

# On the way to FAIR – Nuclear Physics at the Extremes



## Third International SPES Workshop

INFN Legnaro  
October 10<sup>th</sup>-12<sup>th</sup>, 2016



GSI-MAGAZIN  
target  
Augabe Nr. 12  
September 2014

GSI Helmholtzzentrum für Schwerionenforschung  
target  
Augabe Nr. 13  
Januar 2016

GSI Helmholtzzentrum für Schwerionenforschung  
target  
Augabe Nr. 13  
Januar 2016

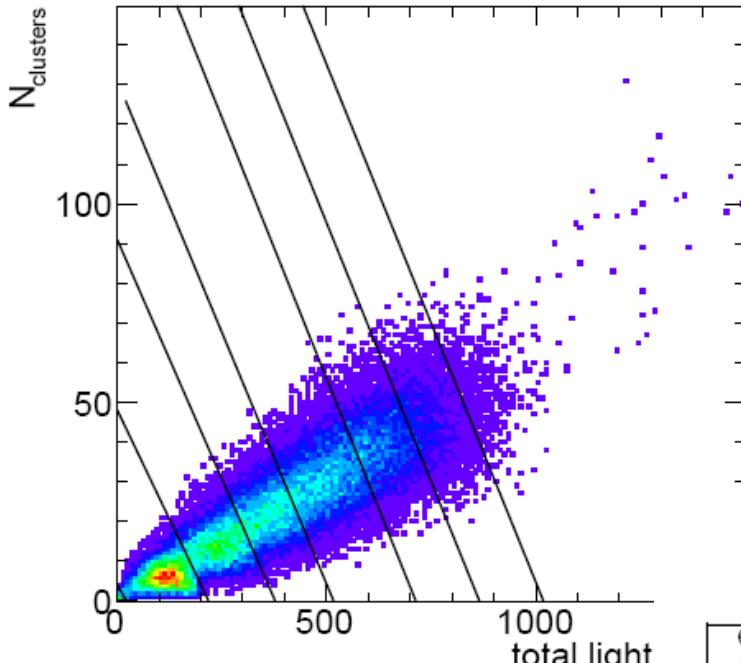
HEILHOLZ  
FORSCHUNG

# Prelude: Novel Neutron Detector: NeuLAND

K. Boretzky

Fully active neutron detector based on scintillators

(calorimetry & tracking)

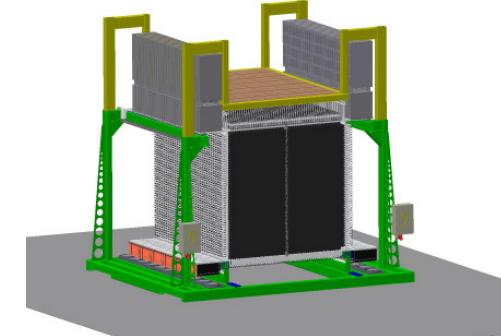


Previously < 50%

Previously <5% !

→ 4/5n decay  
channels in reach

		1000 MeV generated					
		%	1n	2n	3n	4n	5n
detected							
	1n	89	12	1	0	0	0
	2n	7	78	23	3	0	0
	3n	0	8	63	26	5	0
	4n	0	0	12	63	40	0
	5n	0	0	0	7	46	0
	6n	0	0	0	0	0	8

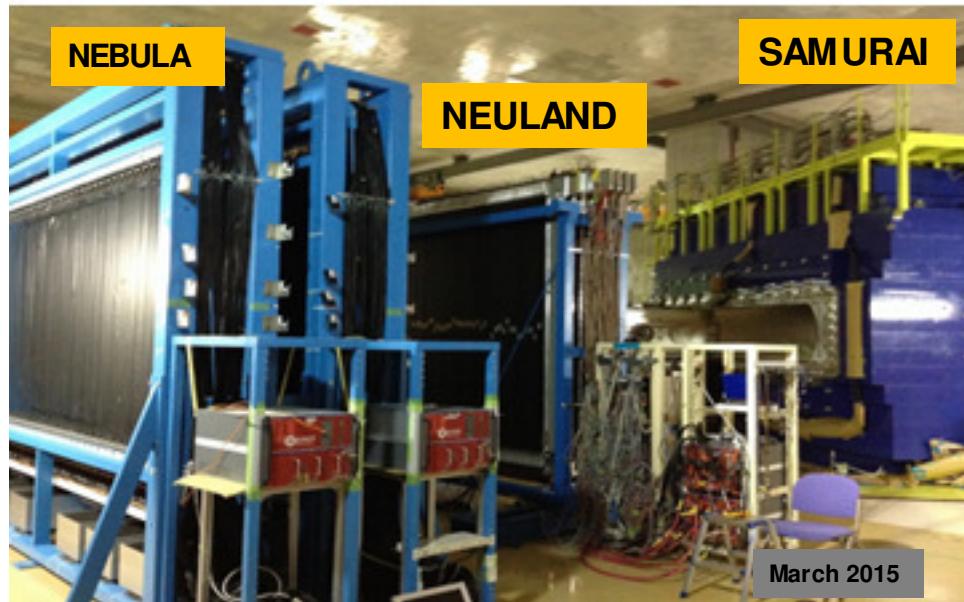


30 double planes  
2 x 50 paddles each  
5 x 5 x 250 cm<sup>3</sup>  
RP408 / R8619ASSY

FPGA TDC readout

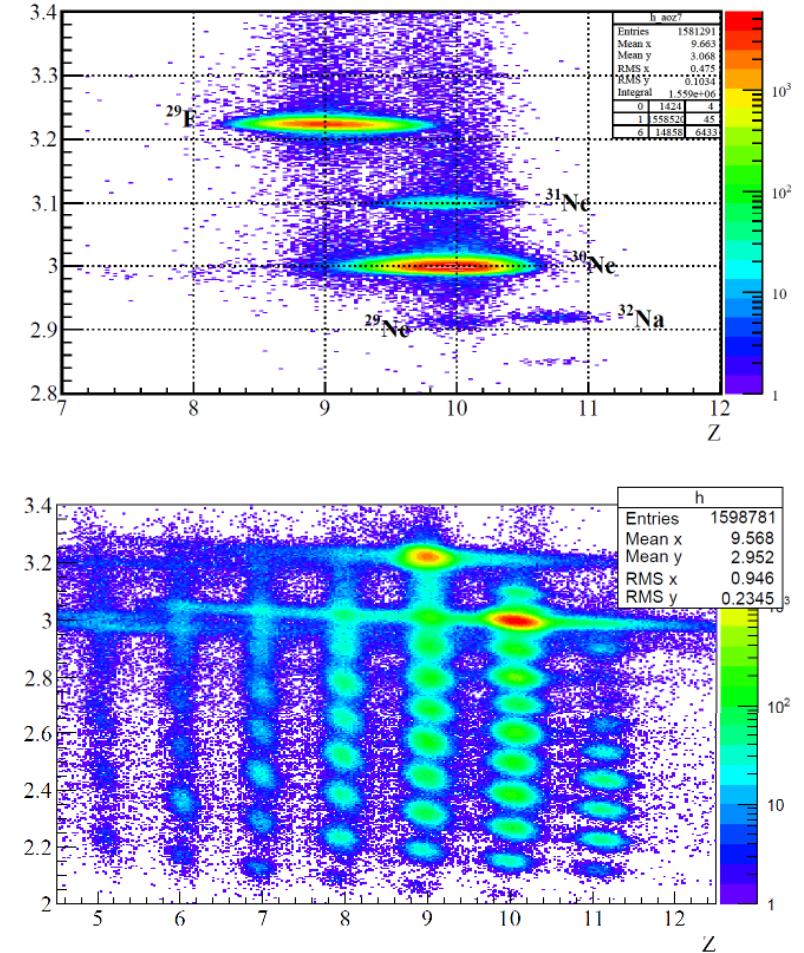
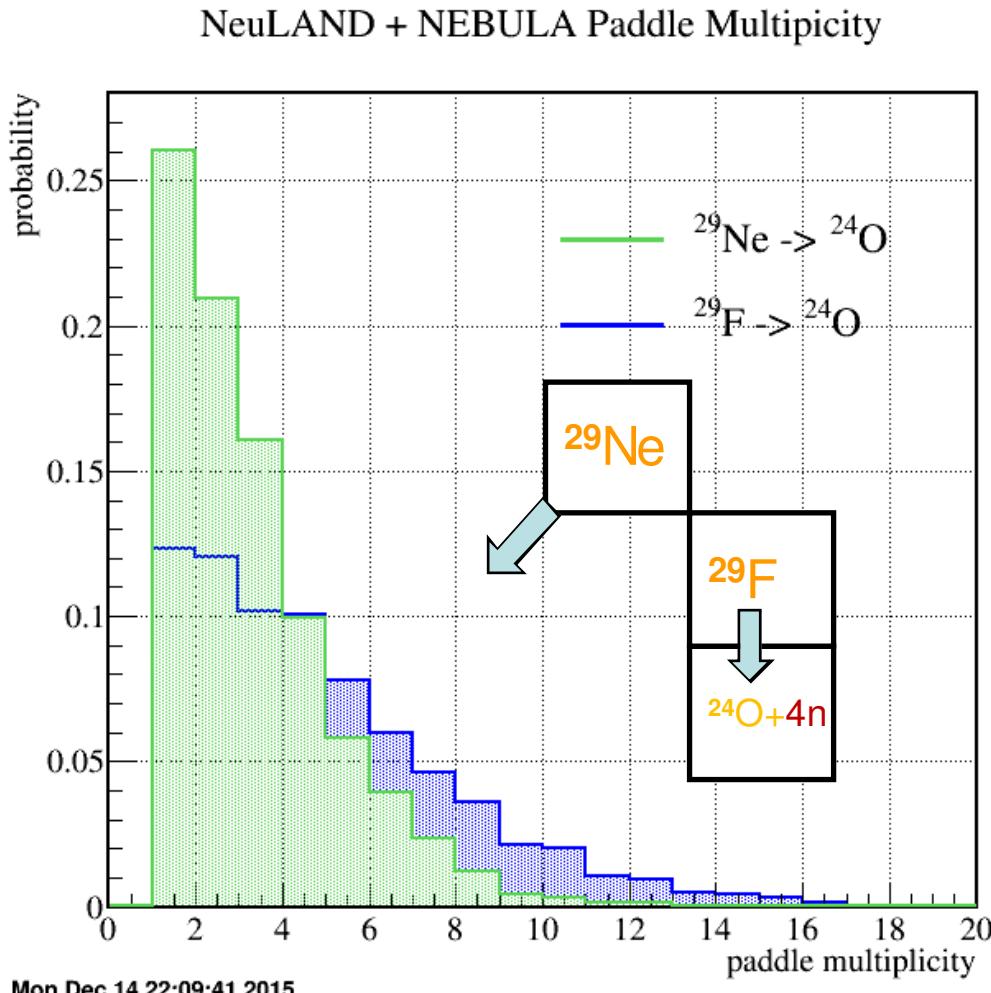
# Experimental equipment on the way ...

- NeuLAND demonstrator (40 cm depth with only **4 double planes** and 800 readout channels) at RIKEN up to end of 2017, participation in various beam times
- at GSI **continuation of production** (4 more double planes ready), production scheme dominated by funding profile, **11-15 out of 30 d.p. in 2018**



4 double planes @ RIBF  
... e.g. to RIKEN  
Back to GSI  
Q4/2017

# RIKEN: “Performance studies for the prototype”

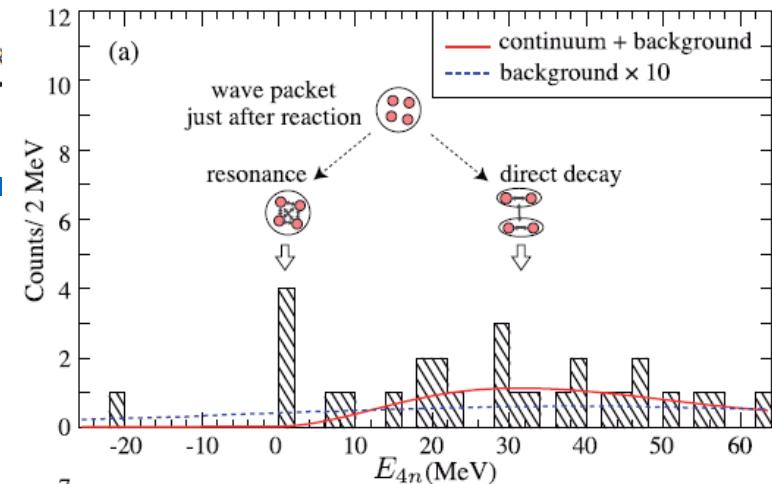
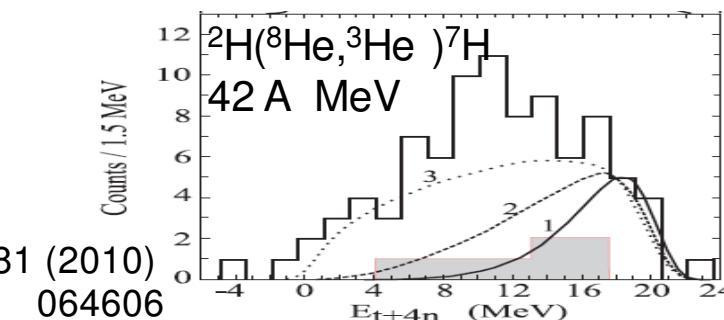
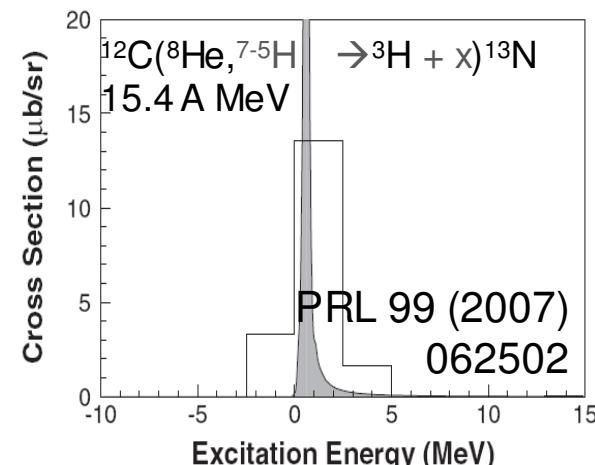
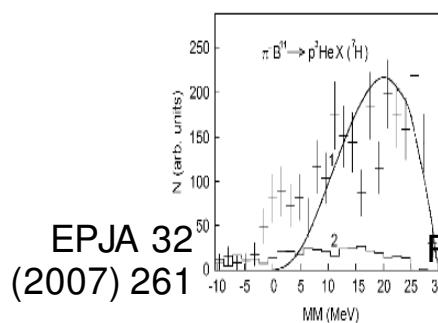
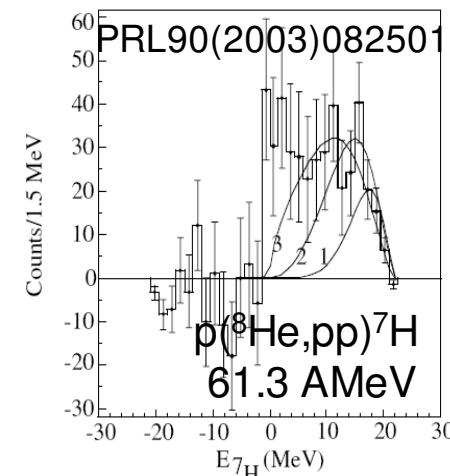


Efficiency evaluations in progress ... not only ;o)

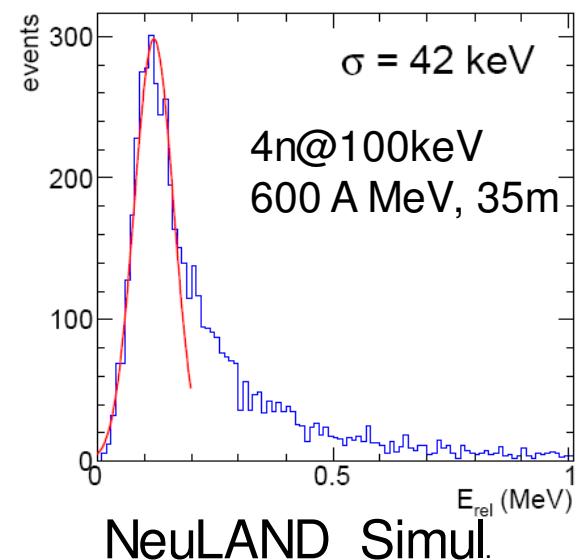
J. Kahlbow/TUDA

$7H \downarrow$  and  $4n \rightarrow$

K. Kisamori et al.  
 $^4He(^8He; ^8B)$   
 @ 186 MeV/u



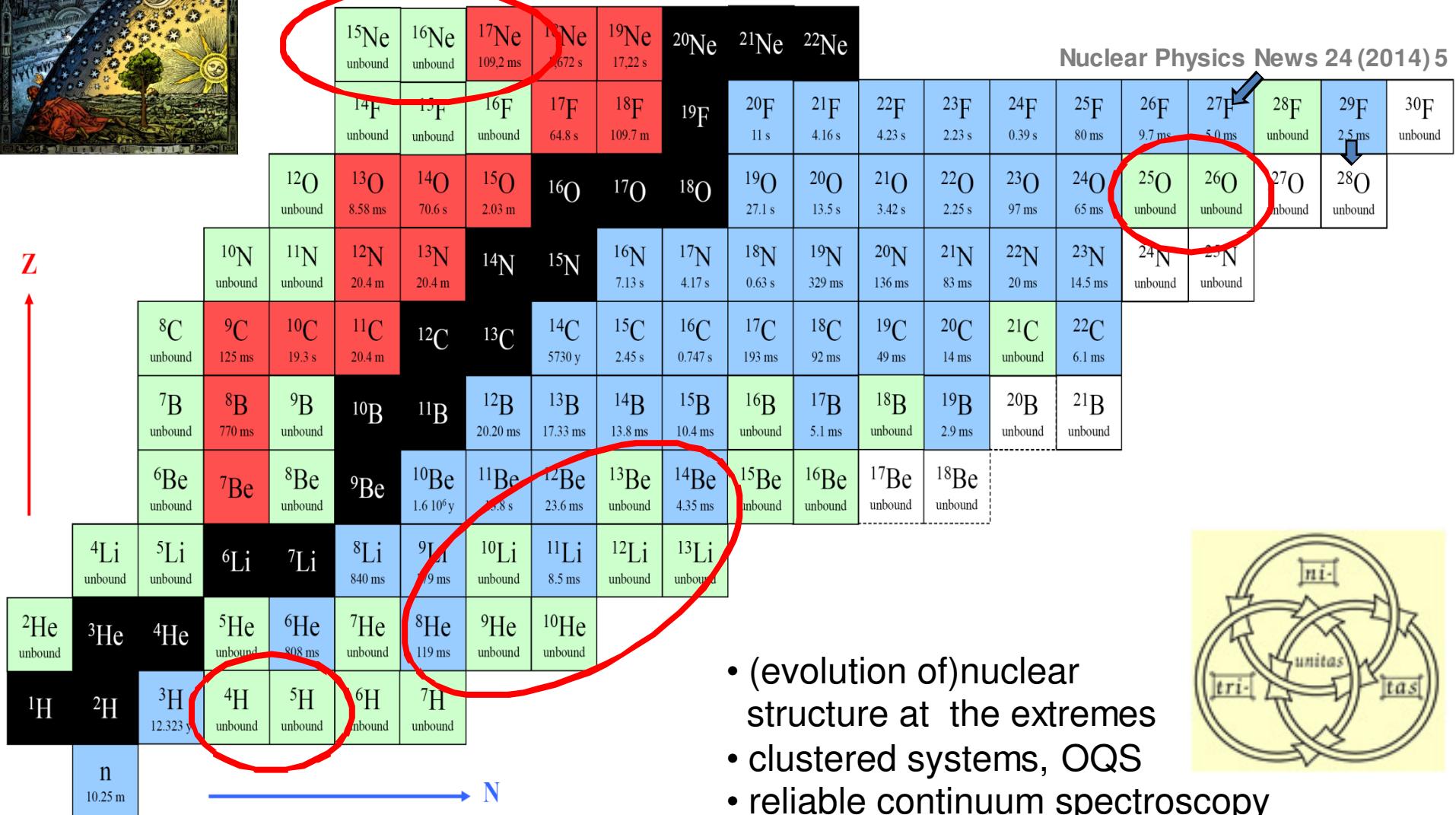
- Improvement by exclusive measurements



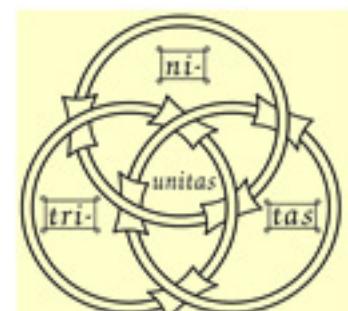
# At the boundaries: Stepping stones across the dripline



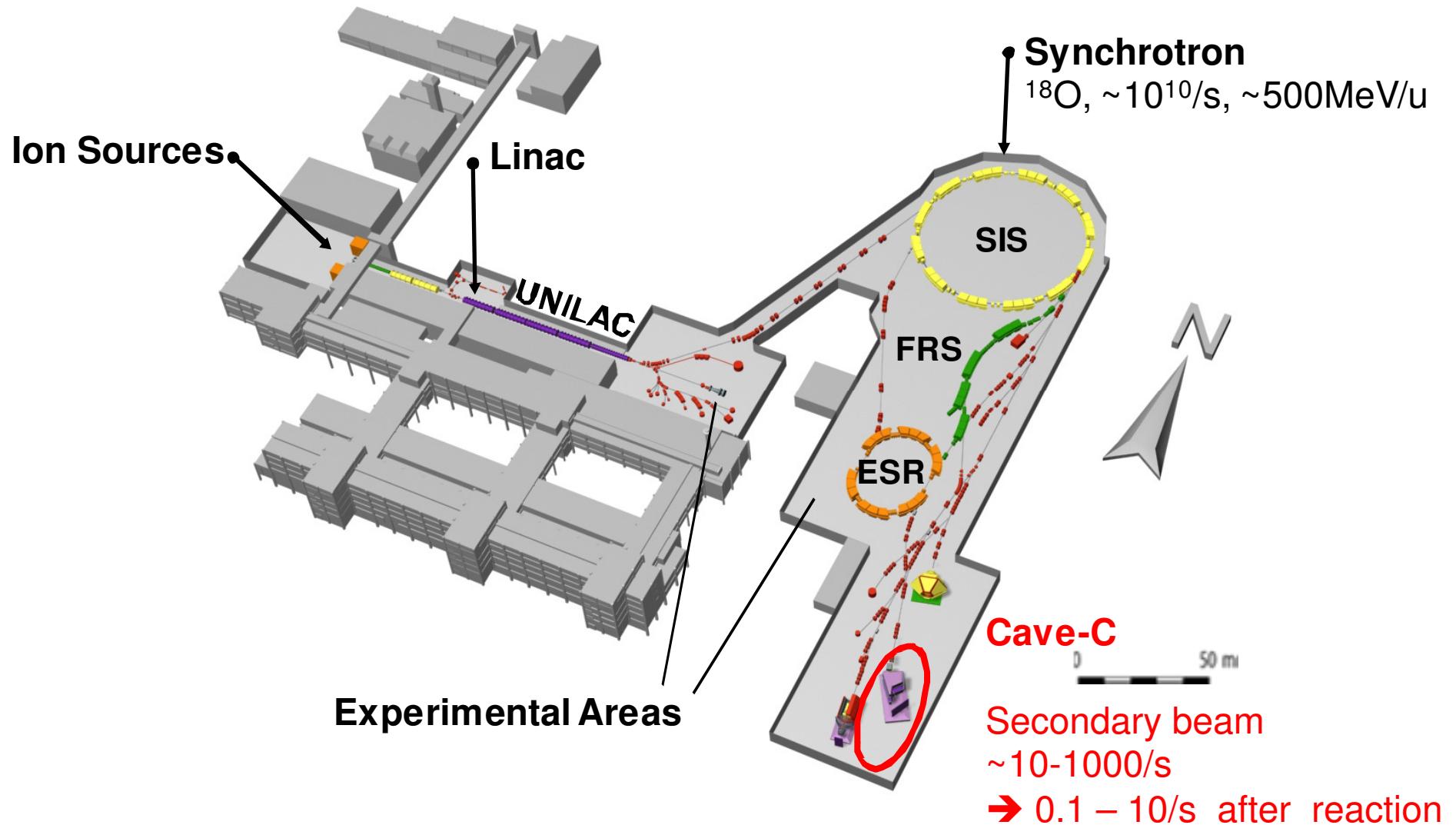
Z  
↑



- (evolution of)nuclear structure at the extremes
- clustered systems, OQS
- reliable continuum spectroscopy



## GSI accelerator facility ...

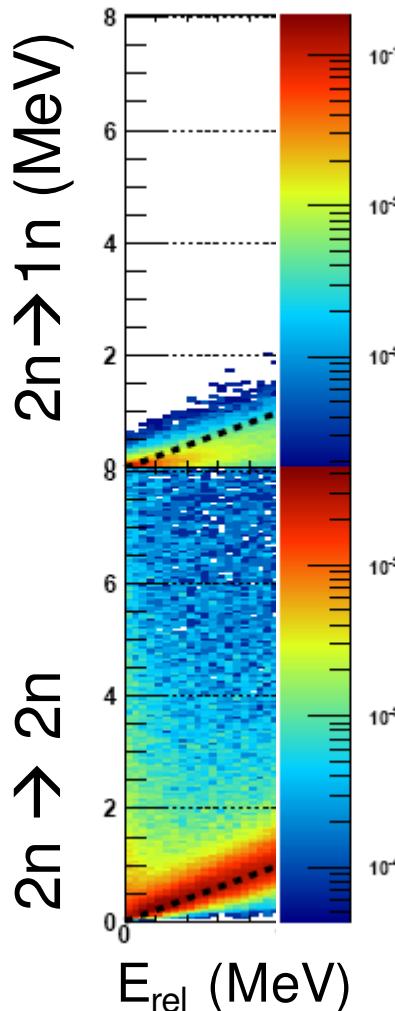


# Current experimental frontiers:

-even this was not a dedicated experiment



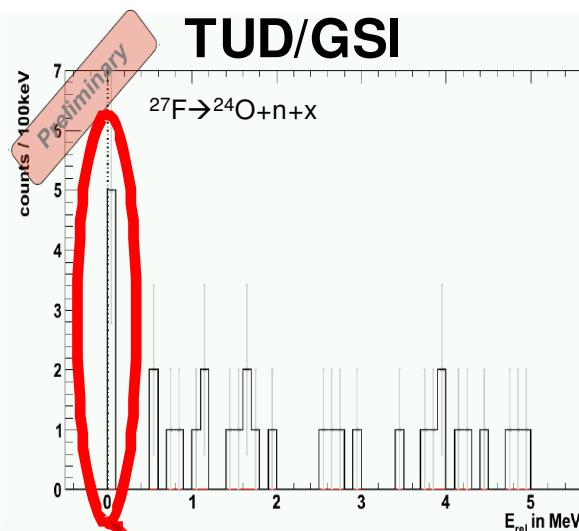
Low energy  
response



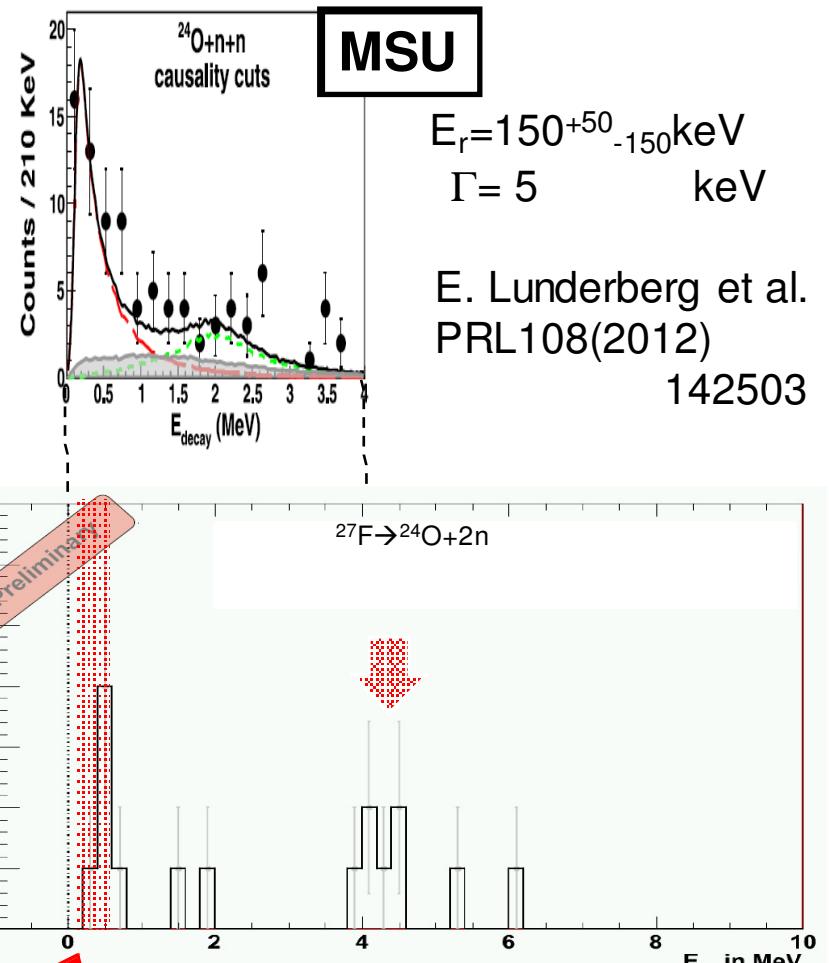
1) LAND:  
Multi neutron  
detection and  
acceptance.

2) Beam intensity !

Thesis: C.Cäsar  
TUD/GSI



<b>24F</b>	<b>25F</b>	<b>26F</b>	<b>27F</b>	<b>28F</b>	<b>29F</b>
0.34 s	50 ms	10.2 ms	4.9 ms	unbound	2.6 ms
23O	24O	25O	26O		
82 ms	61 ms	unbound	unbound		



# Large-acceptance superconducting dipole magnet GLAD → System study for FAIR

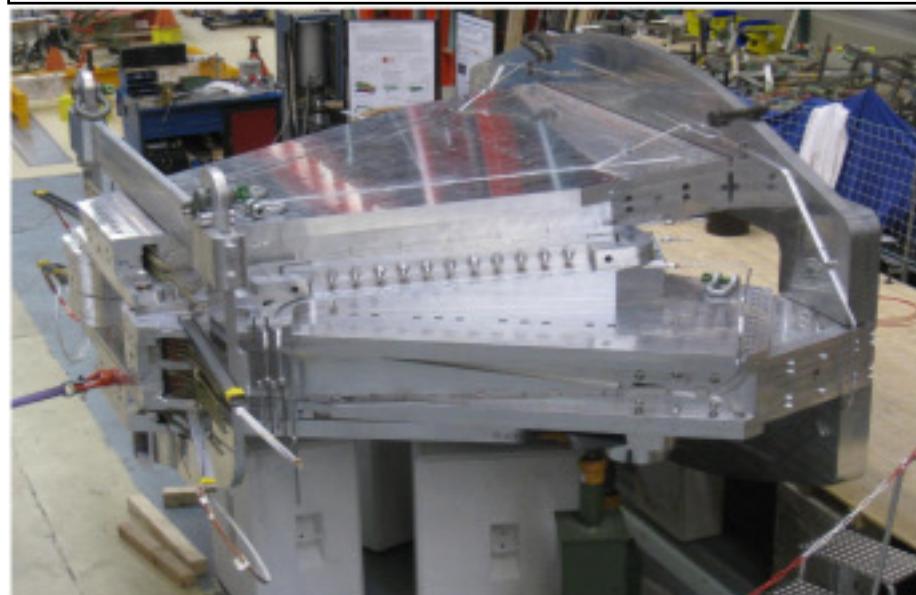
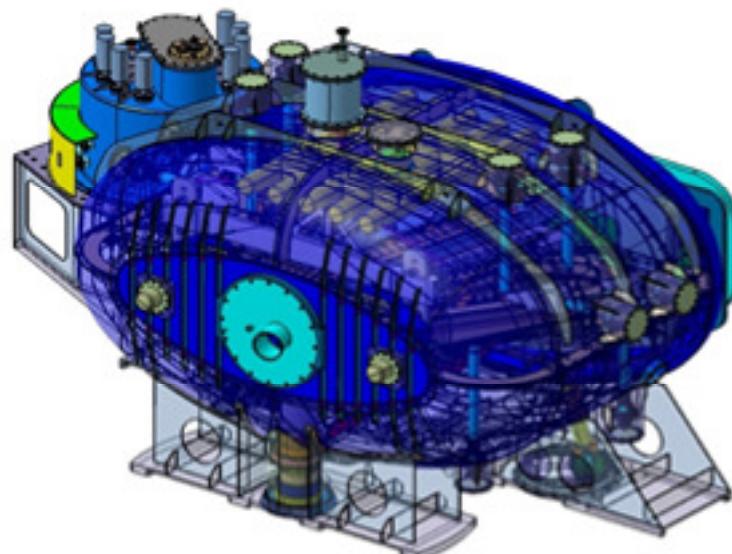


## Magnet parameters:

- Large vertical gap  $\pm 80$  mrad
- High integrated field of 4.8 Tm
- Fringe field at the target position less than 20 mT
- Operational temperature 4.6 K
- The overall size of the conical cryostat: 3.5 m long, 3.8 m high and 7 m wide.

## Challenging Magnet design:

- Collaboration CEA Saclay/GSI
- Tilted coils, ironless design
- Correction Coils
- Lightweight design
- Indirect coil cooling
- Thermosyphon cryo distribution



# The magnet ready ... for travel



- Production (and revision) finalized.
- FAT passed 23.9.2015

→ „Test bench“ operation  
→ Preparation for FAIR



August 2015

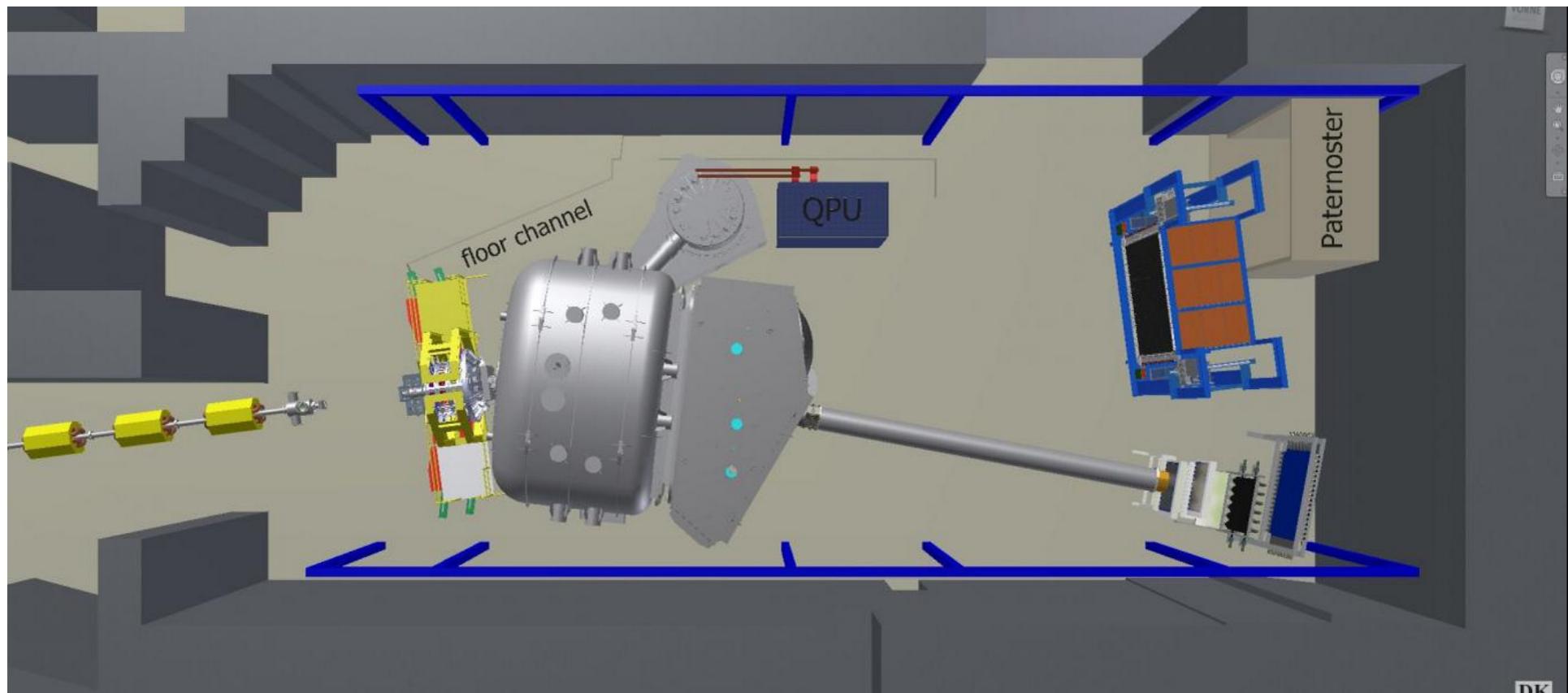


September 2015

Transport to GSI  
November 2015  
SATa Test Q1/2016  
Installation Cave-C  
Q2/2016  
Operation ready  
Q1 /2017

# Test bench: GLAD @ Cave-C

Short Spec.:  
 $B\ell = 4.8 \text{ Tm}$   
Opening angle: 80 mrad  
20 mT field @ target position



## GLAD has arrived and is being installed in Cave-C



- French/German in-kind
  - Power supply there and tested
  - Cryo plant installed and tested
  - Magnet has arrived and passed first series of SAT tests
- non conformity in the exit flange  
fixed 07/2016



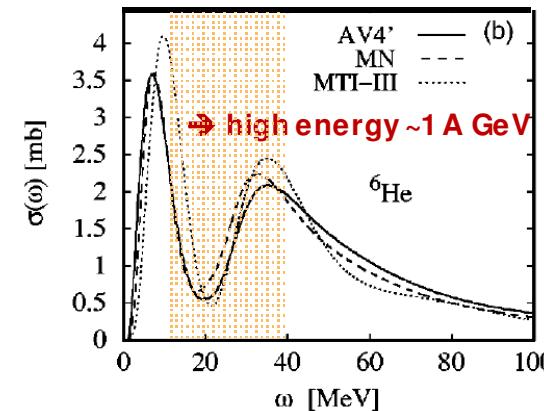
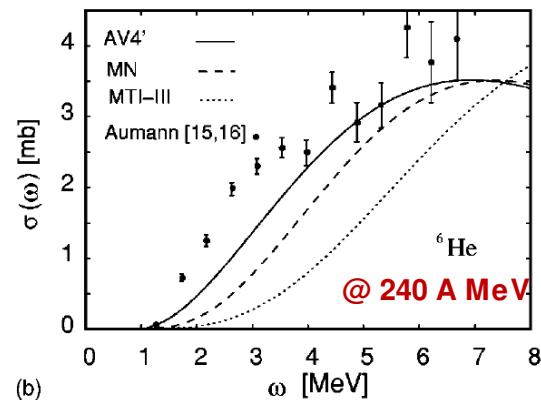
- 04-10/2016 installation and test of instrumentation and MSS/MCS by CEA
- End 2016 to start getting magnet into operation!

# Dipole strength Distributions in neutron-rich nuclei @ high beam energy



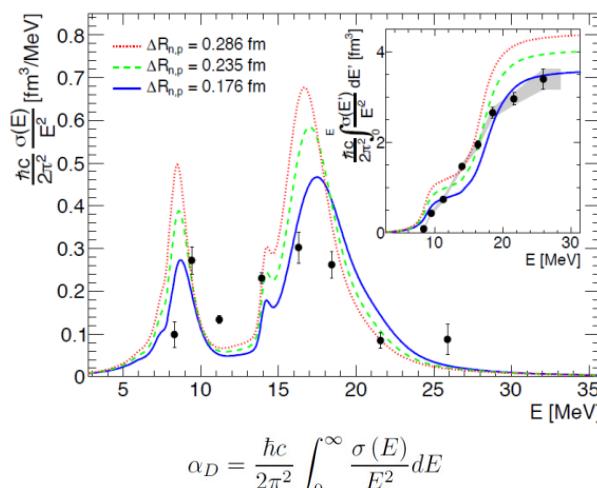
- core vs. neutron skins & halos → density / asymmetry

$^6\text{He}$  (!)  
revisited



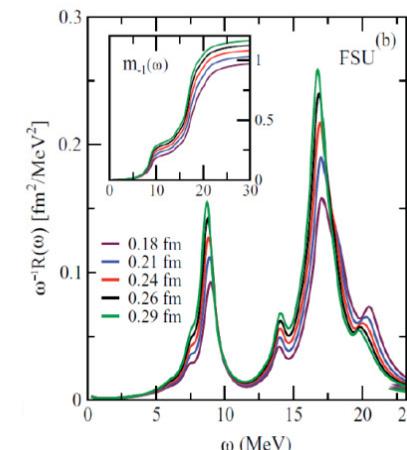
S. Bacca et al.  
PRL 89 (2002) 052502  
PRC 69 (2004) 057001

- access to EoS (e.g. neutron star) & low lying E1 strength (r-process)



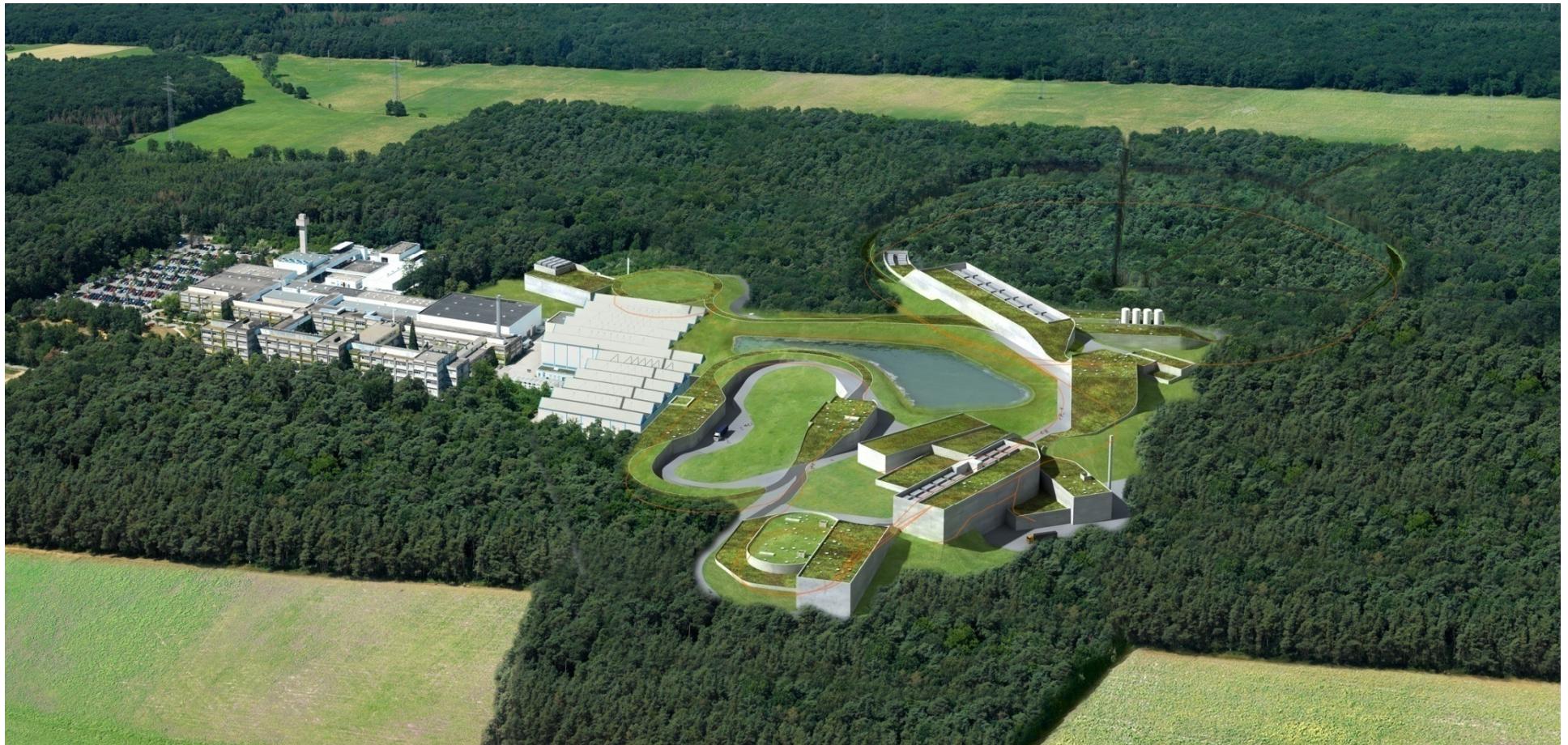
D. Rossi et al.  
PRL 111 (2013) 242503  
skin thickness  $^{68}\text{Ni}$   
 $0.175(21)$  fm

J. Piekarewicz, PRC 83 (2011) 034319



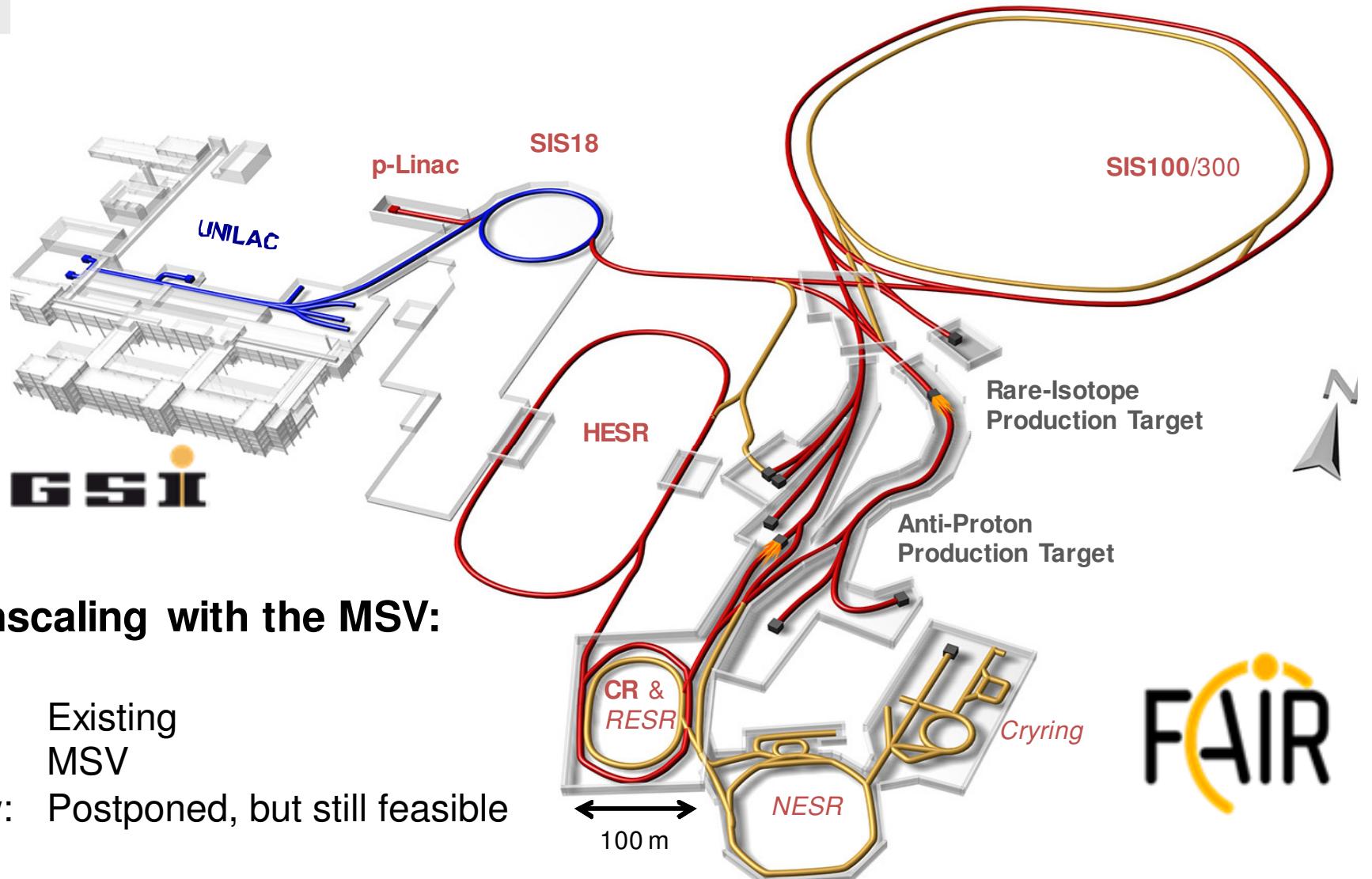
Pb chain &  
N=126 isotones  
~1 A GeV →  
bare ions  
Fragment  
identification

## Next Step: The new FAIR facility



Intensity increase 3-4 orders of magnitude !

# Originally planned FAIR facility



## Downscaling with the MSV:

- Blue: Existing
- Red: MSV
- Yellow: Postponed, but still feasible

# FAIR Civil Construction

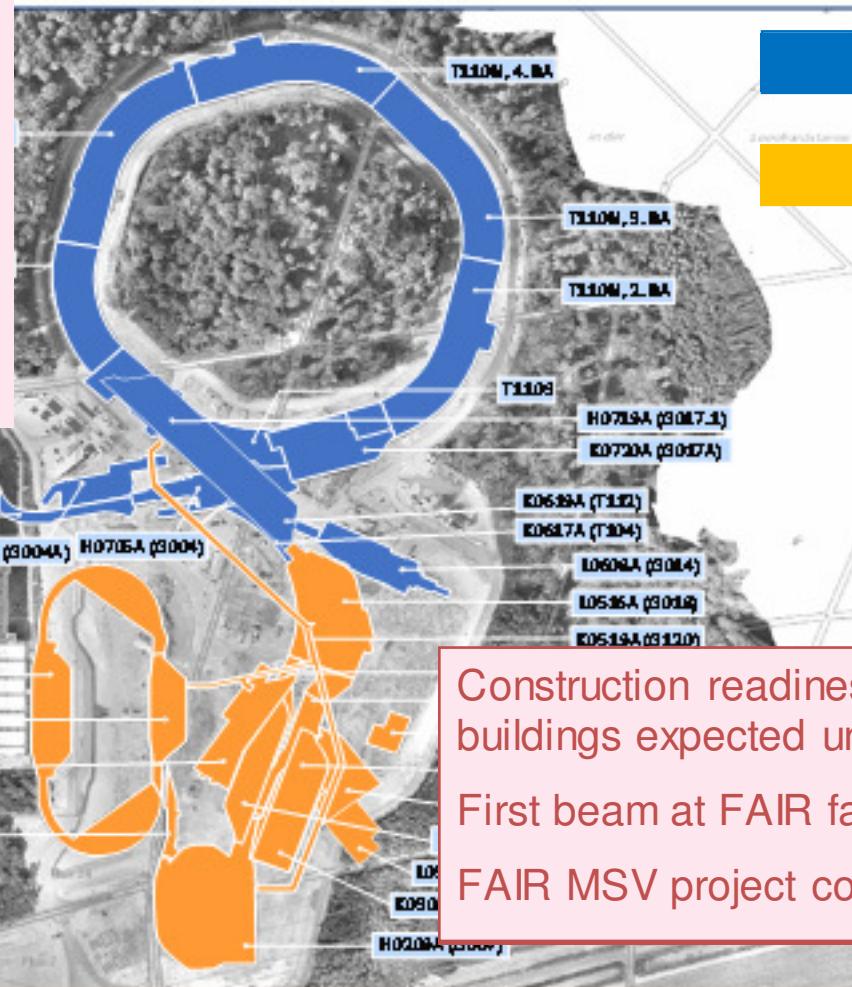
Final BMBF signature for 1. stage of construction funds obtained **September 13<sup>th</sup>**

Tendering just started

Construction work for adoption and enforcement of SIS18 just started

Full scale construction work to start in Summer 2017

*... Realization along the beam line*



north area  
(tendering started)  
south area

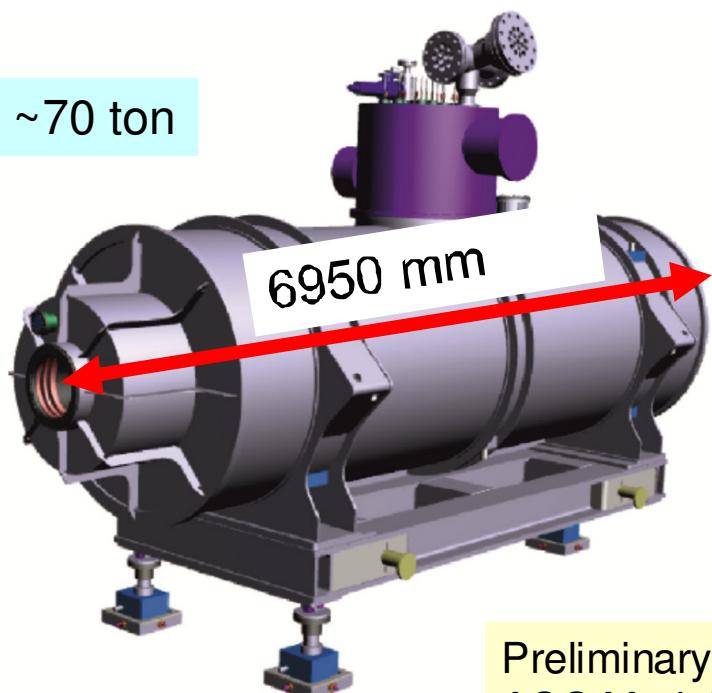
Construction readiness for the different buildings expected until 2022  
First beam at FAIR facility about 2023  
FAIR MSV project completion by 2025

# Major components of SuperFRS

example: SC Multiplets (largest procurement in FAIR/ACC)



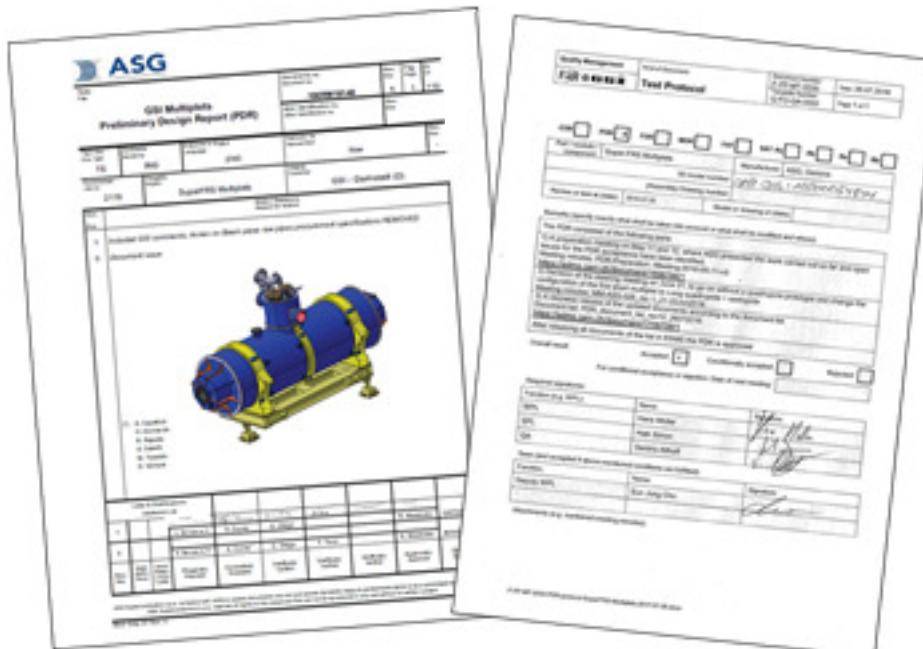
- 8 short multiplets (PS)
  - QS configuration
- 25 long multiplets (mainly MS)
  - Quadrupol triplet
- include corrector elements & steerer



## Overall schedule SC multiplets

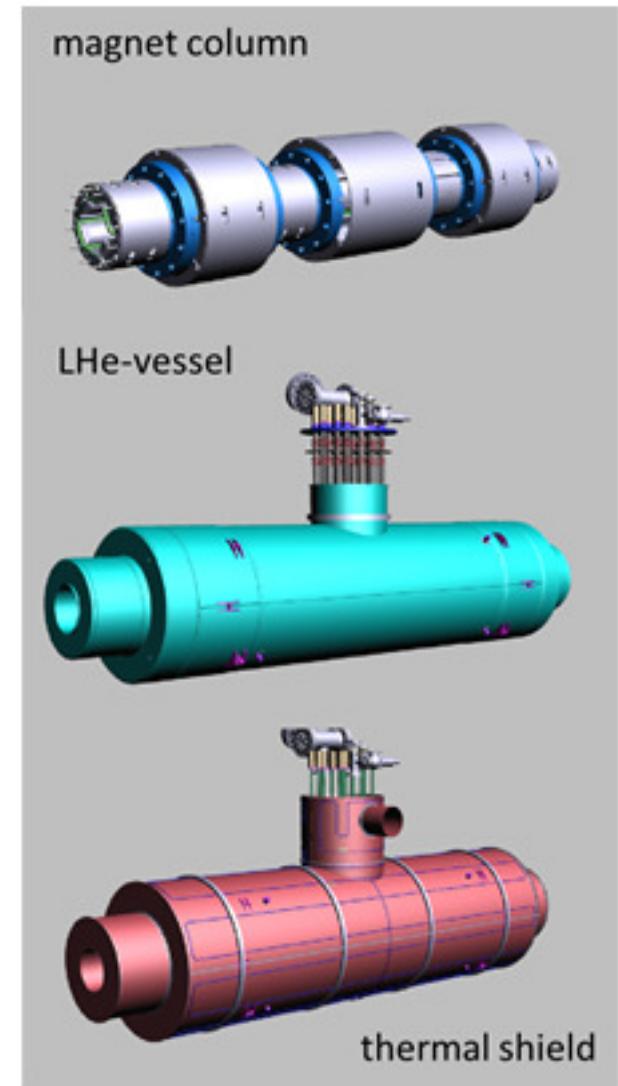
- ✓ Contract closed 07/2015
- ✓ Design phase running
  - ✓ PDR 07/2016
  - FDR 11/2016
  - PRR 02/2017
- FAT of FOS short multiplet 12/2017
  - SAT @ CERN, FOS SM 06/2018
  - SAT ok → start series production
- FAT of FOS long multiplet 07/2018
  - SAT @ CERN, FOS LM 01/2019
- Series testing @ CERN:
  - Q2/2019 – Q3/2022

# SC Multiplets, PDR

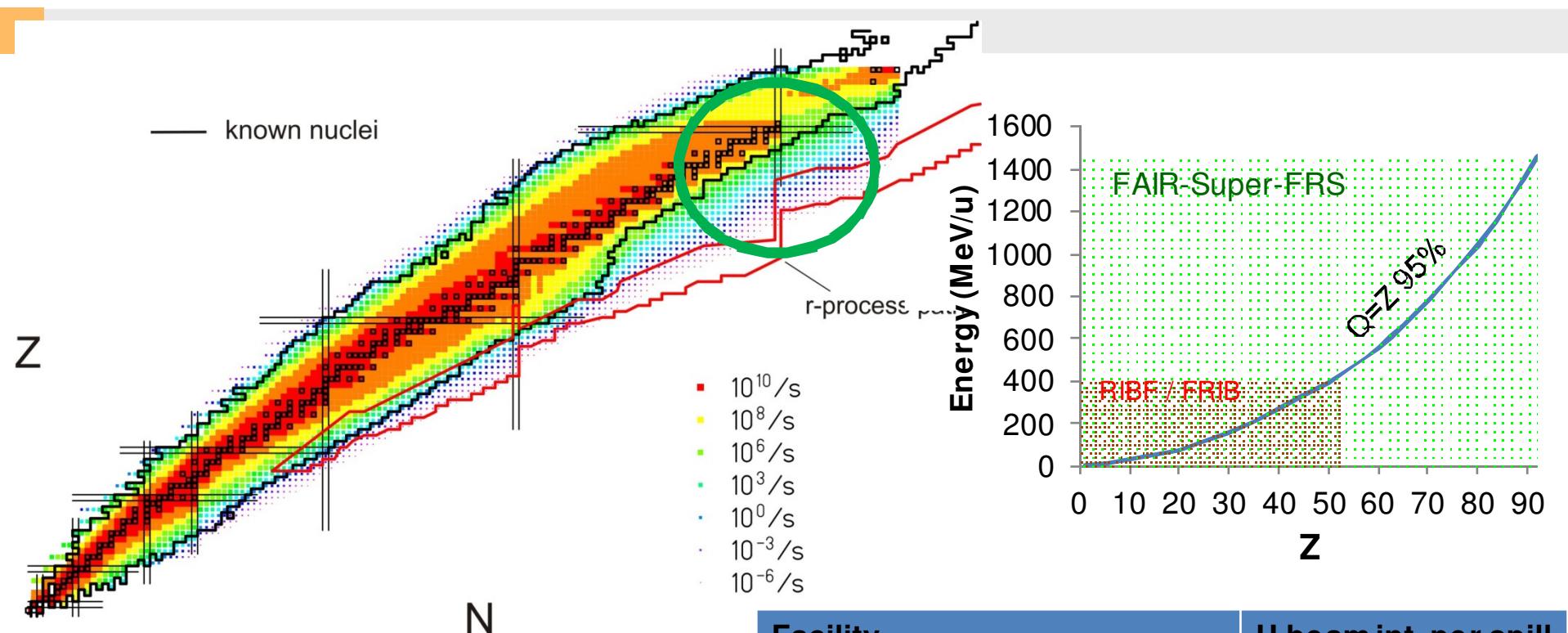


## Preliminary Design Review (PDR)

- Magnetic and mechanical design
- Assembly concept for the pre-series multiplets
- Preparatory meeting on May 11-12
- Approval of 34 documents and model
- PDR released on July 26



# Uniqueness and Competitiveness



- High energies for facilitated separation and unique experiments
- Competitive intensities throughout the periodic table

Facility	U beam int. per spill at production target
previously at GSI	$1 \dots 2 \times 10^9$
after the SIS18 upgrade at GSI	$8 \times 10^9$
commissioning phase SIS100	$2 \times 10^{10}$
final full intensity with SIS100	$3 \times 10^{11}$

# NUSTAR Phases

- **Phase 0**
  - R&D and experiments to be carried out with present facilities (GSI and others) and FAIR/NUSTAR equipment (basic set-ups)
- **Phase 1**
  - Core detectors and subsystems completed
  - First measurements with FAIR/Super-FRS beams
    - **Carry out experiments with highest visibility as part of the core program and within the FAIR MSV ("day-1")**
- **Phase 2**
  - FAIR evolving towards full power
  - Completion of experiments within MSV
    - **Essentially the full program of MSV can be performed**
- **Phase 3**
  - Moderate projects, which have been initiated on the way (outside MSV) can be included (e.g. experiments related to return line for rings or R<sup>3</sup>B spectrometer)
- **Phase 4**
  - Major new investments and upgrades for all experiments

# Beam time FAIR Phase-0

Officially announced as planning basis

Calender year	2018	2019	2020	2021
beam time commissioning/equipment tests [months]	1.5	1.5	1.5	1.5
beam time experiments [months]	3	4	4	4
Total beam time [months]	4.5	5.5	5.5	5.5

*Call for proposals by end of 2016; PAC Meeting in Spring 2017*

## Beam time 2018

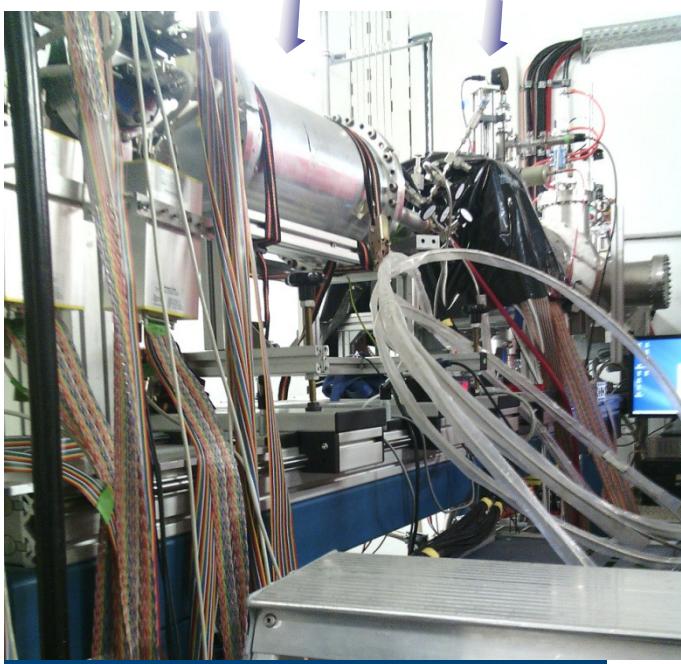
2018 Version vom 06.07.2016 (S.Reimann)												
	Jan	Feb	Mar	Apr	May	Jun	JUL	Aug	Sep	Oct	Nov	Dec
IQ	Shutdown			MC	BC	MK MK		BT	MK		TS	MK
UNILAC	Shutdown		HF-Test	MC HC	BC	MK MK		BT	MK			MK
SIS18	SIS18 upgrade inkl. periodische Dry Runs			MC BC	MK MK		BT	MK			MK	
HEST	Periodische Dry Runs (3-4Tage am Stück)			MC BC	MK MK		BT	MK			MK	
ESR	Periodische Dry Runs (3-4Tage am Stück)			MC		BC	MK				MK	
CRYRING	Periodischer Teststrahlbetrieb local (2x4 Wochen am Stück)			MC		BC						
FERIEN												
Einschränkungen für Experimentbetrieb												
keine												
im Langpulsbetrieb nur A3 Energie												
für 2-3 Monate max. 2 Experimente gleichzeitig												
keine												
nur Speicherbetrieb mit interem Target												
kein Experimentbetrieb möglich												
MC	Machine Checkout = Trockeninbetriebnahme inkl. Kontrollsysteem-/Betriebssoftware Inbetriebnahme											
BC	Beam Commissioning = Inbetriebnahme mit Strahl / Inbetriebnahme Strahlwege (Primärstrahl) mit Pilotstrahl, timing System etc.											
MK	flex. MK-Beamtime (Maschinenexperimente, Maschinenentwicklung, Geräteinbetriebnahmen, Operateursausbildung, FAIR-Detektorentwicklung, Qualifizierung+Referenzmessungen)											
BT	Beamtime = Strahlzeit für PAC-Vergabe vorgesehen											
TS	Flexible technische Strahlunterbrechung für Reparaturen, Softwareupdates usw. (als Block oder verteilt)											
HC	HF-Konditionierung											

# Detector Tests at HTD/HTC

20160618

- TOF systems, including FPGA based read out. Groups from R<sup>3</sup>B: GSI, TUDA, PNPI, Electronics and Detector Lab, Super-FRS
  - Silicon, Diamond, Plastic, Cerenkov
  - Results basis of specifications for In-kind contracts, detailing TDRs and CDRs.

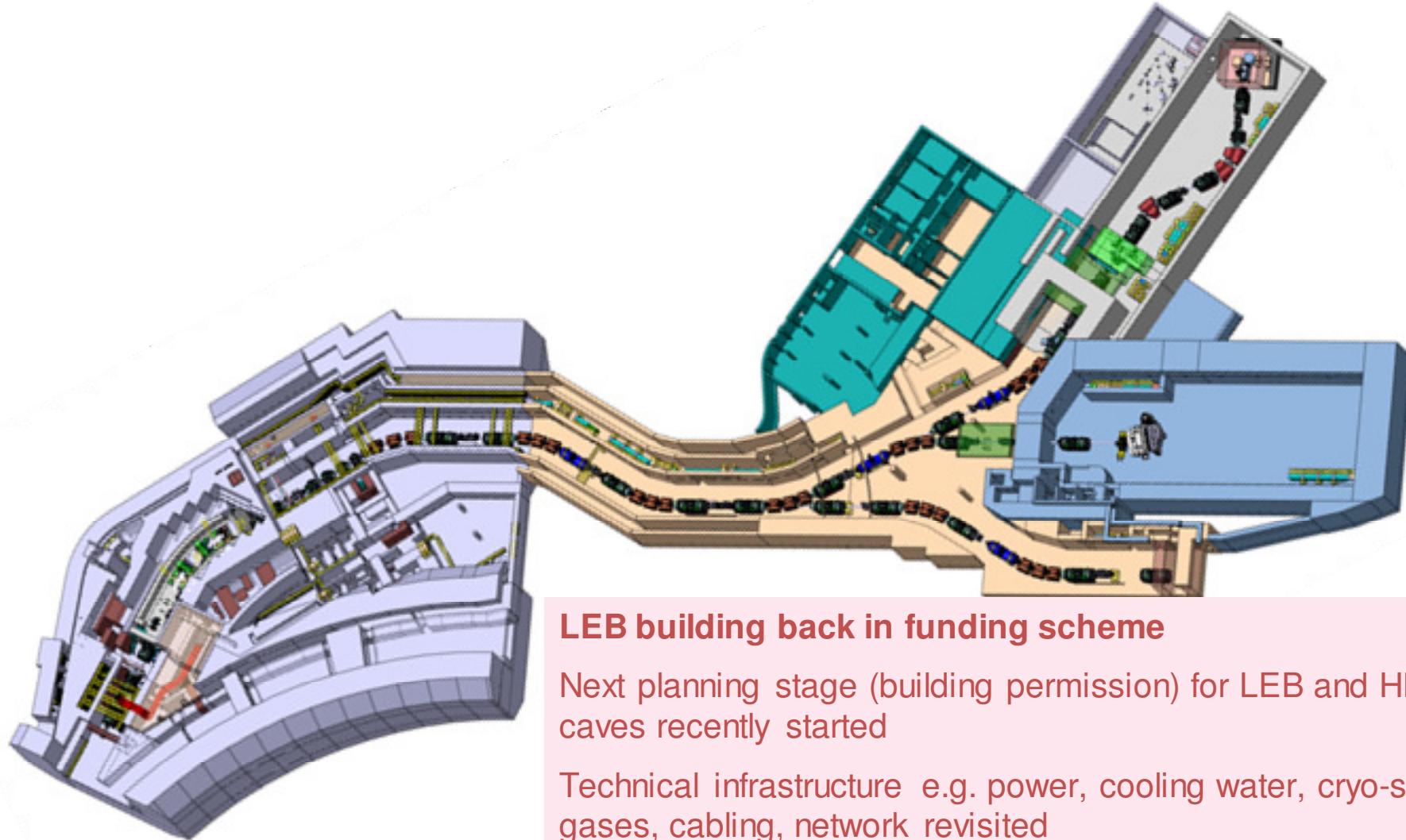
- Active Target & Tracking



- Decay Spectroscopy (DESPEC)



## Super-FRS and NUSTAR caves



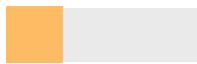
### LEB building back in funding scheme

Next planning stage (building permission) for LEB and HEB caves recently started

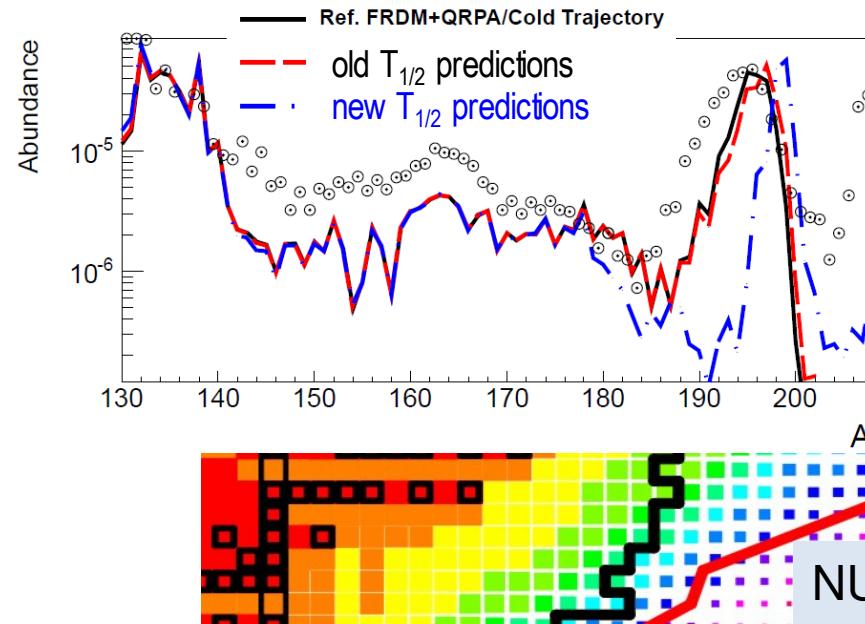
Technical infrastructure e.g. power, cooling water, cryo-supply, gases, cabling, network revisited

LEB Buncher/Spectrometer CDR delivered by VECC Kolkata

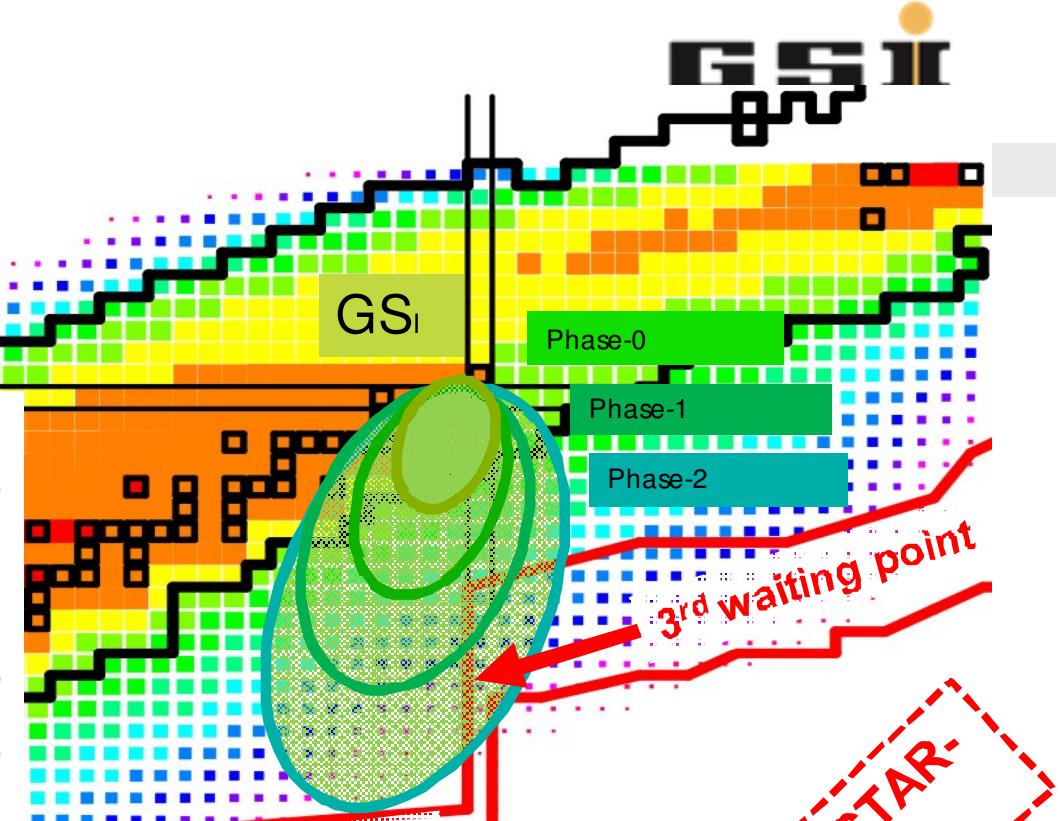
# The N=126 physics case



Previous GSI measurements  
contradict earlier lifetime predictions!  
→ Abundance pattern not understood!



Abundance depends on  
the detailed structure  
of  $N=126$  nuclei around the  
 $3^{\text{rd}}$  r-process waiting point



NUSTAR aims to measure:

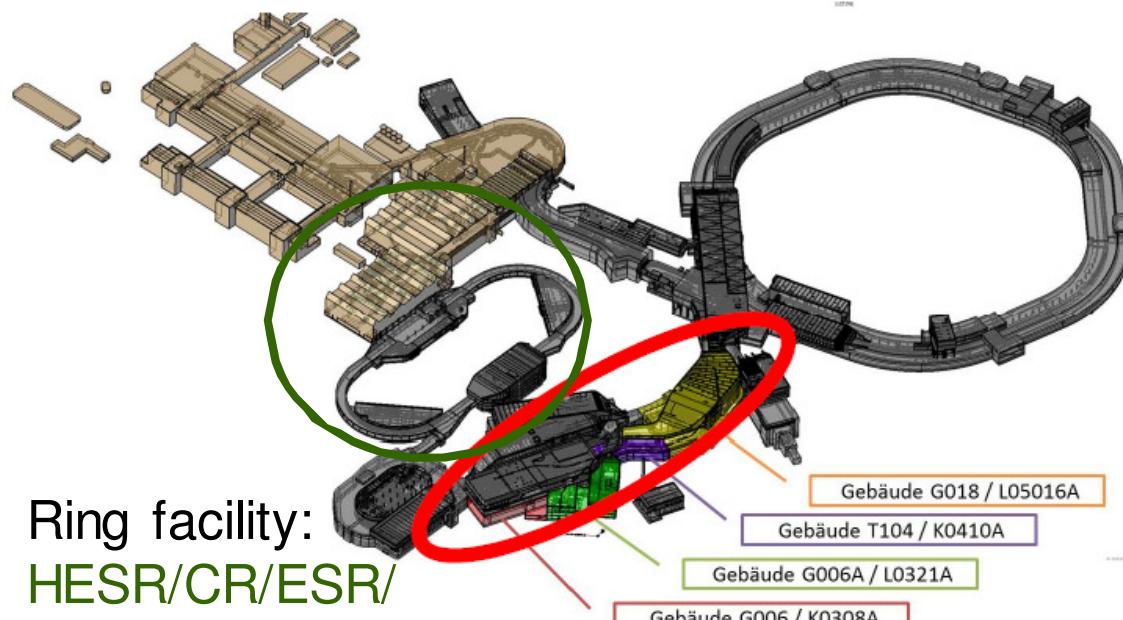
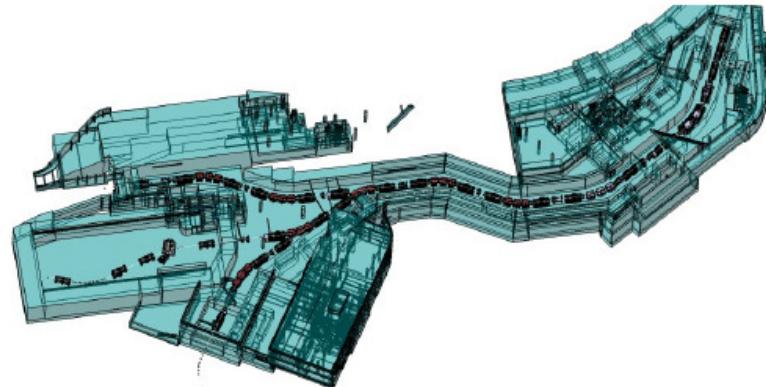
- masses
- $\beta$ -lifetimes
- neutron-branchings
- strength distributions
- level structure

Important unique NUSTAR  
LEB experiment



# Ring experiments with respect to the MSV

- NESR is delayed



Ring facility:  
HESR/CR/ESR/  
Cryring complex



## Some impressions

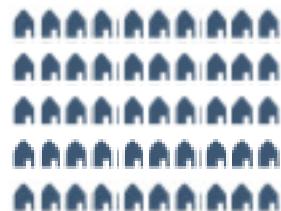
### Baumassen

**2 Mio. m<sup>3</sup>**

**Erde**

werden bewegt

So viel wie für 5.000  
Einfamilienhäuser

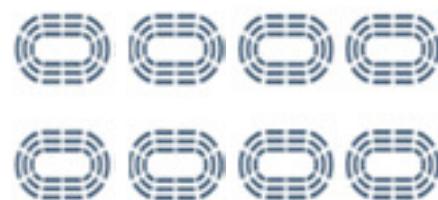


**600.000 m<sup>3</sup>**

**Beton**

werden verbaut

So viel wie 8-mal das Fußballstadion  
Frankfurt

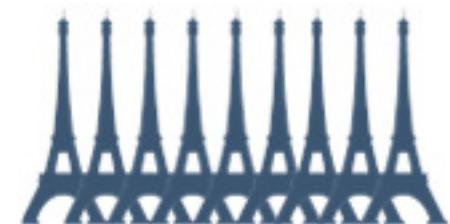


**65.000 t**

**Stahl**

werden eingesetzt

Entspricht neun Eiffeltürmen





**FAIR – das Universum im Labor.**



**FAIR – ein bedeutender Forschungsstandort in Europa.**

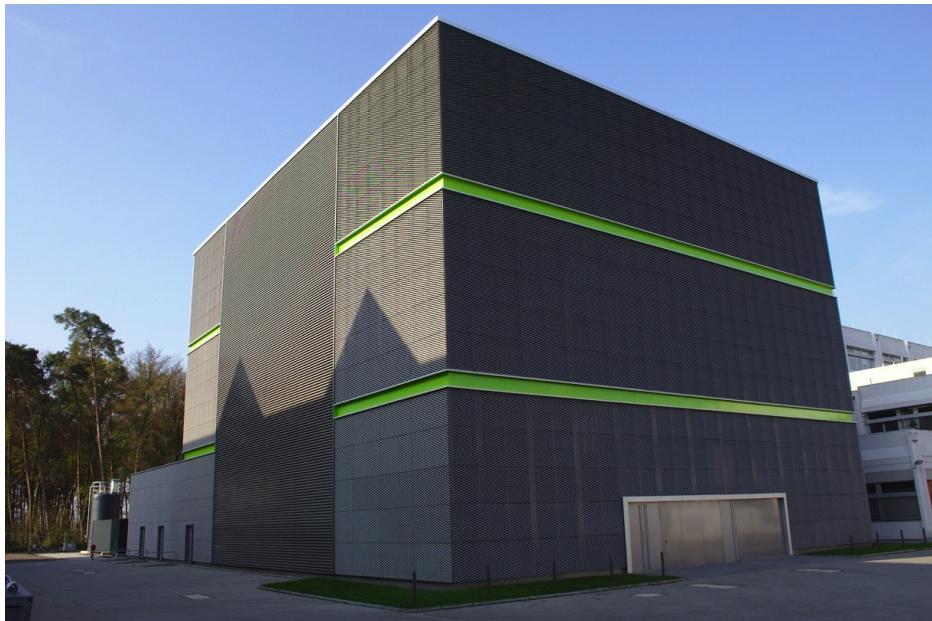


**FAIR – Architektur im Gleichgewicht mit der Natur.**



**FAIR – Hochtechnologie in der Forschung.**

## GSI/FAIR Green Cube



Constructed: Dec '14 – Nov '15

Building: 6 Floors, 4.645 sqm  
768 19" racks  
(256 racks in 1<sup>st</sup> stage)

Cooling/  
Power: 12 MW  
(4 MW in 1<sup>st</sup> stage)

Cost: 16 M€ (1<sup>st</sup> stage: 11.5 M€)

Common data center for

- FAIR Tier 0
- FAIR Experiment Online Clusters
- GSI Computing (ALICE Tier 2, National Analysis Facility)

# Summary



## FAIR construction !

- Phase-0 **physics** program (@GSI) viable and in preparation  
→ Call for proposals end 2016

- Major components become operational
- Buildings on the way!

 Bundesministerium  
für Bildung  
und Forschung

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z.H. Frau Frau Bärbel Geurts  
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64283 Darmstadt

BETREFF FAIR-Projekt  
hier: Zustimmung zum vorgeschlagenen Vorgehen

