. Vorobjev[21], C. Weber[20], K. Wendt[25], M. Winkler[8], D. Yordanov[16], and F. Ziegler[23]

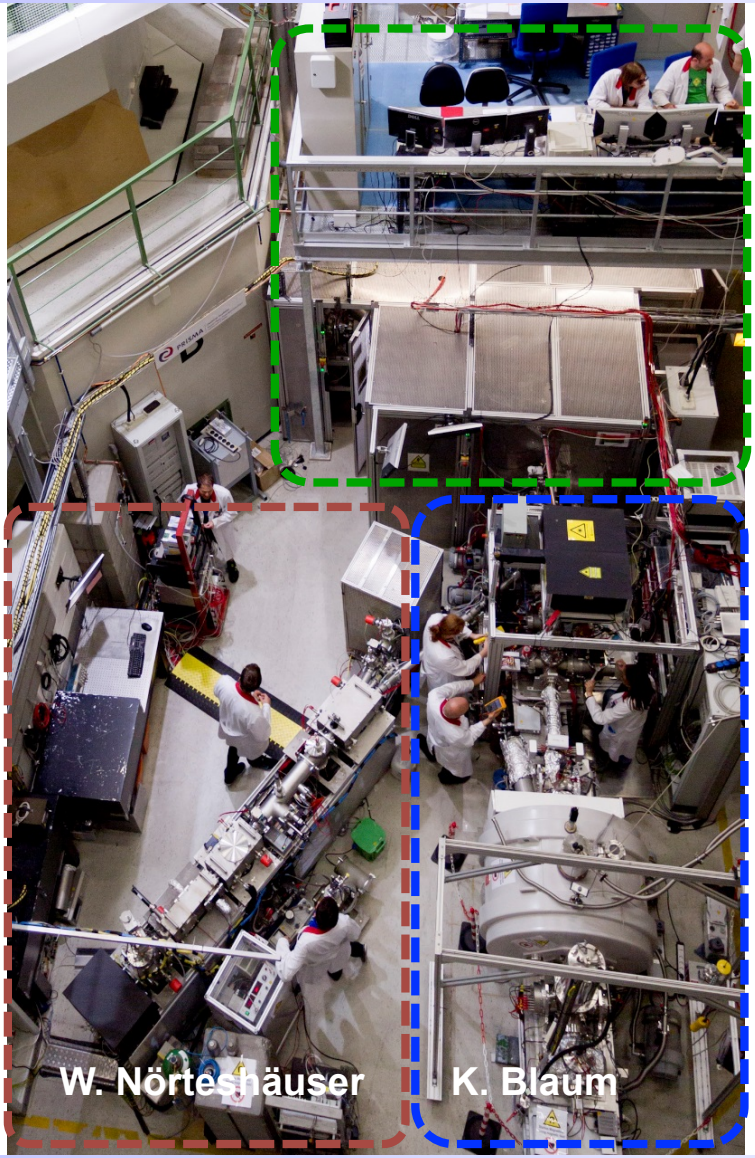
Staging at FAIR
Phases 1 & 2

- Phase 0: Off-line
- Phase 1: First experiments
- Phase 2: Full program

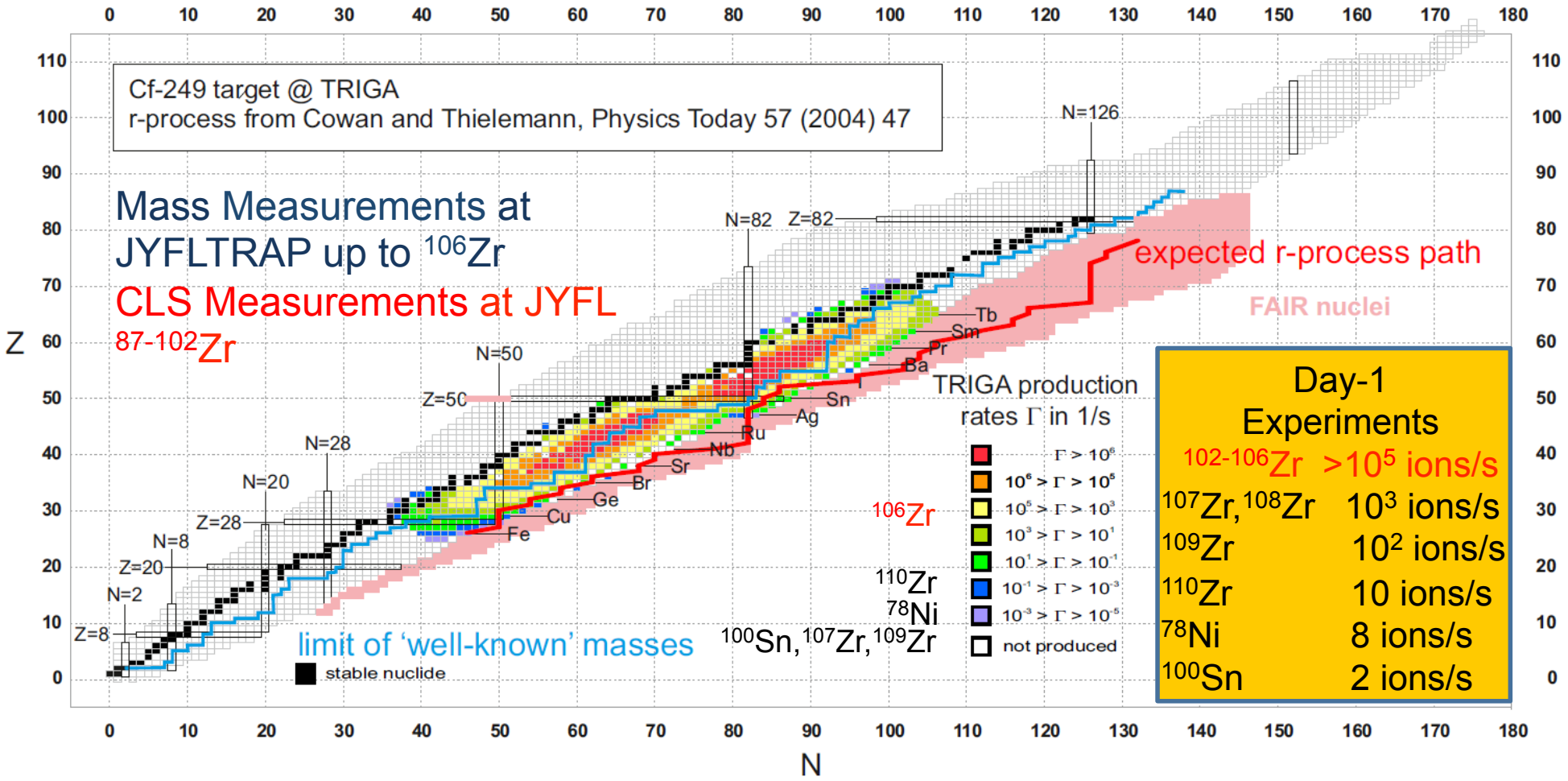


Developments with prospects for MATS & LaSpec
Phase 0 @ TRIGA





First experiments with MATS & LaSpec at FAIR
Phase 0 → Phase 1



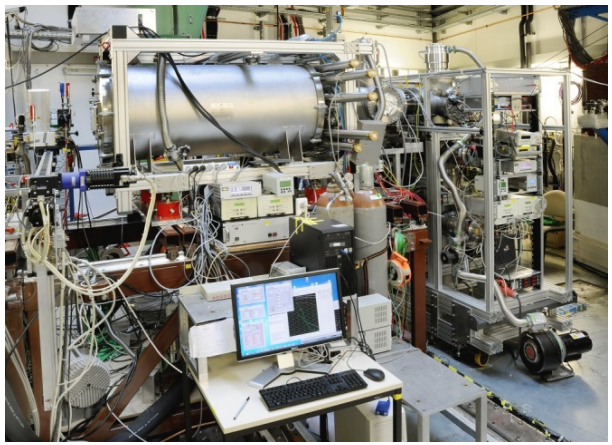
- The accessibility will depend on the performance of the Super-FRS and the ion-gas catcher (TDR of the ion catcher in preparation)

Requirements to run MATS & LaSpec at FAIR
Phases 1 & 2

I. The ion-gas catcher and MR-TOF device (Phase 1)

- On-line test with ^{238}U projectile fragments produced at 1 GeV/u at the FRS in October 2011 and July/August 2012.
- Another beamtime takes place at present at GSI.

Giessen, GSI **(FRS)**, Jyväskylä, KVI
W.R. Plass *et al.*, NIMB, 317 (2013) 457



(talk by S. Purushothaman)

II. Other Penning traps and detection techniques (Phase 2)

- Faster measurements (PI-ICR)

  MPIK, GSI **(SHIPTRAP)**, Greifswald, PNPI

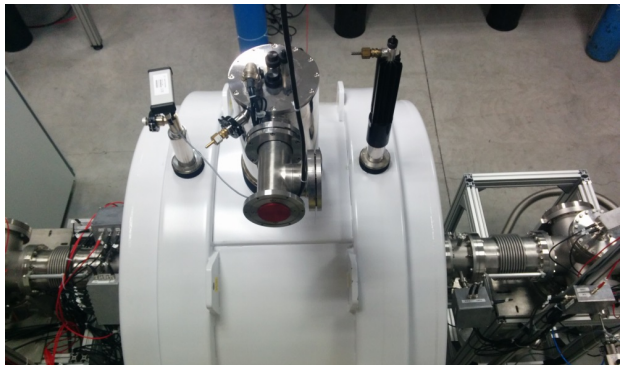
- Developments for beam preparation, new traps and single-ion detection

  Jyväskylä **(JYFLTRAP),** GSI **(SHIPTRAP)**, Granada **(TRAPSENSOR),** MPIK

- Construction of a trap comprised of detectors

  LMU **(MLL-TRAP)**

- New funding applications (VECC)



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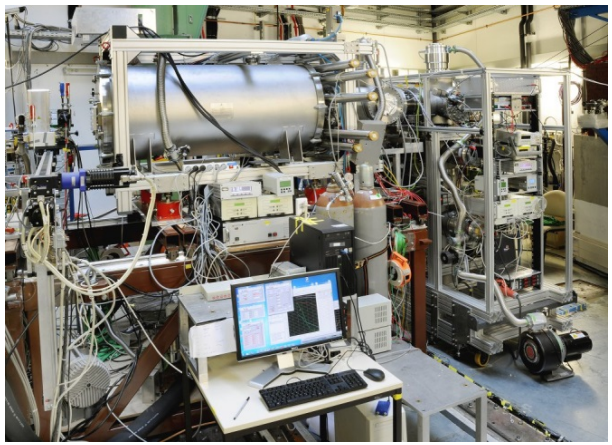

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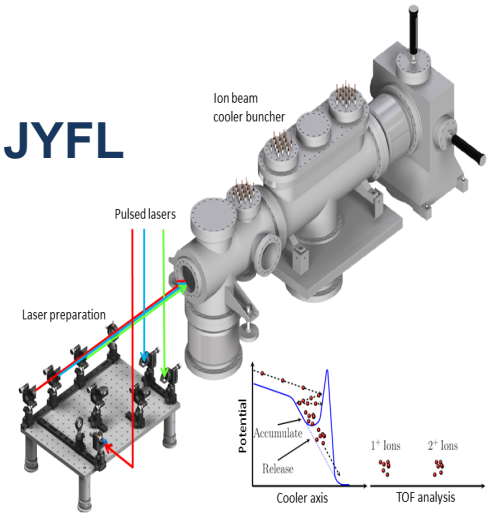
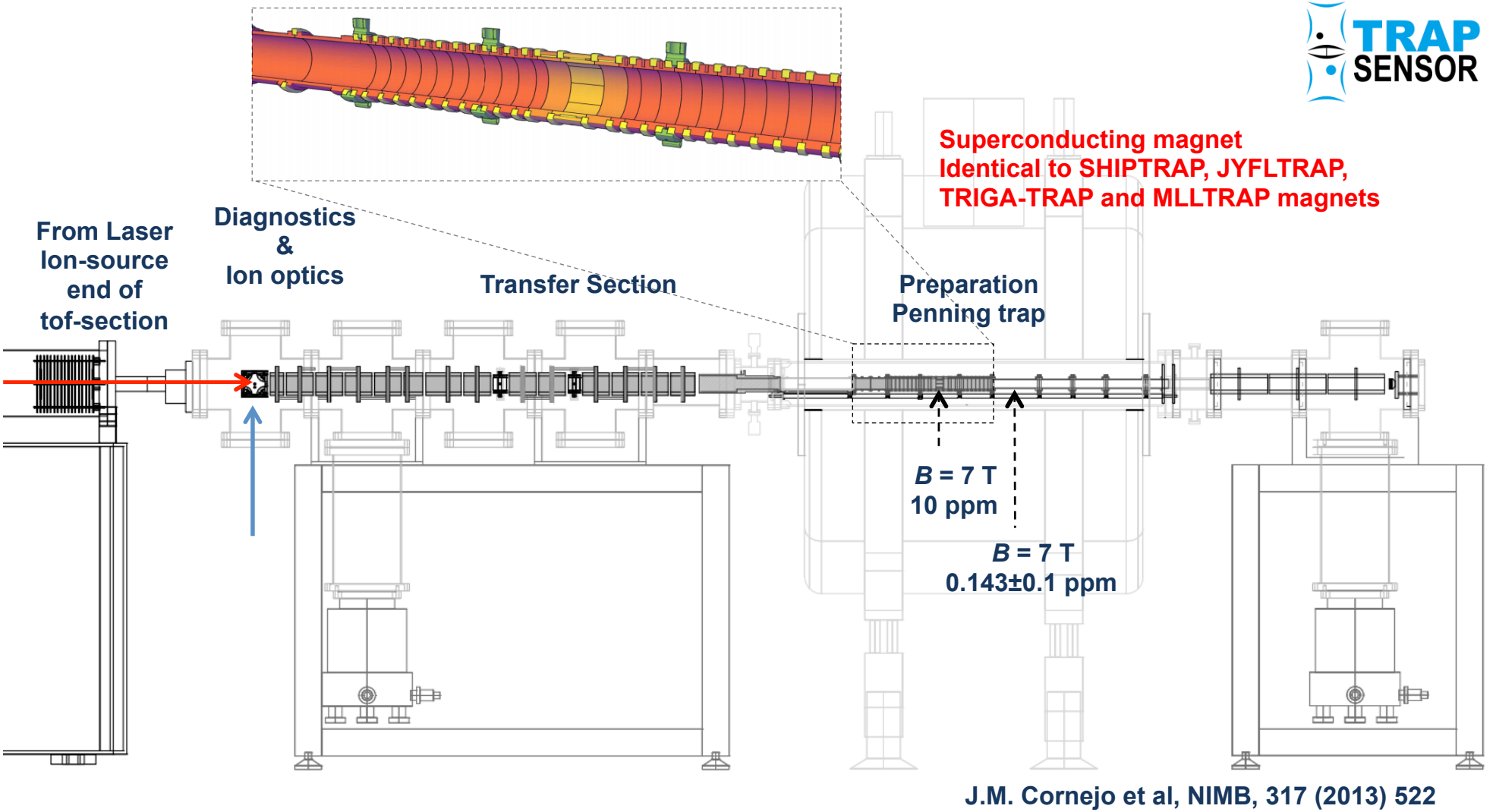
JYFL



III. Laser spectroscopy on highly charged ions (Phase 2)

- Laser spectroscopy on doubly-charged ions Jyväskylä

Requirements to run MATS & LaSpec at FAIR
Phases 1 & 2



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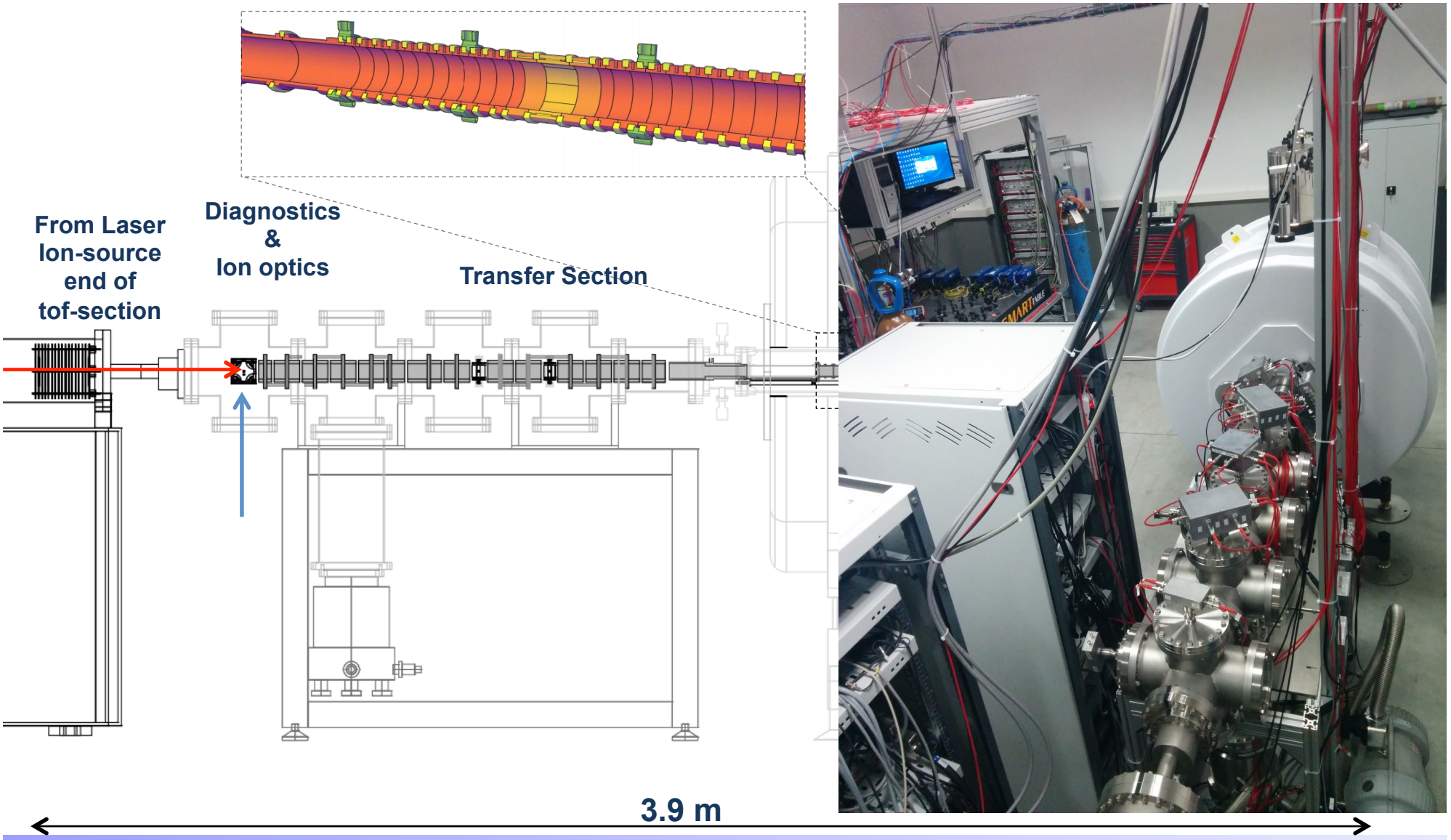
Phases 1 & 2



Summary & Outlook

- MATS and LaSpec will use the high production yields at FAIR to extend precision experiments to very exotic nuclei.
- The TDR was approved in 2010 and the two facilities will be built in two stages.
- The prototypes to run first at FAIR (TRIGA-SPEC and TRIGA-TRAP), are currently in operation at the TRIGA reactor in Mainz.
- Mass measurements on transuranium isotopes and collinear-laser spectroscopy measurements on stable Ca^{+} ions have been performed.
- The results show that the systems meet the requirements to perform first experiments during phase 1 at FAIR, provided the Super-FRS and the ion catcher are in operation.
- Further developments are on-going at several universities and laboratories to reach the full capability of MATS and LaSpec: MLL-TRAP, SHIPTRAP, MPIK, JYFL, T.U. Darmstadt, Manchester, JYFLTRAP, TRAPSENSOR, PNPI, U. Giessen, U. Greifswald, VECC,…

Thank you very much for your attention!!

- **Thank you very much to the MATS and LaSpec collaborators who made most of the work I have presented here as well as those, whose work was not presented, for their understanding.**
- **Picture from the LaSpec-MATS collaboration meeting in Matalascañas (Spain) October 2008 (Decision on the contents of the TDR) FAIR newsletter no. 11**