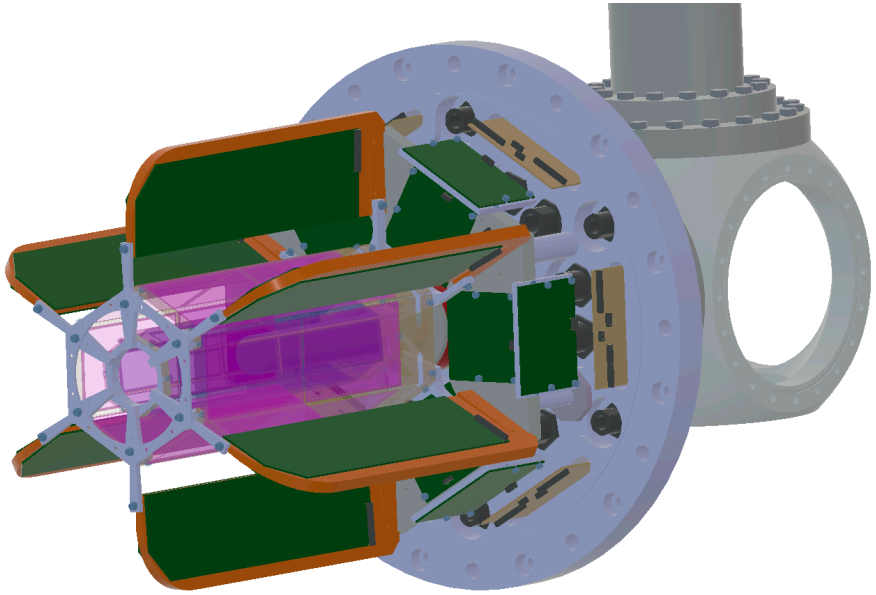
Overview of the status of STRASSE (A08)

I) Project A08
II) STRASSE
III) Motivations
IV) Silicon tracker
V) Future experiments

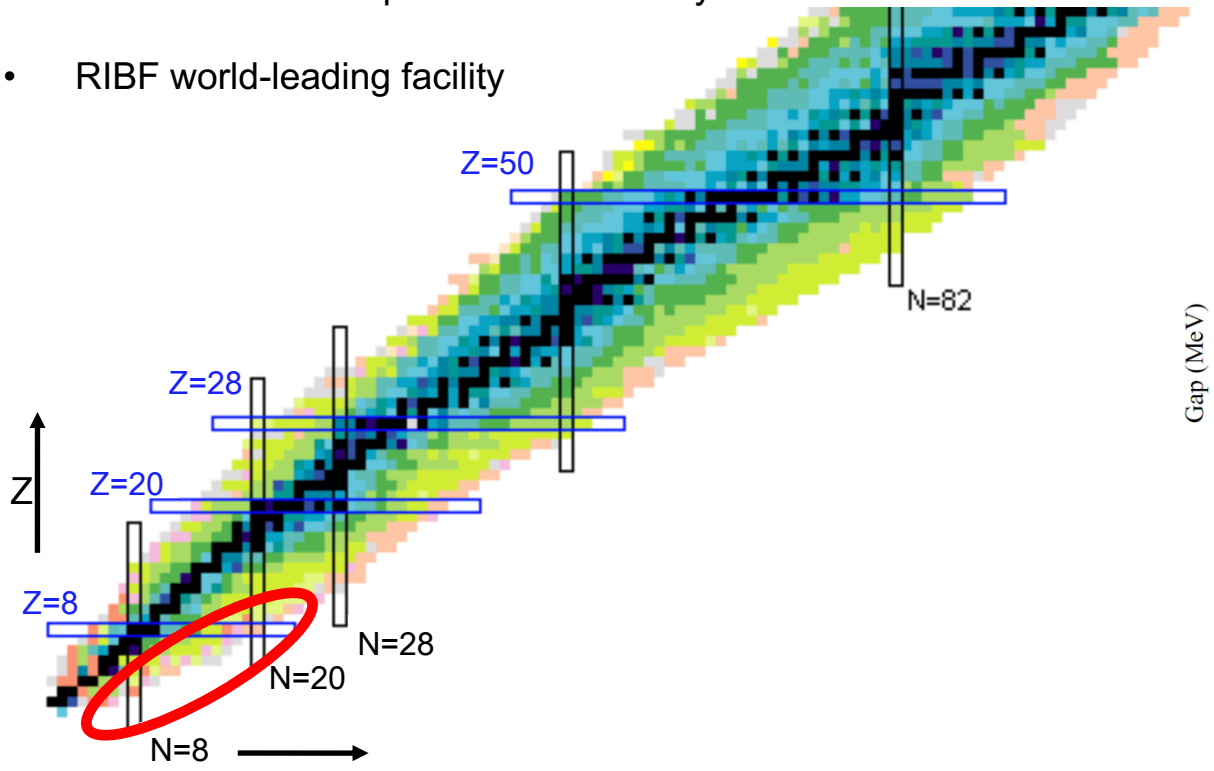


Valerian Alcindor, TU Darmstadt

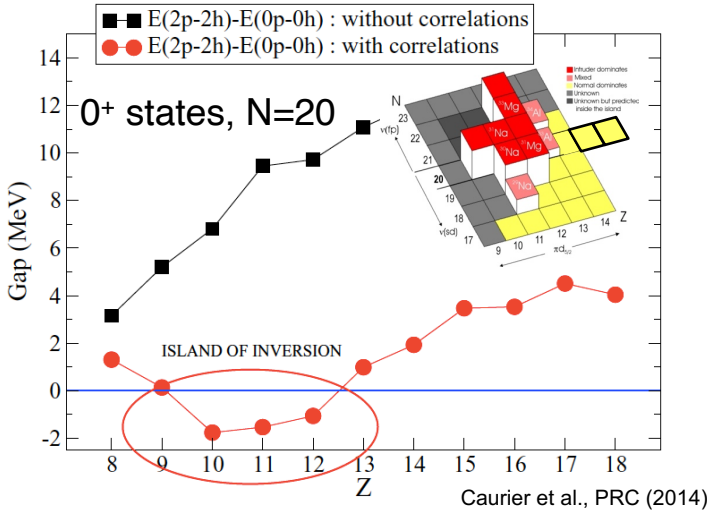
Project (A08)

A08: Shell evolution towards the neutron drip line:

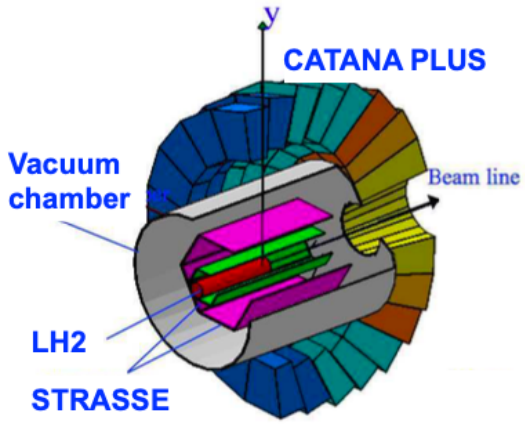
- New phenomena towards, at and beyond the drip line
- New frontiers in experiment and theory
- RIBF world-leading facility



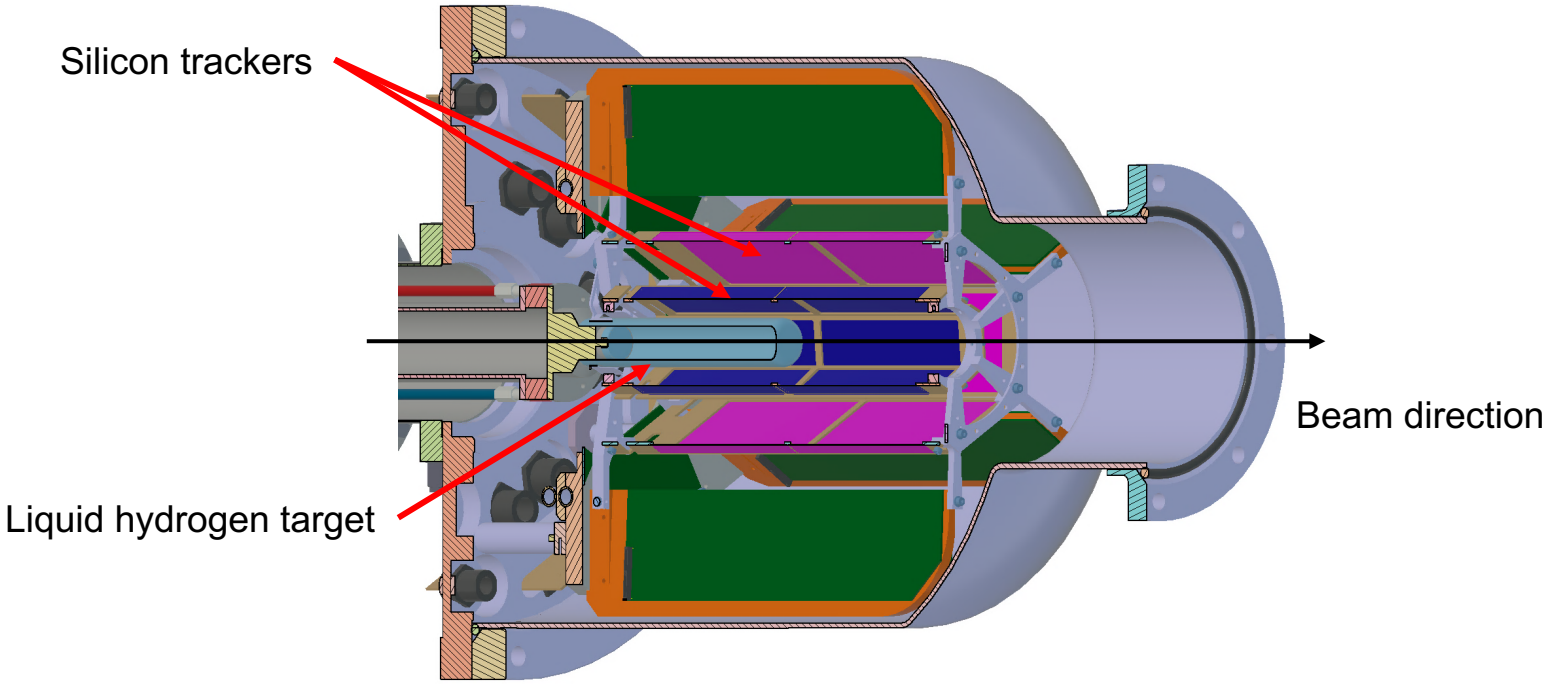
- **Island of inversion** mechanism to be explored: in ^{42}Si, ^{78}Ni
- **Search for low-lying excited 0+ states**: in ^{28,30}Ne and ^{34,36}Mg



Caurier et al., PRC (2014)



STRASSE project



STRASSE: (**S**ilicon **TRA**cker for **S**pectroscopy at **S**AMURAI **E**xperiments) is a device intended to be used for (p,2p) and (p,3p) reactions at RIKEN in Japan.

It consists of:

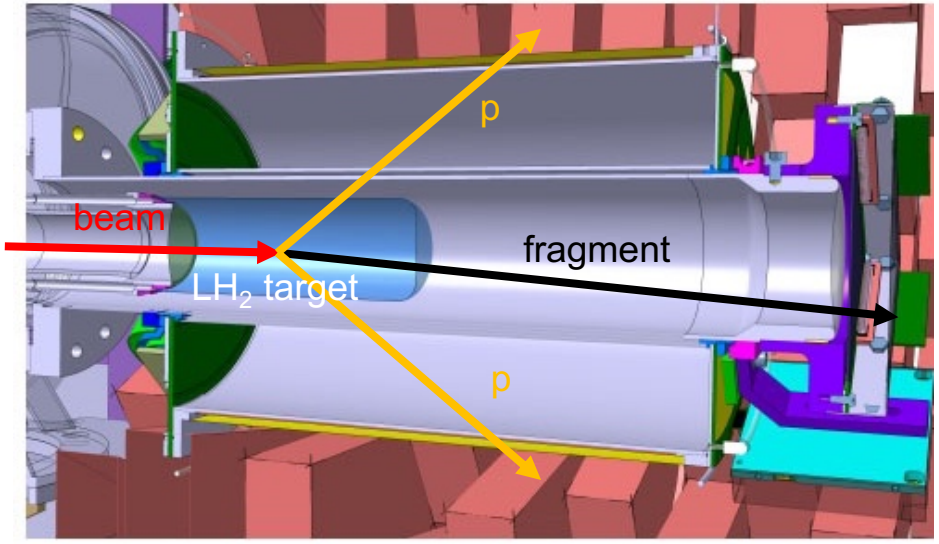
- A cryogenic target (a 150 mm thick liquid hydrogen target)
- A silicon tracker (two stacked DSSDs placed inside the vacuum chamber)

Courtesy of F. Flavigny, LPC

Motivations

Thick LH_2 target + tracker:

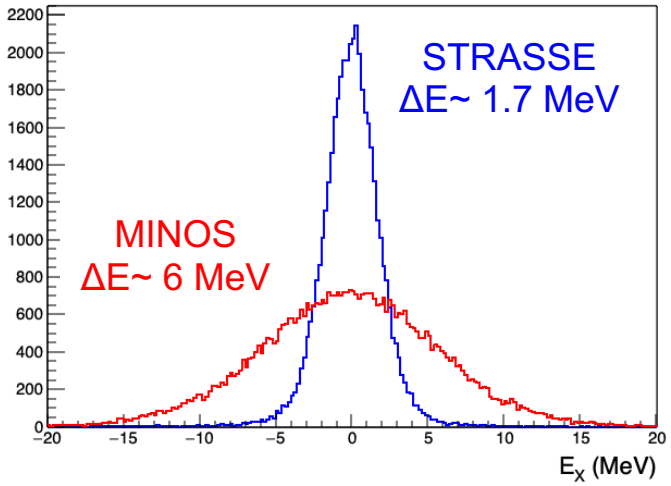
- Improved luminosities
- No carbon background
- Improved energy resolution (vertex)



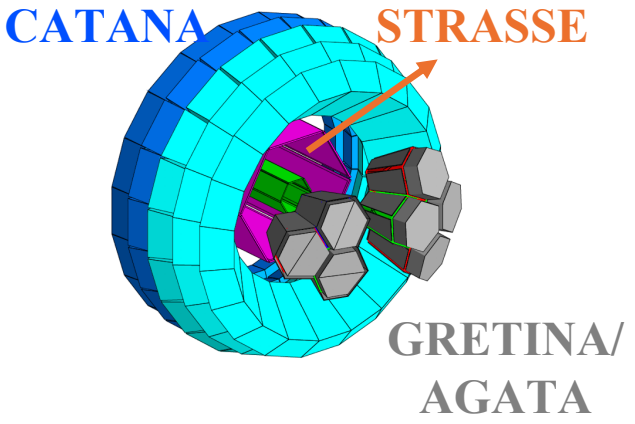
A. Obertelli et al. - Eur. Phys. J. A (2014) 50: 8

	MINOS	STRASSE
LH_2 target radius	26 mm	15.5 mm
Detector type	TPC	Silicon tracker
Vertex resolution	4.5 mm	0.7 mm
Missing mass resolution	6 MeV (no missing mass)	1.7 MeV
ɣ-ray resolution at 1 MeV	10% (MINOS + DALI2)	0.6% (STRASSE + HPGe)
Trigger rate limit	1 kHz	> 100 kHz

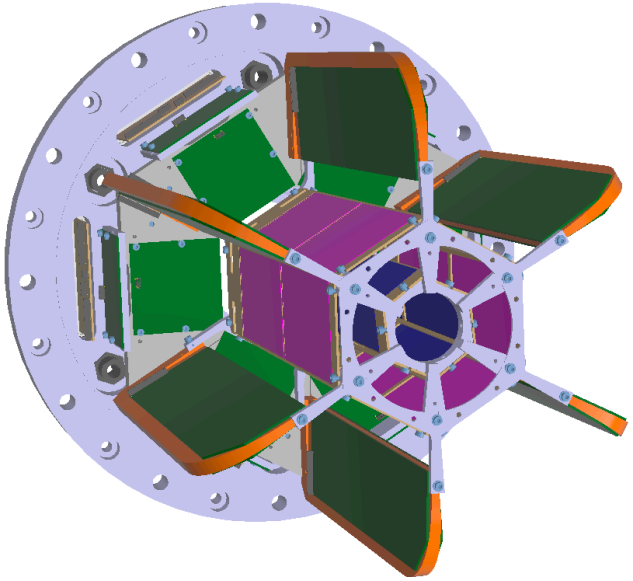
1) Missing mass spectroscopy



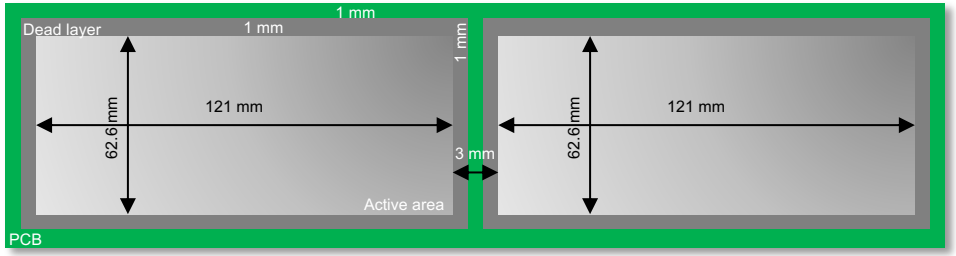
2) High resolution ɣ-ray measurement



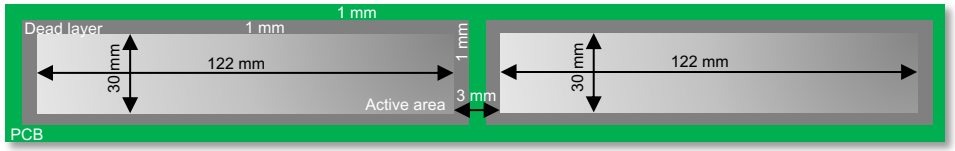
Silicon tracker: general design



Two type of DSSD modules (to be manufactured by micron):



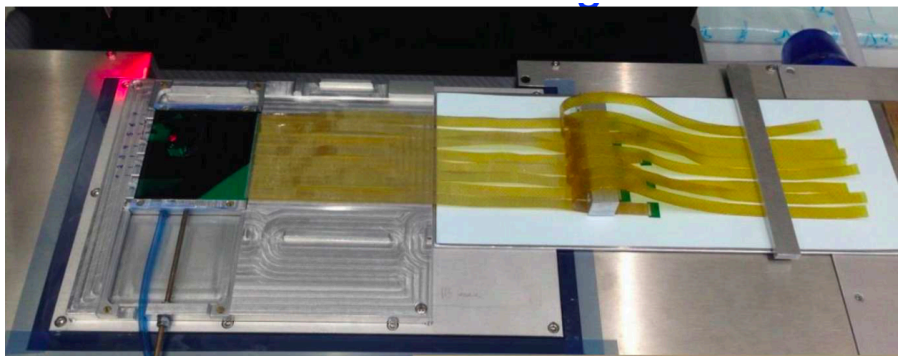
Outer DSSD: 2x6
Active area: 121x62.6 mm (605x313 strips)
Thickness: 300 µm
Strips pitch: 200 µm



Inner DSSD: 2x6
Active area: 122x30 mm (610x150 strips)
Thickness: 200 µm
Strips pitch: 200 µm

- Vertex resolution < 0.7 mm
- Angular resolution < 0.7°
- Missing mass energy resolution ~ 1.5-1.8 MeV
- 1p efficiency ~ 85%
- 2p efficiency ~ 55%

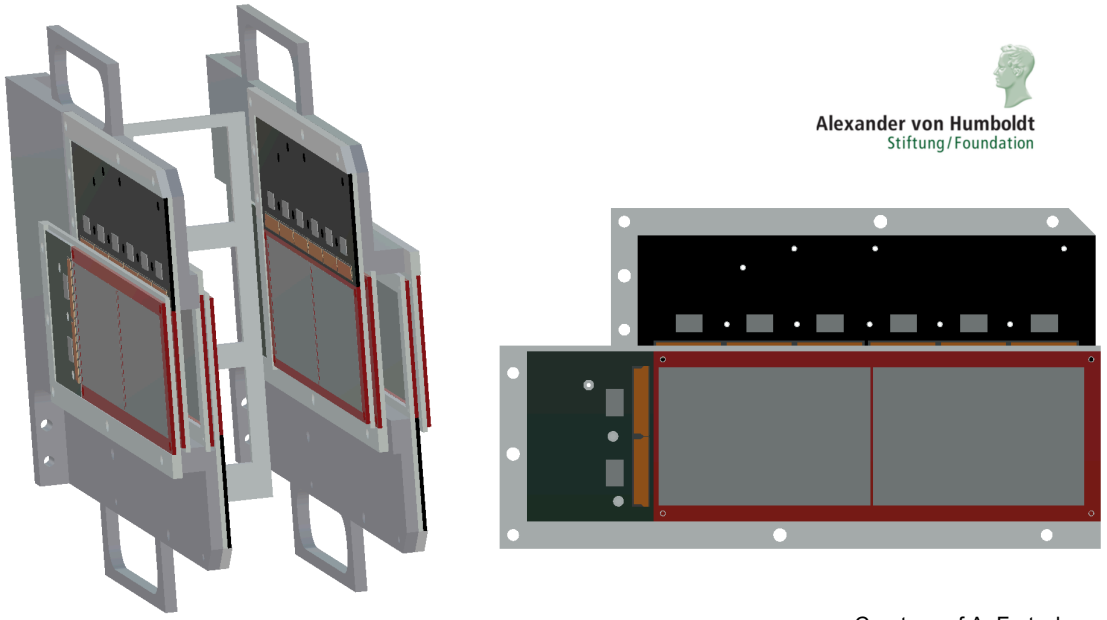
Low mass Microcable:



Ultrasonic TAB bonding
10 µm thick Al on 14 µm polyamide
Low capacitance: 0.382pF/cm

Silicon tracker: PFAD

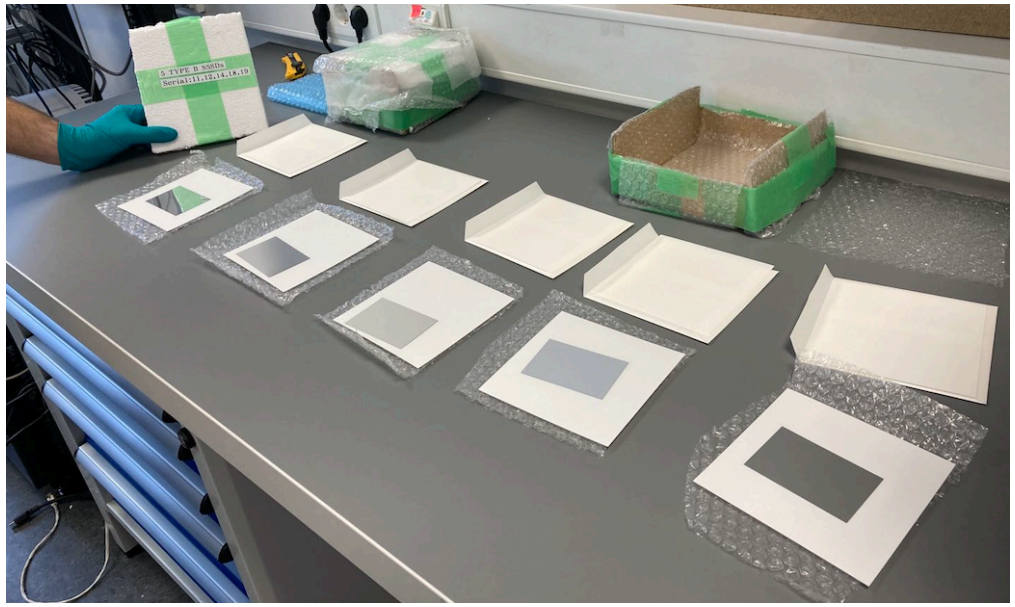
PFAD: **P**rototype **F**or **A**dvanced **D**etector



Courtesy of A. Frotscher

	STRASSE	PFAD
Target	Liquid hydrogen (LH_2)	CH_2
Number of modules	6	2
Detectors per modules	1x200 µm + 1x300 µm DSSSDs	4x100 µm SSD
Electronic channels	17478	4054

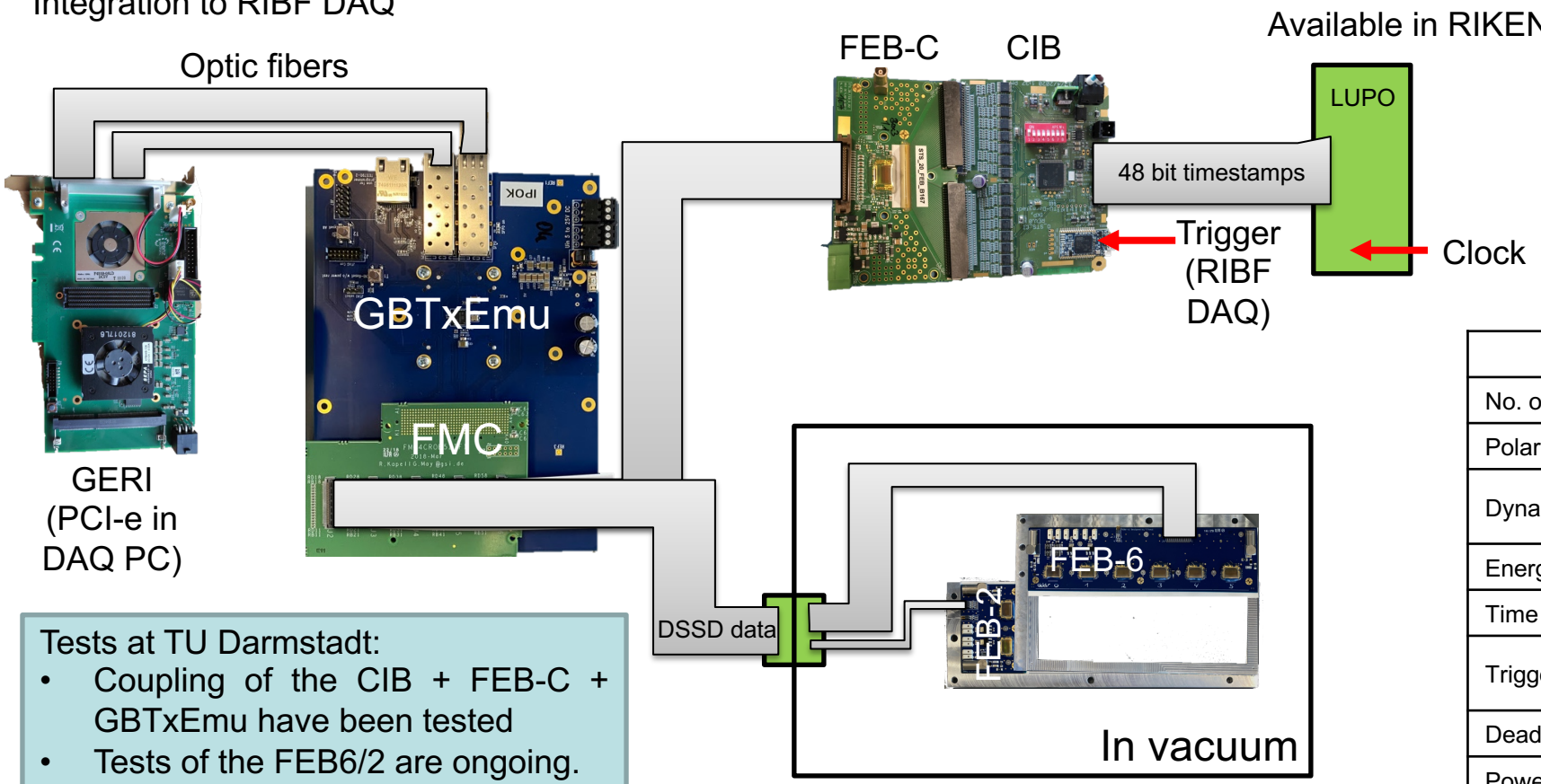
- Same electronic/readout as STRASSE
- To be used combined to CATANA
- 2p coincidence eff: ~7 %
- Resolution: ~0.7 MeV



SSD have been received and are waiting to be bonded

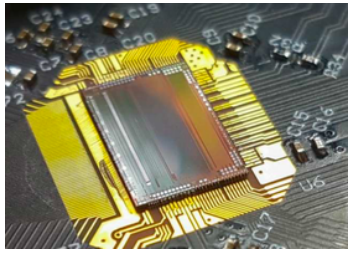
Silicon tracker: readout

- Readout adapted from the CBM experiment at GSI (with the support of J. Lehnert (GSI) and R. Gernhäuser (TUM))
- Triggerless system
- Integration to RIBF DAQ



Tests at TU Darmstadt:
- Coupling of the CIB + FEB-C + GBTxEmu have been tested
- Tests of the FEB6/2 are ongoing.
- Test with RIKEN DAQ

STS-XYTER2



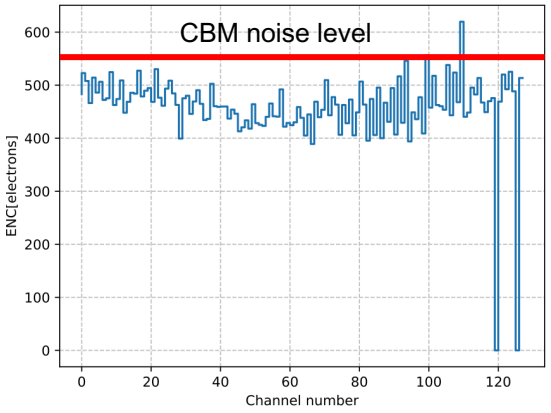
	STS-XYTER2
No. of Channel	128ch/chip, 94 chips 10mmx6.75mm
Polarity	Positive & negative
Dynamic range	0~15 fC (high gain, 35mv/fC) 0~100 fC (low gain, 6mv/fC)
Energy amplitude	5 bit Flash ADC
Time resolution	< 10ns, 14 bit time stamp
Trigger	Triggerless 8 bit threshold after fast shaper
Dead time	~0.8 us
Power consumption	8 mW/ch

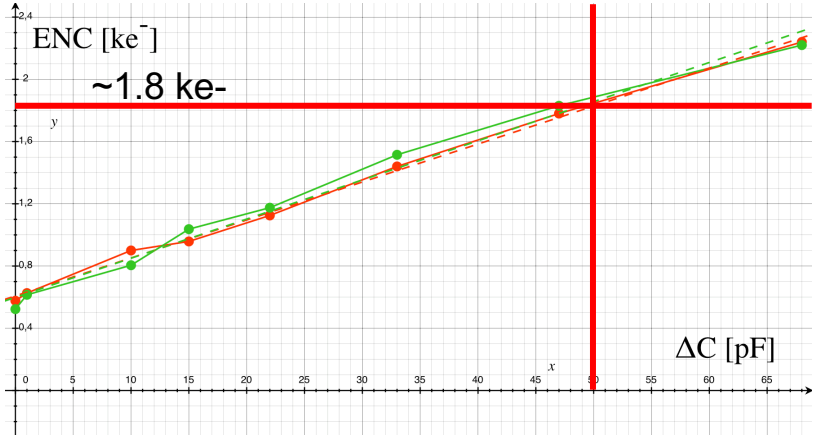
NIMA 908 (2018) 225–235

Silicon tracker: readout

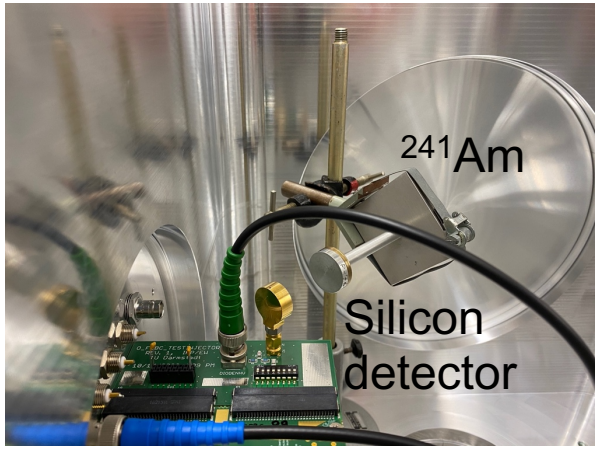
To detect high energy protons (up to 300 MeV):

- DSSD threshold < 100 keV.
- Required ENC at ~50 pF: < 2.8 ke- (10 keV)

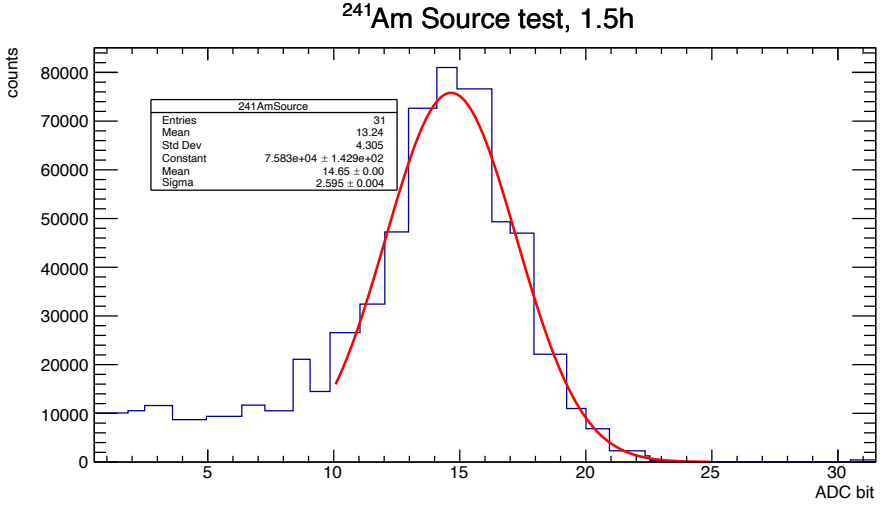




- Measured ENC (450 e-) better than expectations (550 e-)
- Measured ENC at 50 pF ~ 1.8 ke-



First source measurement of 59.5 keV gamma rays from ^{241}Am.



Courtesy A. Frotscher

Experiments at RIBF

Publications:

- **Quenching of single-particle strength from direct reactions** - T. Aumann et al., PPNP 118, 103847 (2021)
- **Pairing forces govern population of doubly magic ^{54}Ca from direct reactions** - F. Browne et al., submitted
- **Break-up reactions and their ambiguities** - M. Gomez et al., submitted
- **Level structures of ^{56,58}Ca unveil a hidden nuclear shell** - S. Chen et al., in preparation
- **One-neutron removal from ^{52}Ca and the magic character of N=32** - M. Ravar et al., ongoing analysis

Proposals:

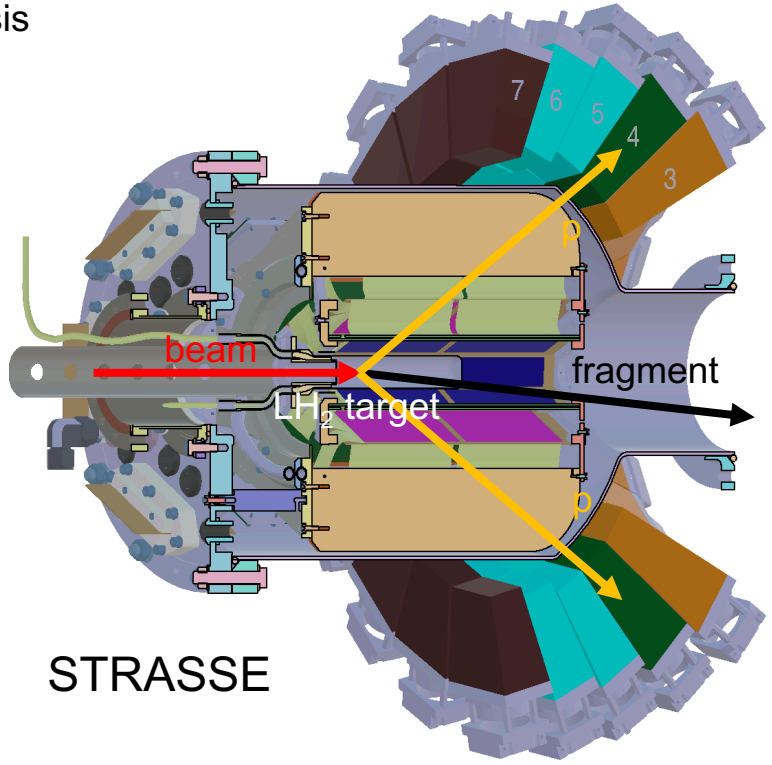
Approved - Grade A = Accepted:

- **Search for multi-neutron states in ^{10}He: ^{11}Li(p,2p)^{10}He @ 200 MeV/u** - Spokespersons: T. Nakamura and T. Tomai
- **Determination of the nn scattering length from a high-resolution measurement of the nn relative-energy spectrum produced in the ^{6}He(p,pa)^{2}n, t(p,2p)^{2}n, and d(^{7}Li,^{7}Be)^{2}n reactions** - Spokesperson: T. Aumann
- **Cluster and nucleon knockout reaction studies of neutron-rich calcium isotopes** - Spokesperson: T. Uesaka

Approved - Grade B = Not accepted:

- **Search for the first excited 0+ state in the doubly-magic ^{54}Ca** - Spokesperson: H. Liu
- **Search for diproton correlations in the Borromean nucleus 17Ne via quasi-free knockout (p,2p) reaction** - Spokesperson: Y. Sun
  - Only 45 days of beam time for BigRiPs + STRASSE under development
  - Will be submitted again this year (December 2021)

CATANA



STRASSE

Validation experiments at HIMAC

Two HIMAC experiments
Spokesperson: V. Alcindor

Alcindor Valérian

重粒子線がん治療装置等共同利用研究課題申請書 （___年度）
Proposal for Research Project with Heavy Ions at NIRS-HIMAC (FY 2021)

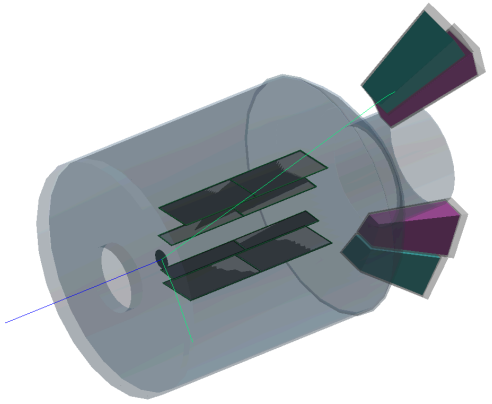
*1 課題整理番号 Project No.	□装置共用 C.U. 年 月 日 Date(yy/mm/dd) 20/11/13
*2 分類 Category	■新規 New □継続2年目 2nd year □継続3年目 3rd year □4年目新規 4th year □治療・診断 Clin & Diag □生物 Biology ■物理・工学 Physics
研究課題名 Title of Research Project	Measurement of the energy dependence of the quasi-free scattering cross section of the $^{16}O(p,2p)^{15}N$ reaction from 130 MeV/u to 430 MeV/u with STRASSE
*3 課題申請者 Spokesperson	氏名 Name (Last/First/M): Alcindor Valérian; 職名 Title: Dr. 所属機関名、部署名 Institution: Institüt fur kernphysik (IKP), TU Darmstadt 住所 〒 Address: S2114, Schlossgartenstraße 9, 64289 Darmstadt 電話 phone: +49 6151 16-23500 fax: +49 615116-23305 e-mai l: 放医研での身分 Status at NIRS:
所内対応者 Liaison at NIRS	氏名 Name: E. Takada; 所属部課 Division: Accelerator & Medical Physics; 内線 ext.

*4 研究分担者 List of Participants (Last/First/M)	氏名 Name	所属 Institution	職名 Title	放医研での身分 Status at NIRS
	V. Alcindor	TU Darmstadt	Dr.	
	A. Obertelli	TU Darmstadt	Professor	
	H. Liu	TU Darmstadt	Dr.	
	M. Gomez	TU Darmstadt	Dr.	
	T. Aumann	TU Darmstadt	Professor	
	A. Frotscher	TU Darmstadt	PhD student	
	T. Pohl	TU Darmstadt	PhD student	
	M. Ravar	TU Darmstadt	PhD student	
	Y. Sun	TU Darmstadt	Dr.	
	Y. Togano	Rikkyo University	Assistant professor	
	T. Nakamura	TiTech	Professor	
	Y. Kondo	TiTech	Assistant professor	
	J. Tanaka	Riken	Dr.	
	H. Otsu	Riken	Dr.	
	H. Wang	Riken	Dr.	
	M. Sasano	Riken	Dr.	
	F. Flavigny	LPC Caen	Dr.	
	A. Matta	LPC Caen	Professor	
	N. Orr	LPC Caen	Dr.	
	M. Marques	LPC Caen	Dr.	
	J. Gibelin	LPC Caen	Dr.	
	L. Achouri	LPC Caen	Dr.	
	F. Delaunay	LPC Caen	Dr.	
	T. Lotko	LPC Caen	Dr.	
	L. Plagnol	LPC Caen	PhD student	

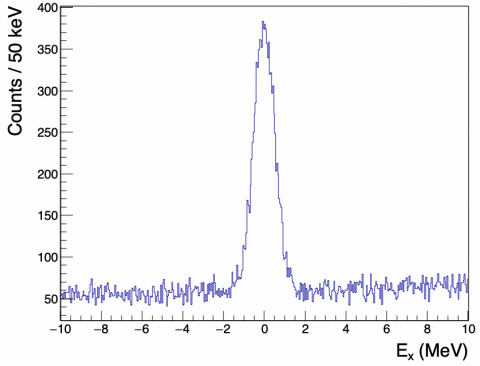
Accepted !

研究の目的と意義 Objective of Project	The nucleon removal from the doubly magic nucleus ^{16}O is commonly used as a benchmark for reaction mechanisms since it was well characterized via the $^{16}O(e,e'p)^{15}N$ reaction and because the first excited state of ^{15}N (5.27 MeV) is well separated from the ground state. Concerning (p,2p) reactions, there are currently discrepancies between cross section predictions for the $^{16}O(p,2p)^{15}N$ reaction, as consequence, there is a need for more experimental data. Especially, concerning the energy dependence of the quenching factors which has rarely been studied. In this regard, the HIMAC facility would give us a unique opportunity to study the (p,2p) reaction mechanism for a continuous range of energies from 130 MeV/u to 430 MeV/u. For this measurement, the STRASSE silicon tracker and cryogenic target system will be used together with 14 CATANA crystals to measure the energy and momentum of the two recoil protons. This will be the first in-beam experiment of STRASSE and would require a thorough testing of the electronic as well as the capability of this system to perform precise vertex reconstruction and missing mass measurements coupled to CATANA crystals. As a consequence, we propose a two steps experimental program: (i) the commissioning of STRASSE's demonstrator called PFAD with 4 CATANA crystals and (ii) the above-mentioned study of the $^{16}O(p,2p)^{15}N$ reaction using the full STRASSE setup and 14 CATANA crystals.

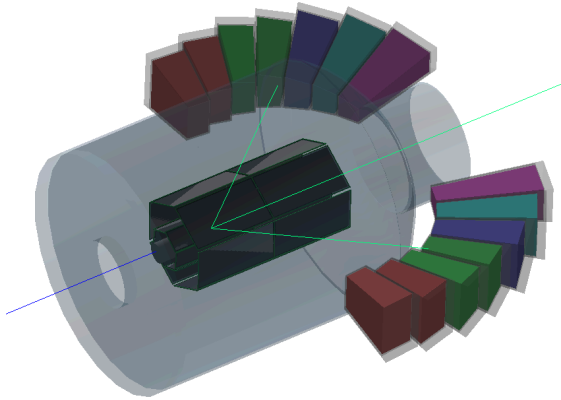
First experiment:
PFAD commissioning

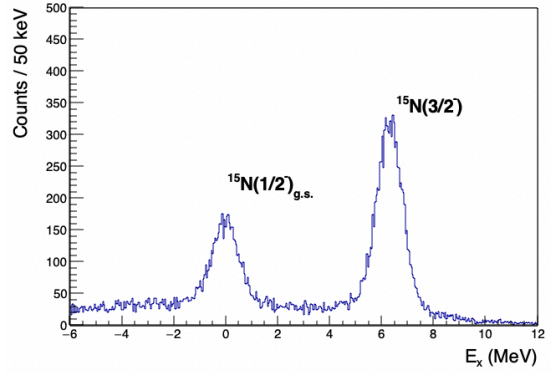


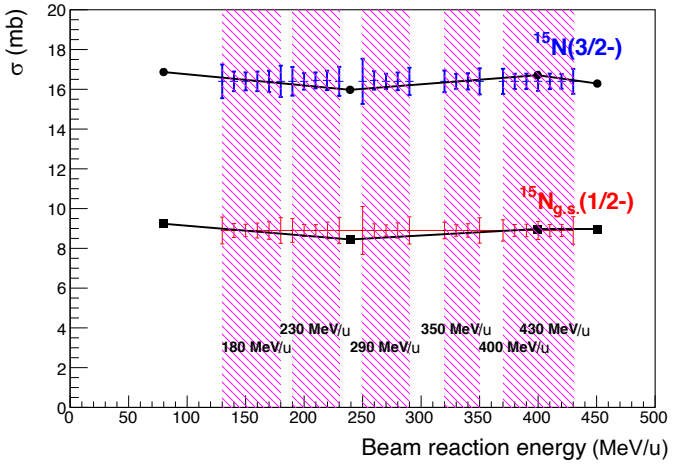
Elastically scattered protons

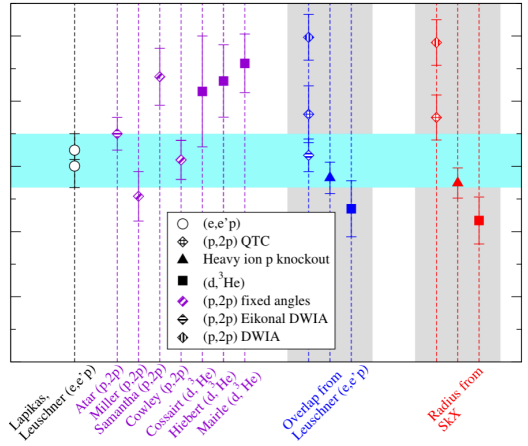


Second experiment:
$^{16}O(p,2p)^{15}N$ with STRASSE



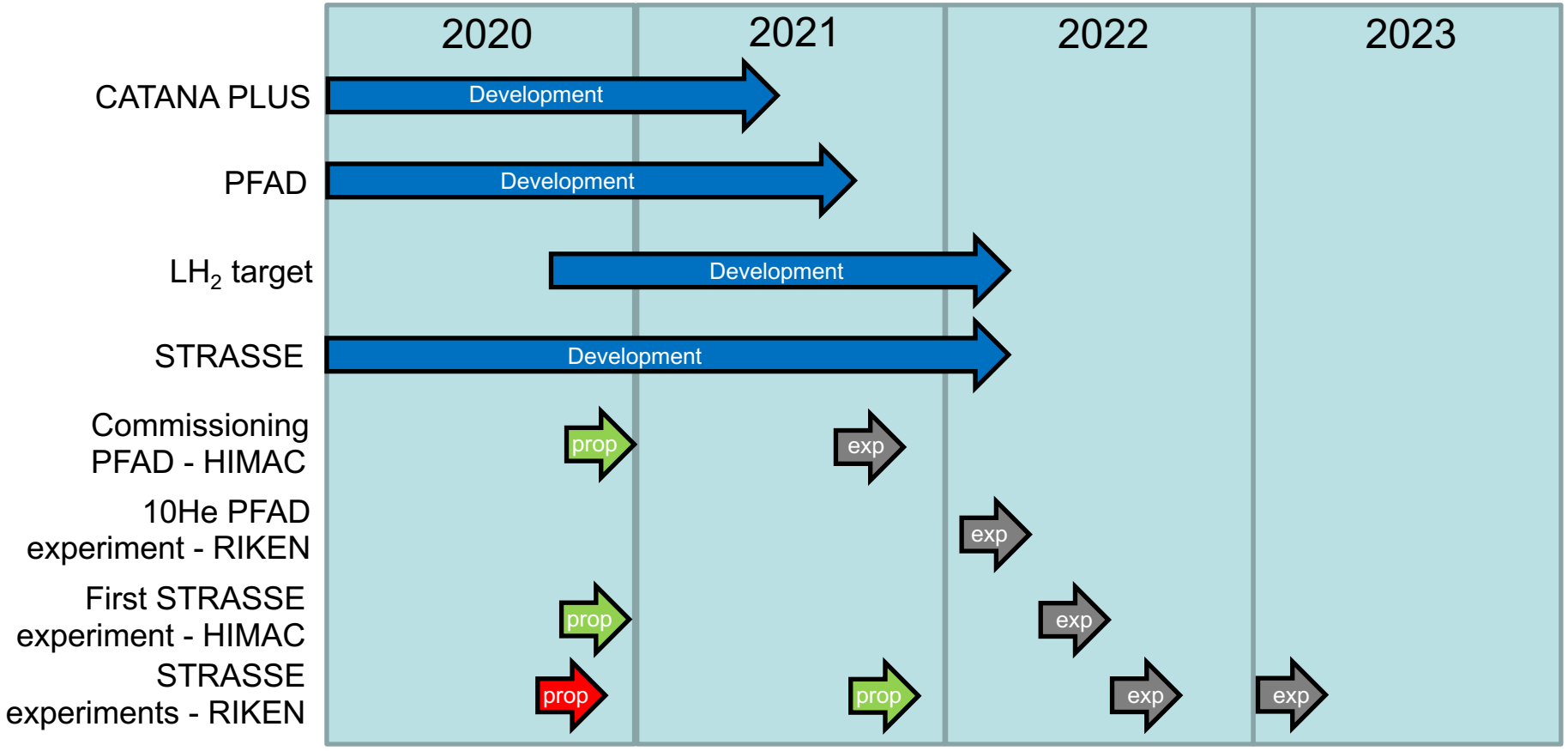






T. Aumann et al., Prog. Part. Nucl. Phys.

Timeline



- H. Liu et al. overview paper in preparation (2021)
- All DFG documents have been submitted to M. Brunken for review (March 2021)

Collaboration

- **TU Darmstadt** (Germany): V. Alcindor, A. Frotscher, H. Liu, A. Obertelli, T. Pohl, M. Ravar
- **GSI** (Germany): J. Heuser, R. Kapell, J. Lehnert, C. Schmidt, C. Simons
- **TU München** (Germany): R. Gernhäuser, B. Michael
- **LPC** (France): F. Flavigny, D. Goupillère, A. Matta
- **TiTech** (Japan): N. Ebina, Y. Kondo, T. Nakamura, N. Nakatsuka
- **RIKEN** (Japan): H. Otsu, M. Sasano, T. Uesaka, H. Wang
- **Rikkyo** (Japan): Y. Togano

Supported by: