Shell evolution towards the neutron drip line
A08 Plan

TECHNISCHE UNIVERSITÄT DARMSTADT

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SFB workshop, TU Darmstadt
March 27th, 2019

Neutron-to-proton asymmetry in nuclei: a degree of freedom to explore

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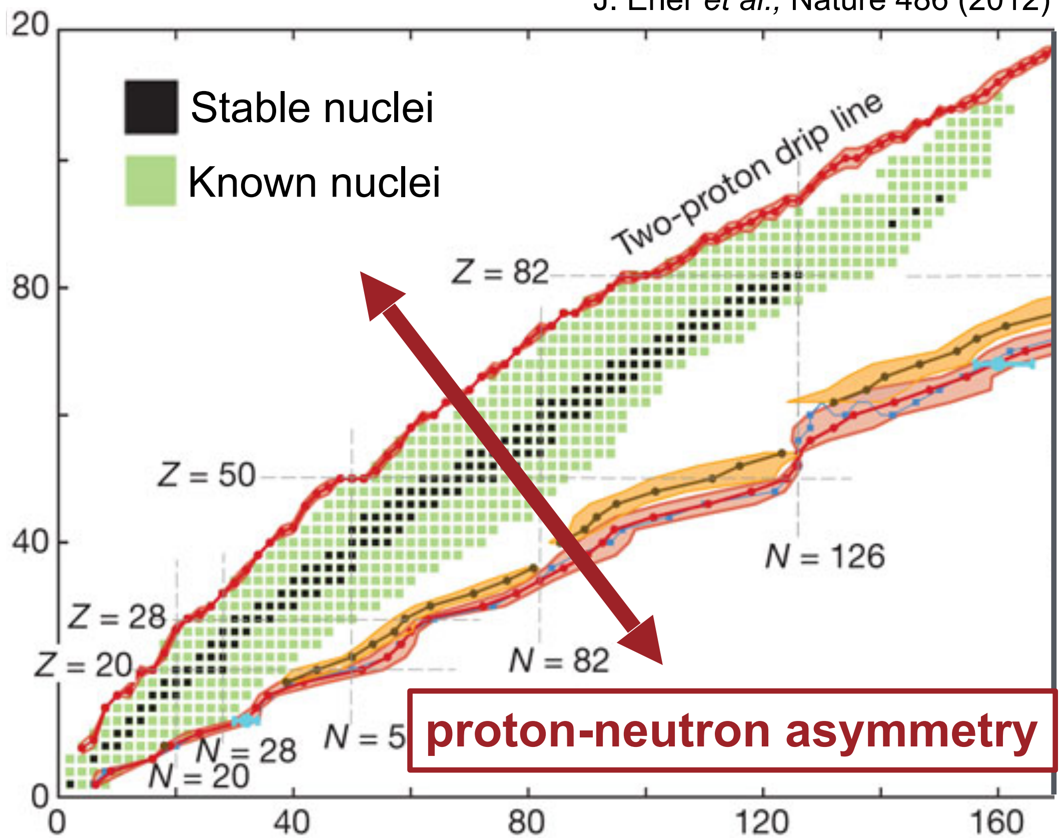
J. Erler *et al.*, Nature 486 (2012)



- Shell structure evolves with N,Z

Examples: new shell closures, island of inversions

- Single particle orbitals
- Correlations

- Neutron-rich = low intensities

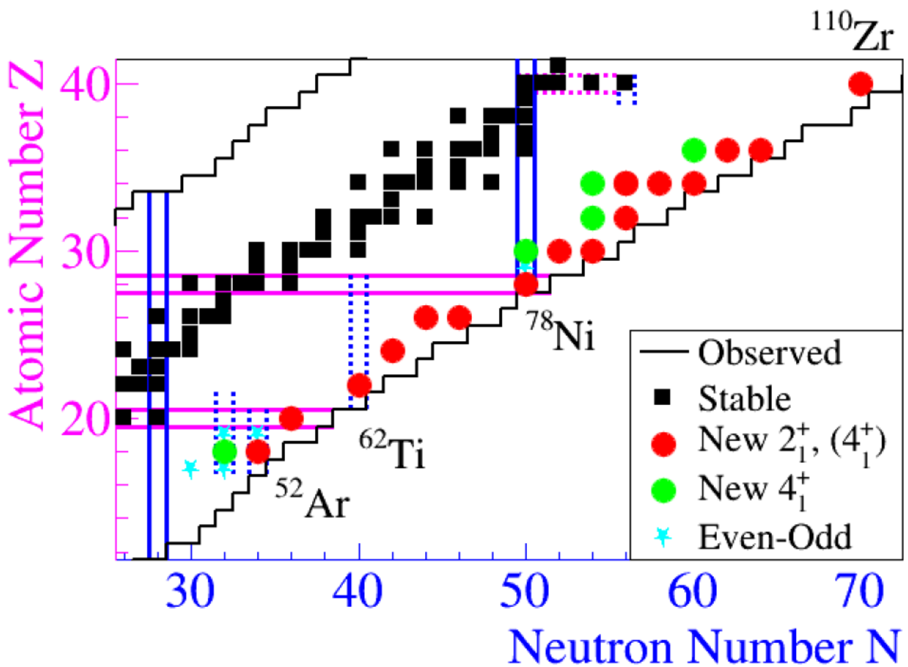
- *Observables:*

Masses, spectroscopy, charge radii…

Spectroscopy at the RIBF, RIKEN

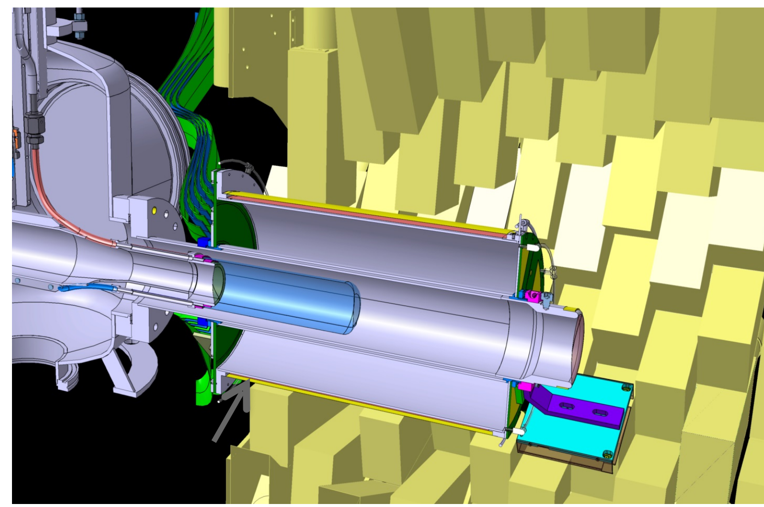
RIBF : >100 more intensities than anywhere else
Opened new opportunities in the recent years

- RIBF in operation since 2007
- Heavy-ions accelerated up to 345 MeV/nucleon



SEASTAR: spectroscopy program at RIKEN (data taking: 2014-2017)

- MINOS + DALI2
- High luminosity (100-150 mm target)
- high efficiency: 30% at 1 MeV
- **low energy resolution**: 10% (sigma) at 1 MeV
- gamma spectroscopy **ONLY**



Objectives of A08

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1) First physics cases: low-lying 0^+ states at N=20, 28
   Planned investigations for heavier systems (N=40, ^{78}Ni, ^{110}Zr regions)

2) Build a new device STRASSE (based on the MINOS concept)
   for particle AND gamma spectroscopy

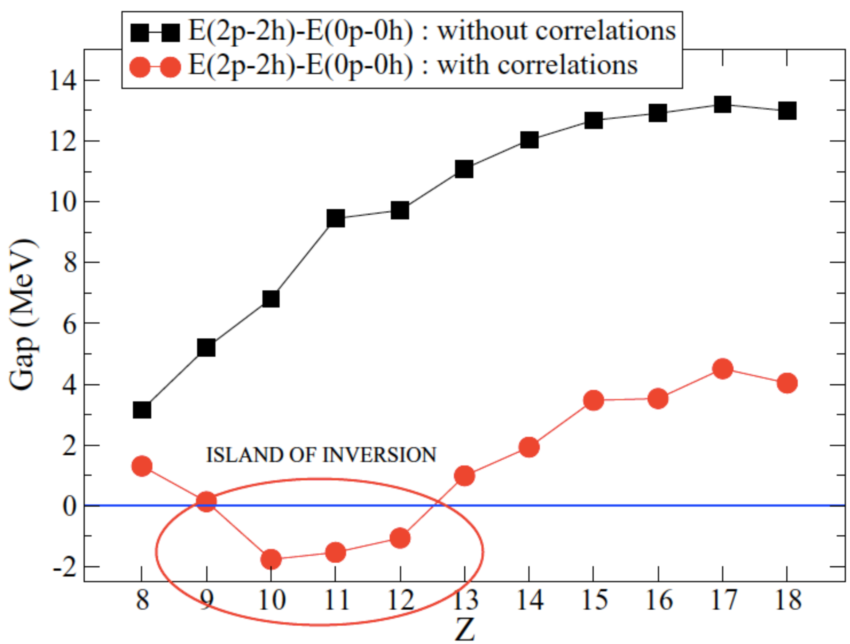
3) Proof of concept for high resolution (tracking Ge array) with vertex tracker

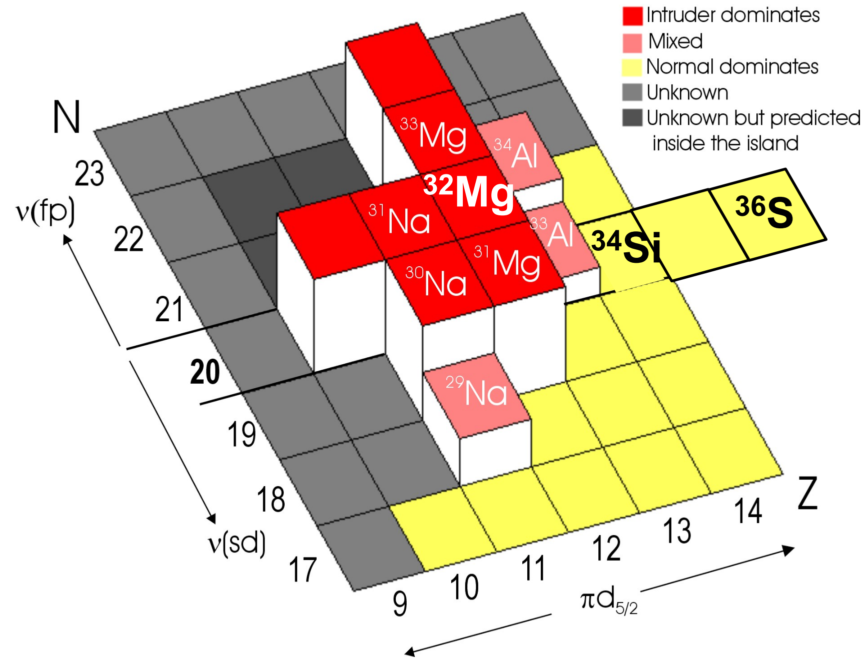
Island of Inversion

- **Island of Inversion**: Due to quadrupole deformation, the « intruder » configuration (np-nh) is energetically favored relative to the « normal » configuration.

  X. Campi et al., NPA 251, 193 (1975); A. Poves, J. Retamosa, PLB 184, 311 (1987); W. Warburton et al., PRC 41, 1147 (1990).

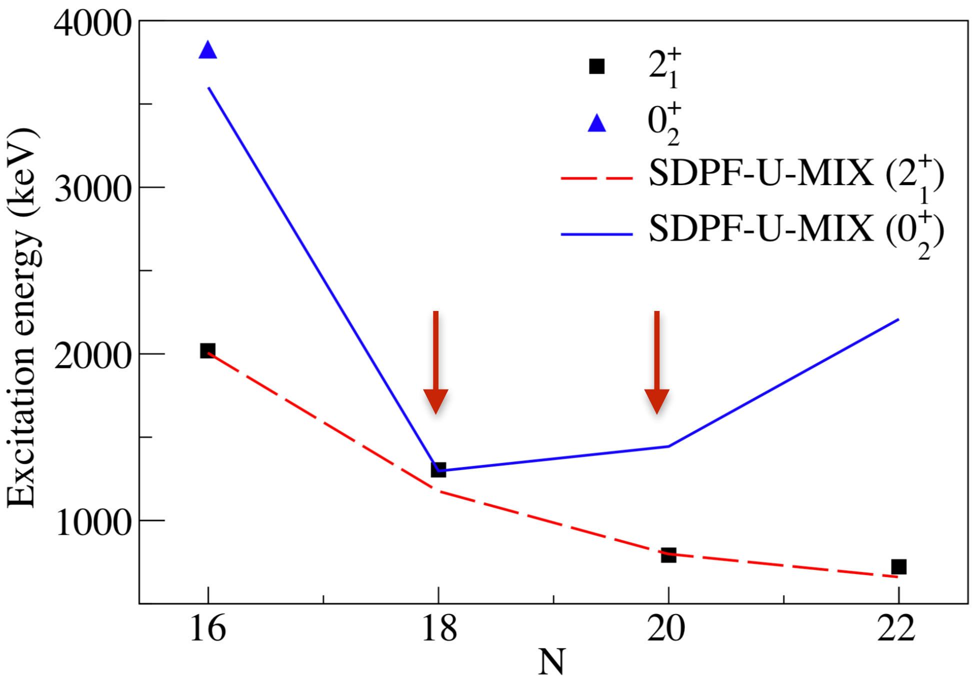
- **Key observable**: low lying 0+ states

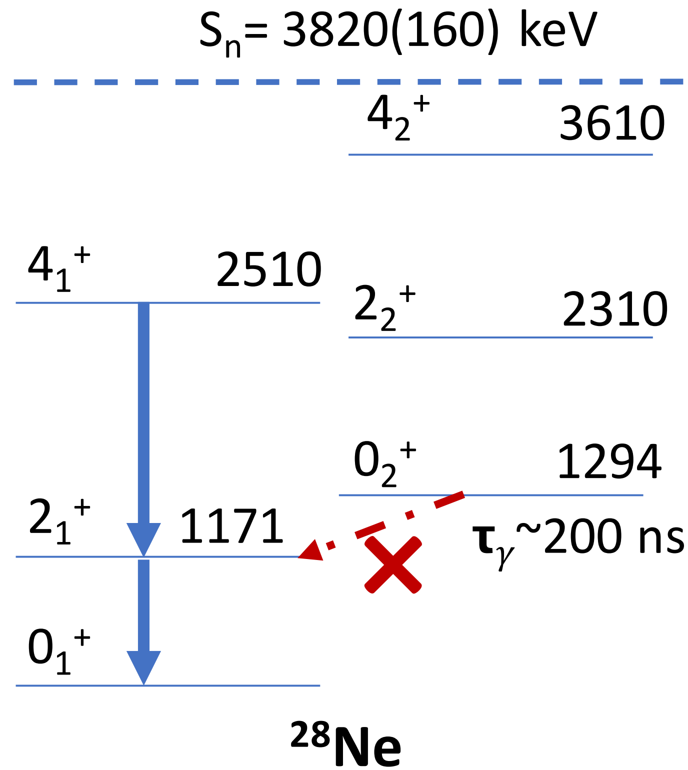




Low lying 0^+ states in Ne

SDPF-U-MIX calculation: A. Poves & F. Nowacki



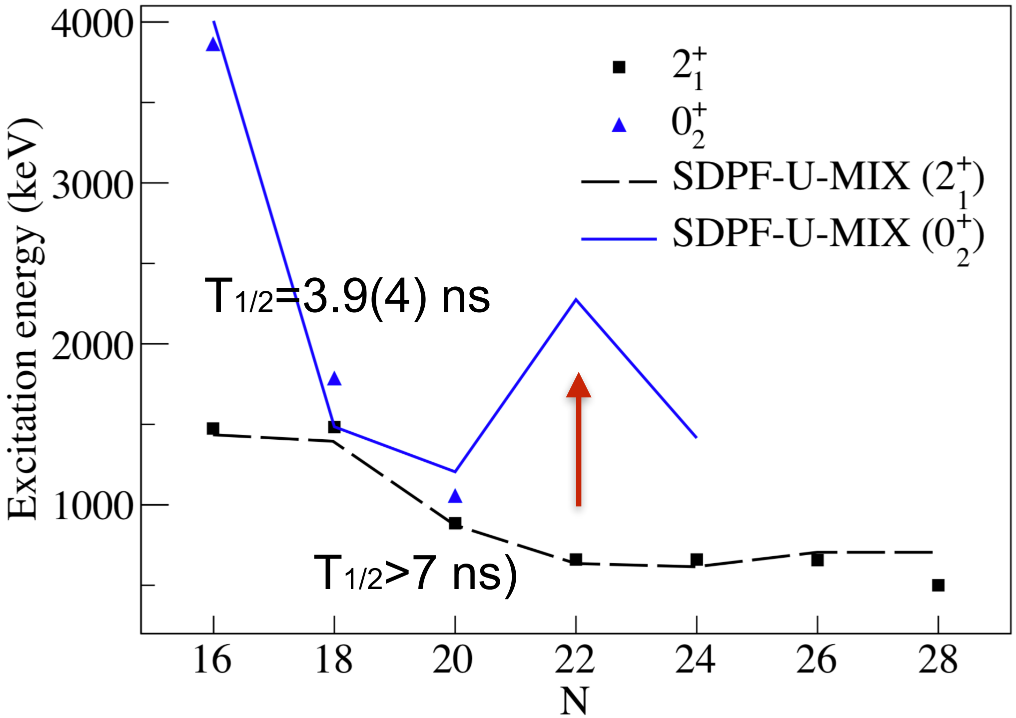


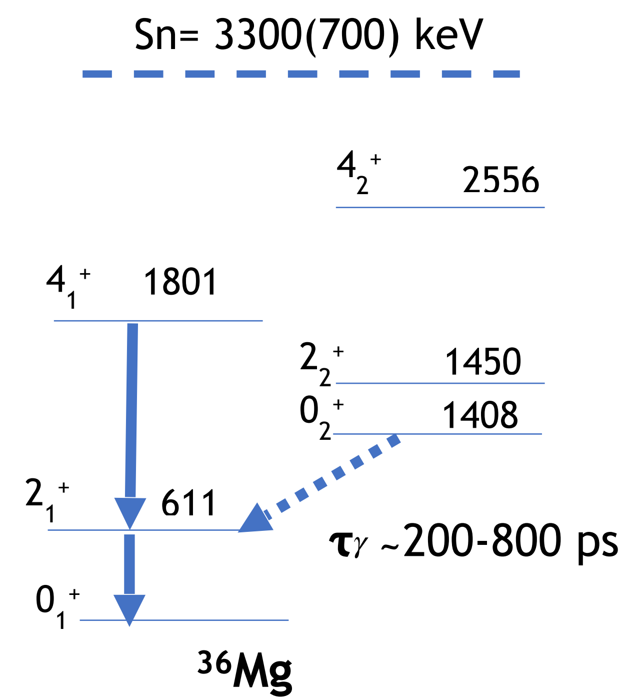
- Beam intensities (LISE++):

^{29}Na(p,2p)^{28}Ne: 100 kpps, ^{31}Na(p,2p)^{30}Ne: 10 kpps, ^{33}Na(p,2p)^{32}Ne 100 pps

Low lying 0⁺ states in Mg isotopes

SDPF-U-MIX calculation: A. Poves & F. Nowacki

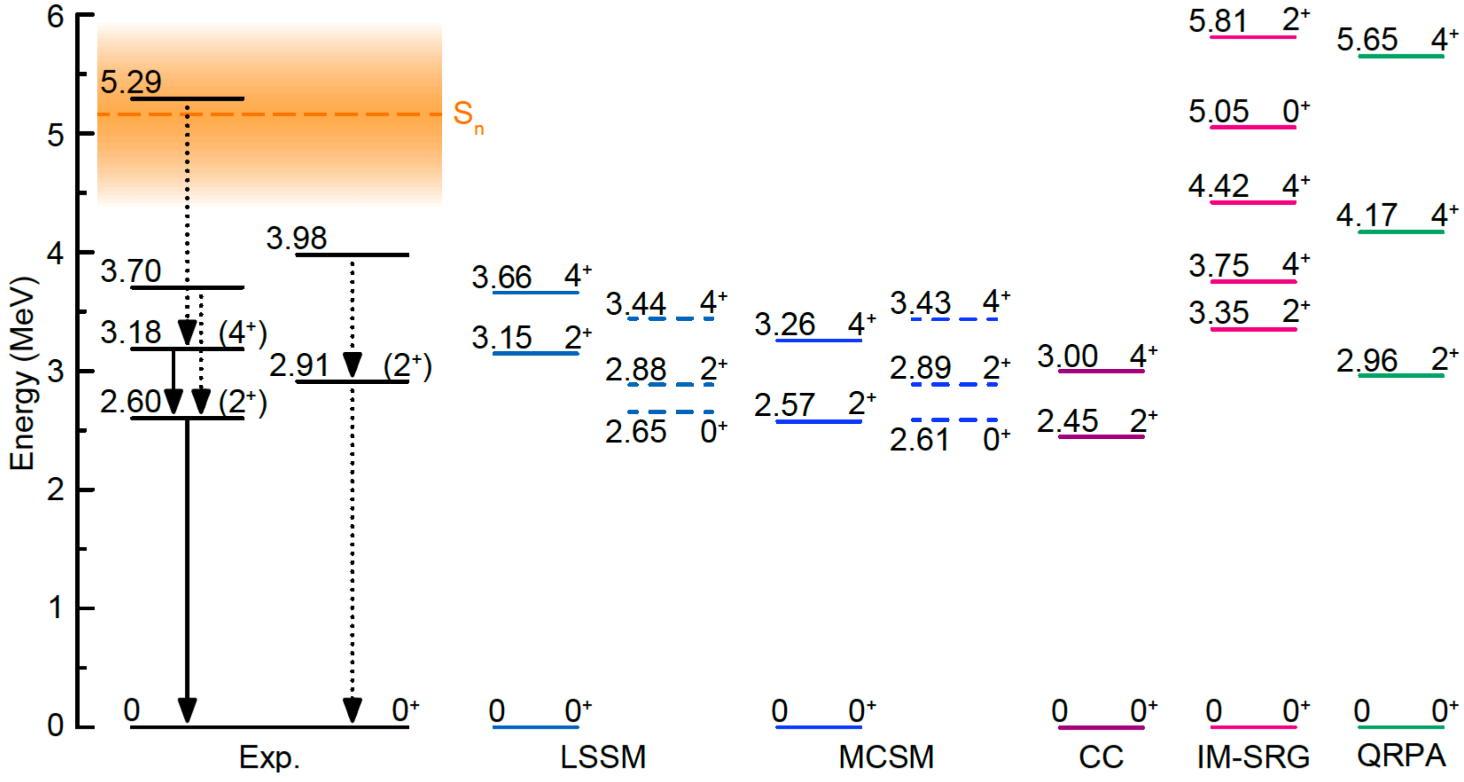




W. Schwerdtfeger et al., PRL 103, 012501 (2009)
K. Wimmer et al., PRL105, 252501 (2010)

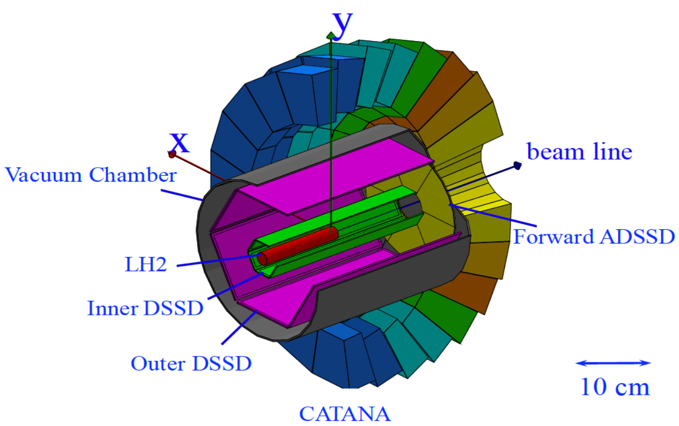
- Beam intensities (LISE++): ^{35}Al(p,2p)^{34}Mg: 100 kpps, ^{37}Al(p,2p)^{36}Mg: 5 kpps

Possibilities for heavier systems (N=40, ^{78}Ni, ^{110}Zr regions)



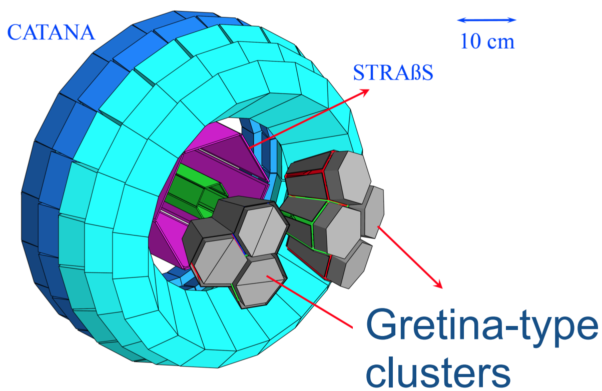
R. Taniuchi et al., Accepted in Nature

STRASSE concept



Coupled with CsI(Na) detector array (CATANA) for detection of total energy of protons

Vertex resolution: 0.8 mm (FWHM) [**MINOS: 4.5 mm**]
Missing mass resolution : **1.4 MeV** (sigma) [**New**]



Vertex efficiency: 80%
Photopeak efficiency with 2 **tracking** clusters: 2%
E resolution: ΔE_{γ}=**0.6%** (FWHM) with thick target [**New**]

STRASSE Status

General design:
TU Darmstadt, TiTech, RIKEN

Detectors: **two options available** (1) DSSD Micron, (2) SSD Hamamatsu
Quotes available or on the way

Electronics: **option CBM readout**, **under consideration**
XYTER chip and readout for the CBM silicon tracker (GSI / Poland development)
contacts taken with J. Lehnert and C. Schmidt (**GSI)** / **Meeting in April 2019**

PCB adaptation and connections: **collaboration agreed**, **not started**
collaboration with **TUM** (Roman Gernhäuser) and **TiTech**

Mechanics and cooling system: **not started**
TU Darmstadt

Prototype tests, assembly: **not started**
TU Darmstadt

Today, the timeline is not fixed yet due to uncertainties on the electronics
LH2 target: TU Darmstadt (**starting now**)

STRASSE Agenda

1) Collaboration with TiTech (Nakamura) and RIKEN (Uesaka)

2) **Construction proposal** submitted to RIBF PAC committee in Dec. 2018
Positive letter from the PAC committee

3) Prototype **experiment accepted**: ^{11}Li(p,2p)^{10}He
Spokesperson: Nakamura, PhD: Tomai-san

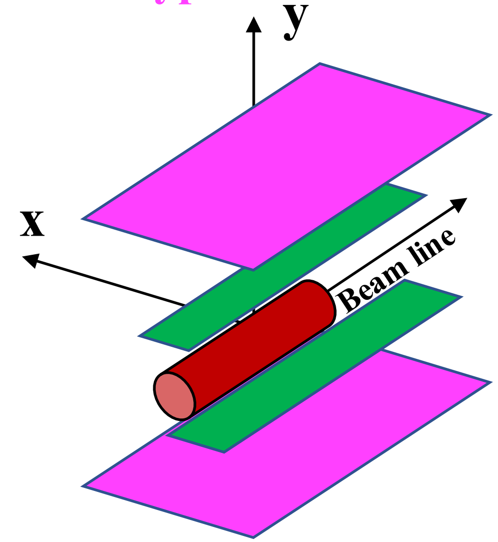
Agenda for STRASSE
Proposals to RIBF PAC in December 2019

January 2020: “Prototype” ready

March 2020: Prototype experiment

March 2021: STRASSE ready

September 2021: LH2 target operational in RIKEN



Foreseen physics cases

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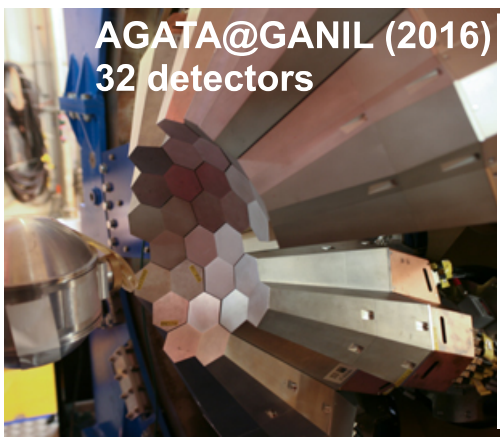
In the **Pre-proposal** as key experiments:
- excited 0^+ states in neutron-rich Ne, Mg isotopes
- excited 0^+ state in ^{42}Si and neighbouring nuclei (***recently done at the NSCL?***)

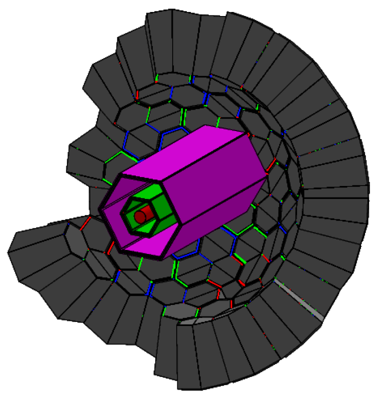
To be investigated further:
- excited 0^+ states in N=40 (Fe, Cr), N=50 (^{78}Ni), Z=40 (^{110}Zr) **[proposal]**

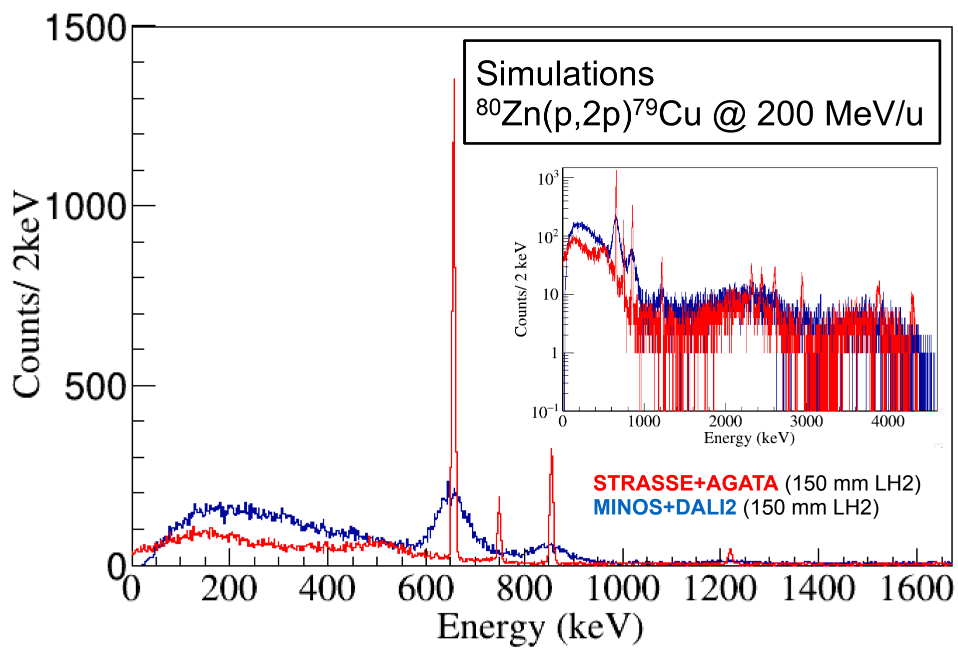
- Low-statistics (10 counts) spectroscopy **?**
- Masses of very-short lived / unbound nuclei from missing mass **?**
  (precision of 100 - 800 keV)

Proof of concept
Spectroscopy with tracking detectors

- **Ge** tracking arrays open new opportunities
- High intrinsic resolution (0.2%) and high « granularity » (< 5 mm FWHM, pulse shape)
- Fast beams: exciting future with GRETA at FRIB (>2021) and with **AGATA** at FAIR (>2025)







Summary of A08

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1) Build a new device called STRASSE for particle AND gamma spectroscopy

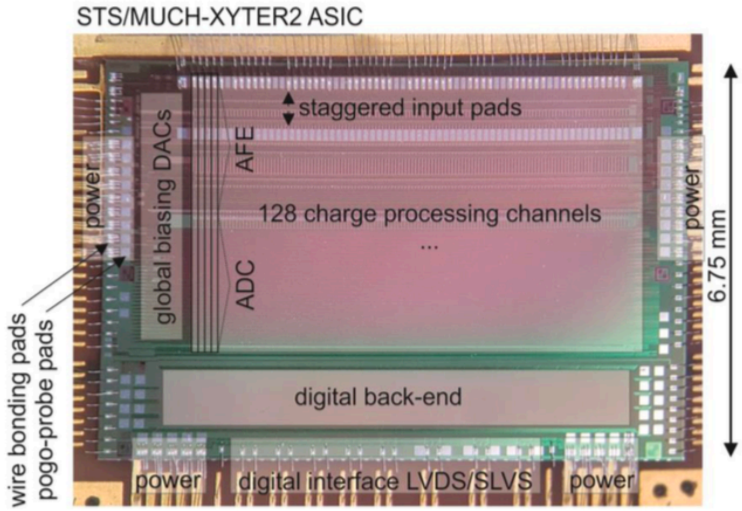
2) Accepted prototype experiment $^{11}Li(p,2p)^{10}He$, planned in spring 2020

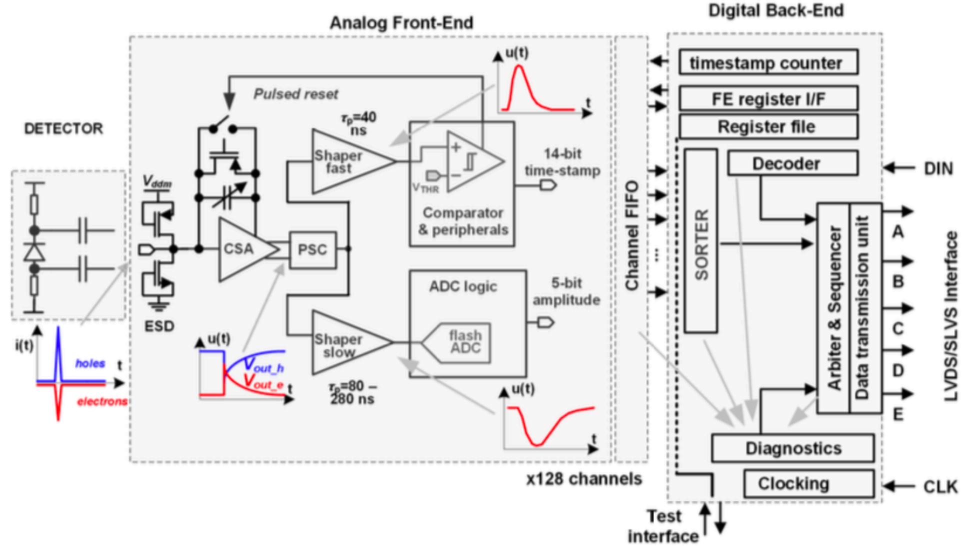
3) Foreseen physics cases:
   i. excited 0^+ states in neutron-rich nuclei around N=20, 28
   ii. excited 0+ states in N=40 isotones (Cf, Fe), N=50 (^{78}Ni), Z=40 (^{110}Zr)
   iii. low-statistics (10 counts) spectroscopy ?
   iv. masses from missing mass measurements (precision of 100 - 800 keV) ?

4) Proof of concept for high resolution (tracking array) with vertex tracker

Backup

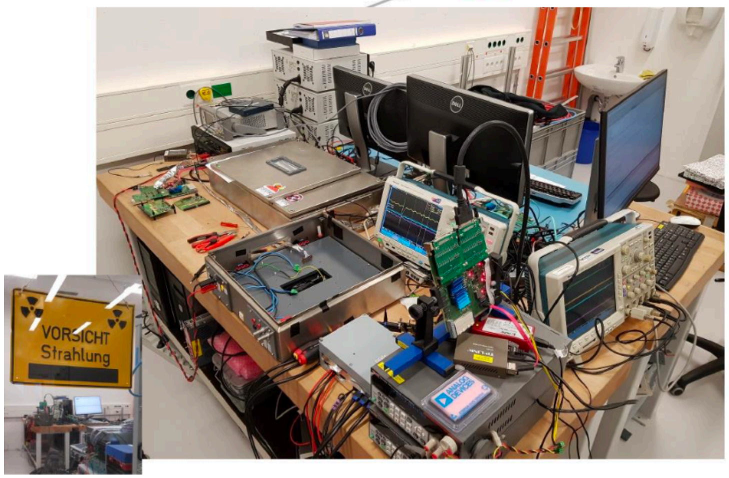
XYTER Chips

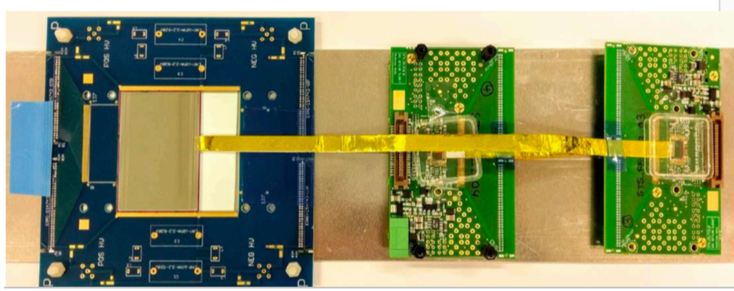




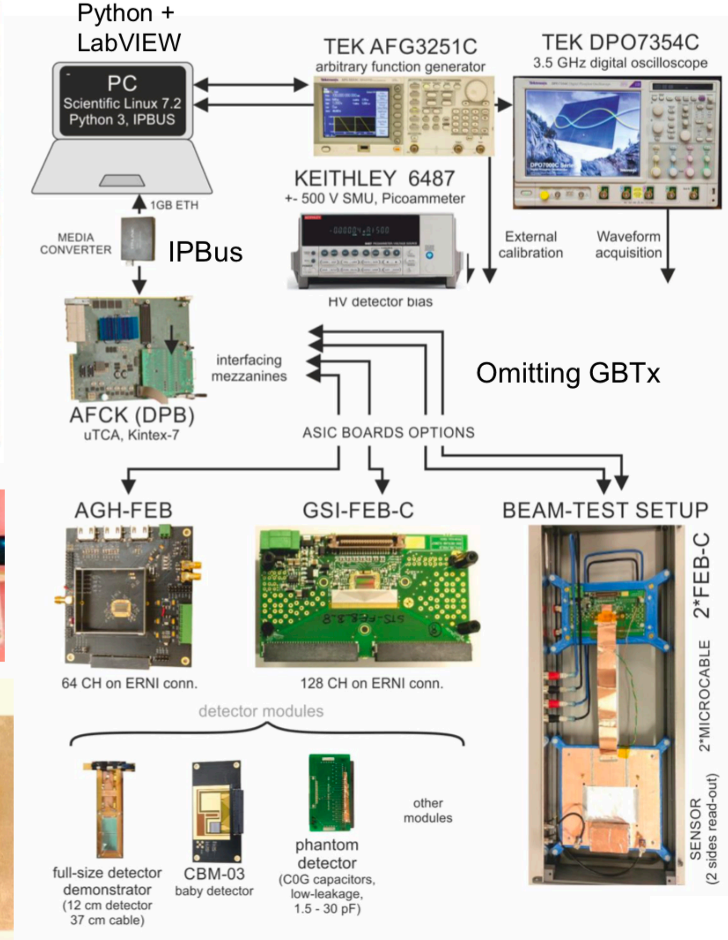
- 128 channels + 2 test channels
- charge sensitive amplifier (continuous+pulsed reset, switchable gains (STS/MUCH) + trim)
- 5-bit amplitude measurement (shaper slow + ADC)
- 14-bit timestamp measurement (shaper fast + leading edge discriminator)

XYTER Chips





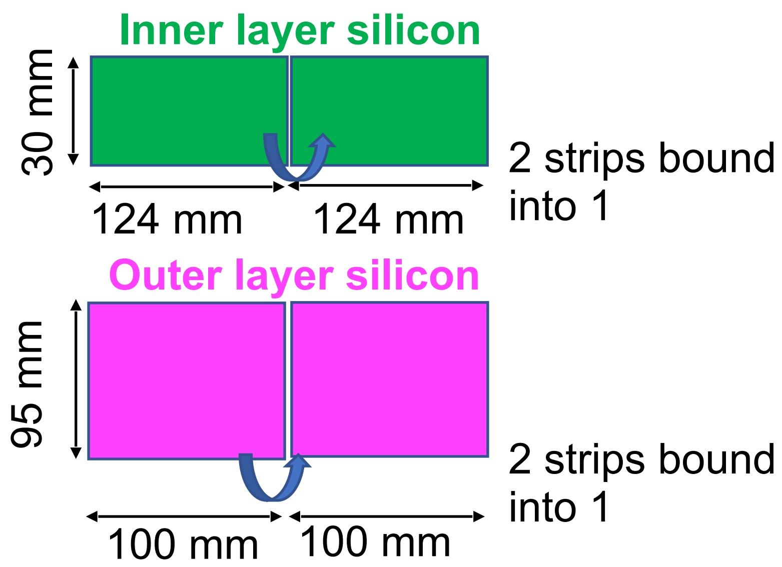
Test setup

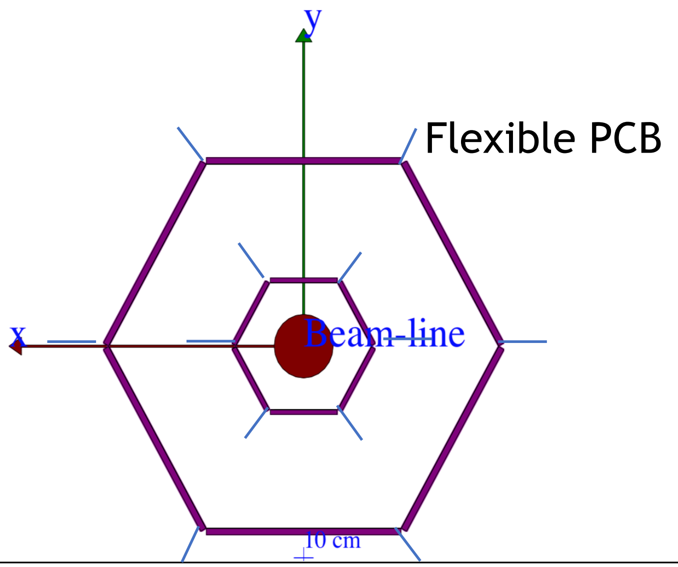


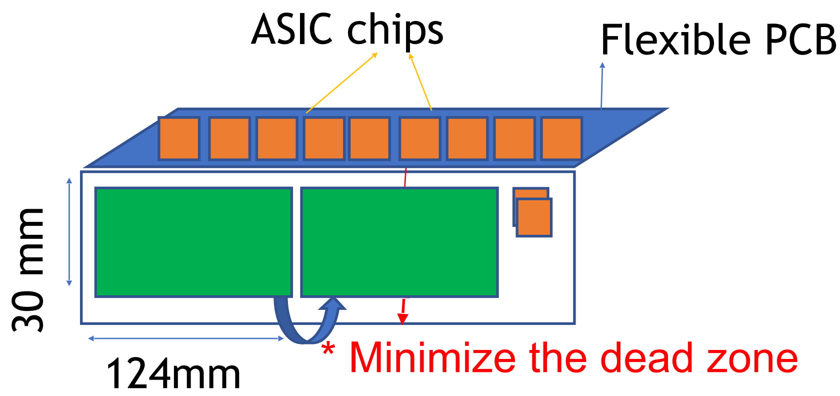
STRASSE Status

Inner layer silicon (2×6 BB23)
Effective area of each DSSD: 30 mm × 124 mm
Thickness: 150 microns
Pitch: 200 microns

Outer layer silicon (2×6 TTT15)
Effective area of each DSSD: 95 mm × 100 mm
Thickness: 300 microns
Pitch: 300-500 microns







XYTER Chips

Table 1

Key requirements for the STS/MuCh readout circuit.

Detector system	STS [2]	MuCh [9]
Sensor type	Silicon microstrip, double-sided, AC-coupled, stereo-angle −7.5° on p-side, 280–320 μm thickness	Gas electron multiplier, 3-foil, trapezoidal GEM sensors
Sensor lengths	2 cm, 4 cm, 6 cm, 12 cm	
Microcable lengths	15 cm–47 cm	
Expected total capacitance	Up to 40 pF	Up to 50 pF
Hit rate	250 kHz average	Below 100 kHz
Channel pitch	58 μm	116 μm
Power consumption [mW/channel]	< 10	
Dynamic range	0–15 fC 4 fC typical signal	1–100 fC
Time measurement accuracy	< 10 ns	
Signal polarity	Positive, negative	Negative
Operating temperature	∼−10 °C	∼60 °C