NUSTAR Status

J. Gerl

NUSTAR Annual Meeting

FAIR/GSI Darmstadt, Germany

March 2015

NUclear STructure Astrophysics and Reactions

What are the limits for existence of nuclei?

- Where are the proton and neutron drip lines situated?
- Where does the nuclear chart end?

How does the nuclear force depend on varying proton-to-neutron ratios?

- What is the isospin dependence of the spin-orbit force?
- How does shell structure change far away from stability?

How to explain collective phenomena from individual motion?

- What are the phases, relevant degrees of freedom, and symmetries of the nuclear many-body system?

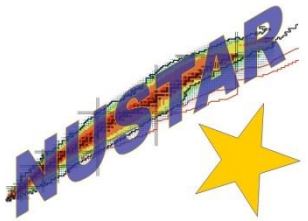
How are complex nuclei built from their basic constituents?

- What is the effective nucleon-nucleon interaction?
- How does QCD constrain its parameters?

Which are the nuclei relevant for astrophysical processes and what are their properties?

- What is the origin of the heavy elements?

NUSTAR - The Project



DESPEC	γ-, β-, α-, p-, n-decay spectroscopy
ELISE	elastic, inelastic, and quasi-free e^--A scattering
EXL	light-ion scattering reactions in invere kinematics
HISPEC	in-beam γ spectroscopy at low and intermediate energy
ILIMA	masses and lifetimes of nuclei in ground and isomeric states
LASPEC	Laser spectroscopy
MATS	in-trap mass measurements and decay studies
R3B	kinematically complete reactions at high beam energy
Super FRS	RIB production, identification and spectroscopy
SHE	Nuclear physics and chemistry of super-heavy elements

The Approach

Complementary measurements leading to consistent answers

The Collaboration

> 850 scientists

186 institutes

39 countries

The Investment

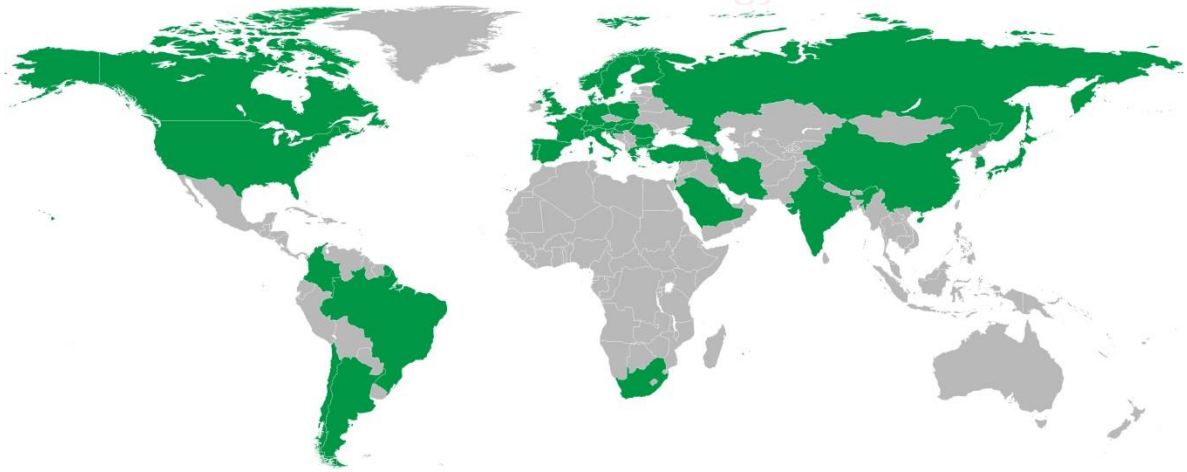
82 M€ Super FRS

73 M€ Experiments

NUSTAR - The Project

Evolutionary approach:

Advancing instrumentation by continuous development and gaining experience by physics exploitation



>50 instrumentation sub-projects (MSV)

several 1000 major components

The Approach

Complementary measurements leading to consistent answers

The Collaboration

> 850 scientists

186 institutes

39 countries

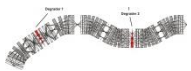
The Investment

82 M€ Super FRS

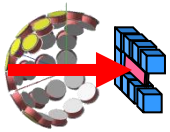
73 M€ Experiments

Complementarity of NUSTAR experiments

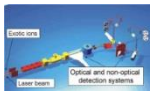
Super-FRS



HISPEC/ DESPEC

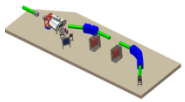


LASPEC

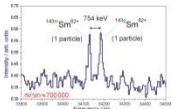


MATS

R3B



ILIMA



SHE

ELISE

EXL

	Super-FRS	HISPEC/DESPEC	LASPEC	MATS	R3B	ILIMA	SHE	ELISe	EXL
Masses		Q-values, isomers		dressed ions, highest precision	unbound nuclei	bare ions, mapping study	precision mass of SHEs		
Half-lives	ps...ns-range	dressed ions, ms...s			resonance width, decay up to 100ns	bare ions, ms…years	μs...days		
Matter radii	interaction x-section				interaction x-section				matter densitiy distribution
Charge radii	charge-changing cross sections		mean square radii		charge-changing cross sections			charge density distribution	
Single-particle structure	high resolution, angular momentum	high-resolution particle and γ-ray spectroscopy	magnetic moments, nucl. spins	evolution of shell str., pairing int., valence nucl.	quasi-free knockout, short-range and tensor	evolution of shell closures, pairing corr.	shell structure of SHEs		low momentum transfers
Collective behavior		electromag. transitions	quadrupole moments	halo structure	dipole response	changes in deformation		electromag. transitions	monopole resonance
EoS					polarizability, neutron skin			neutron skin ➔	neturon skin, Compressibility
Exotic Systems	bound mesons, hypernuclei, nucleon res.								

NUSTAR - The Facility

Low Energy Branch:

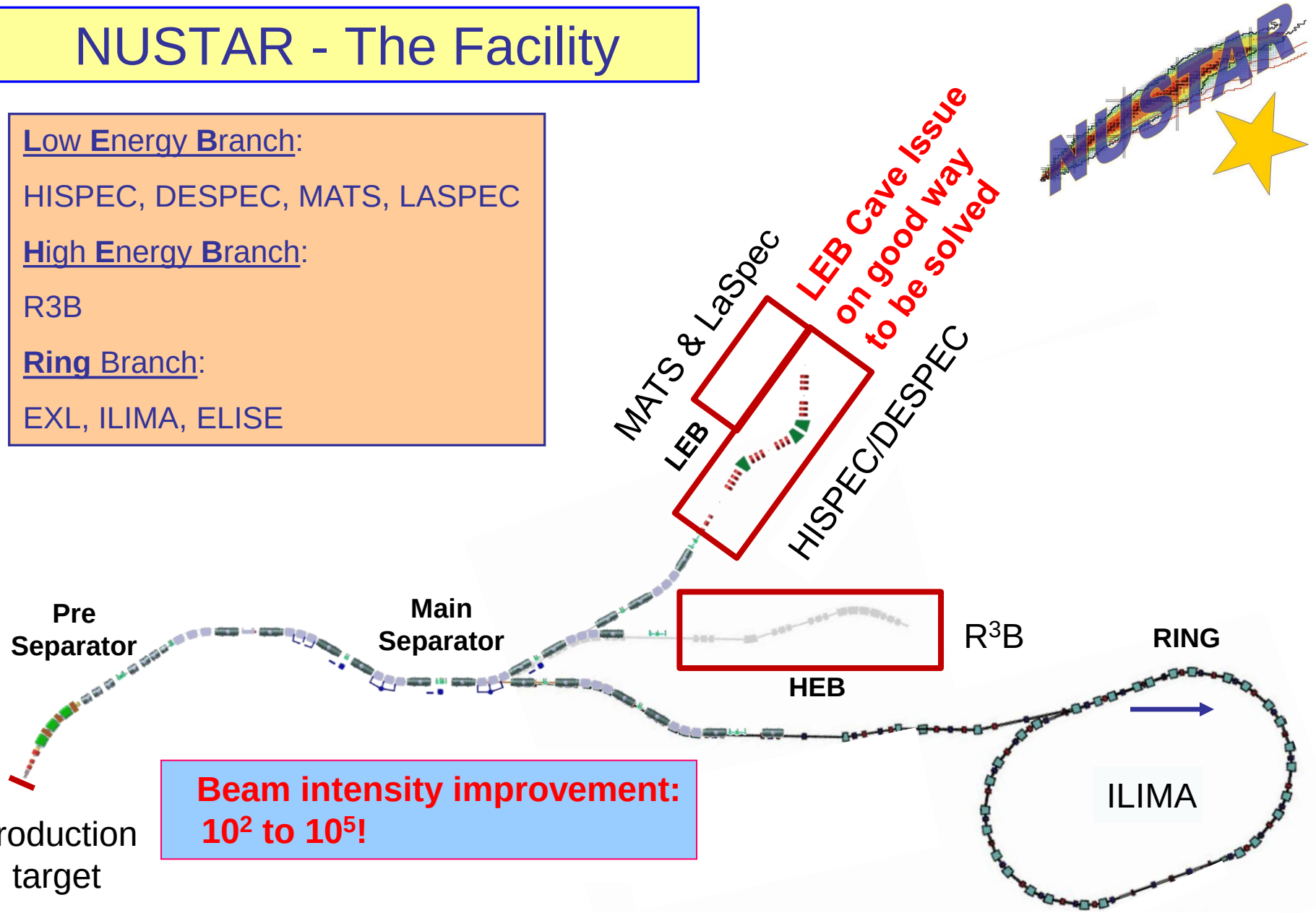
HISPEC, DESPEC, MATS, LASPEC

High Energy Branch:

R3B

Ring Branch:

EXL, ILIMA, ELISE



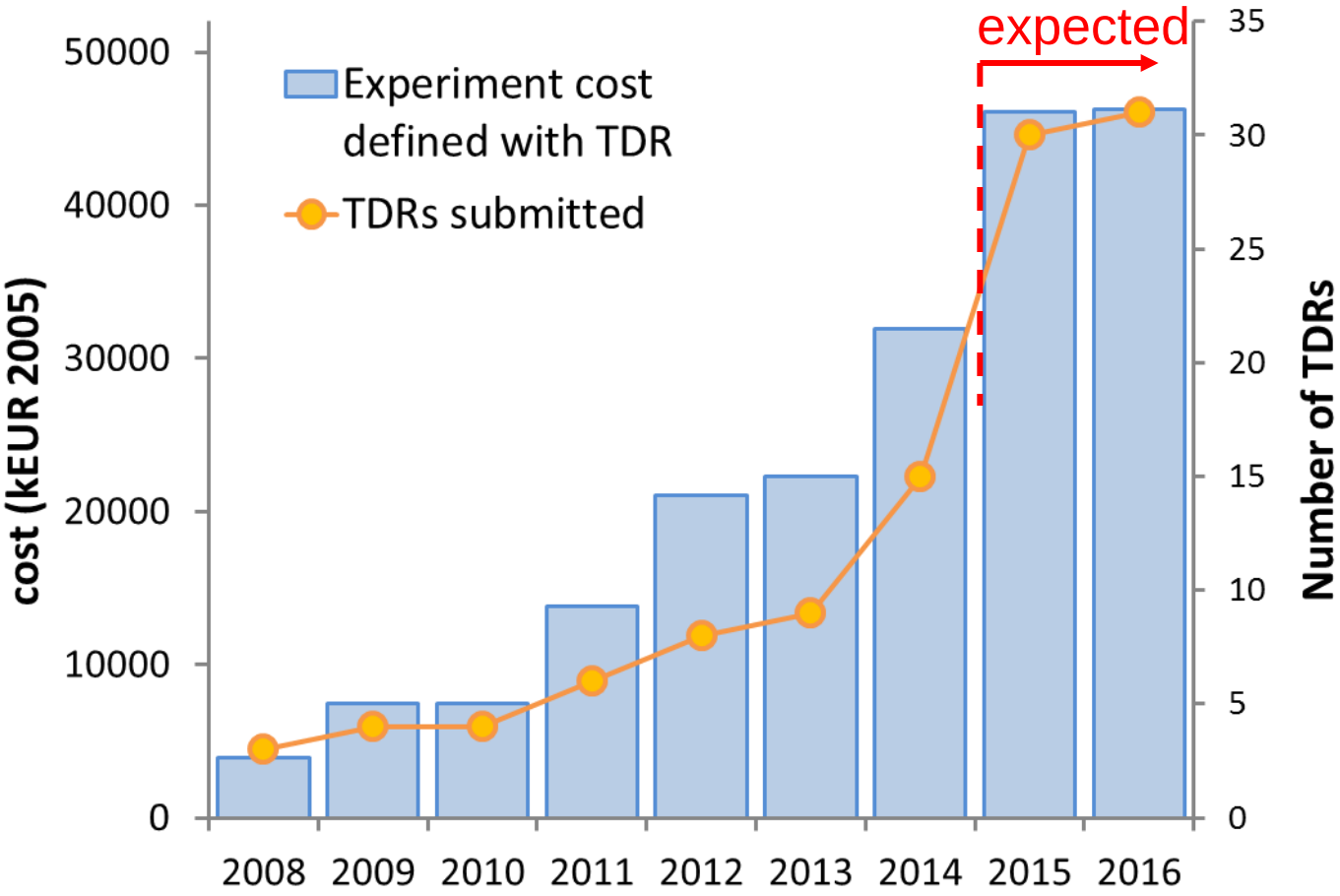
NUSTAR Work Packages

NUSTAR - TDR Status

- Approved TDRs (10):
  - HISPEC/DESPEC (6) (LYCCA, Plunger, AIDA, BELEN, MONSTER,DTAS)
  - MATS + LaSpec (1) (all subsystems)
  - R^3B (3) (Multiplet, NeuLAND, CALIFA-barrel)
- Submitted (6):
  - HISPEC/DESPEC (AGATA, DEGAS, NEDA)
  - R^3B (GLAD, CALIFA forward endcap, tracking detectors)
  - AGATA and GLAD special cases and not (yet) with ECE

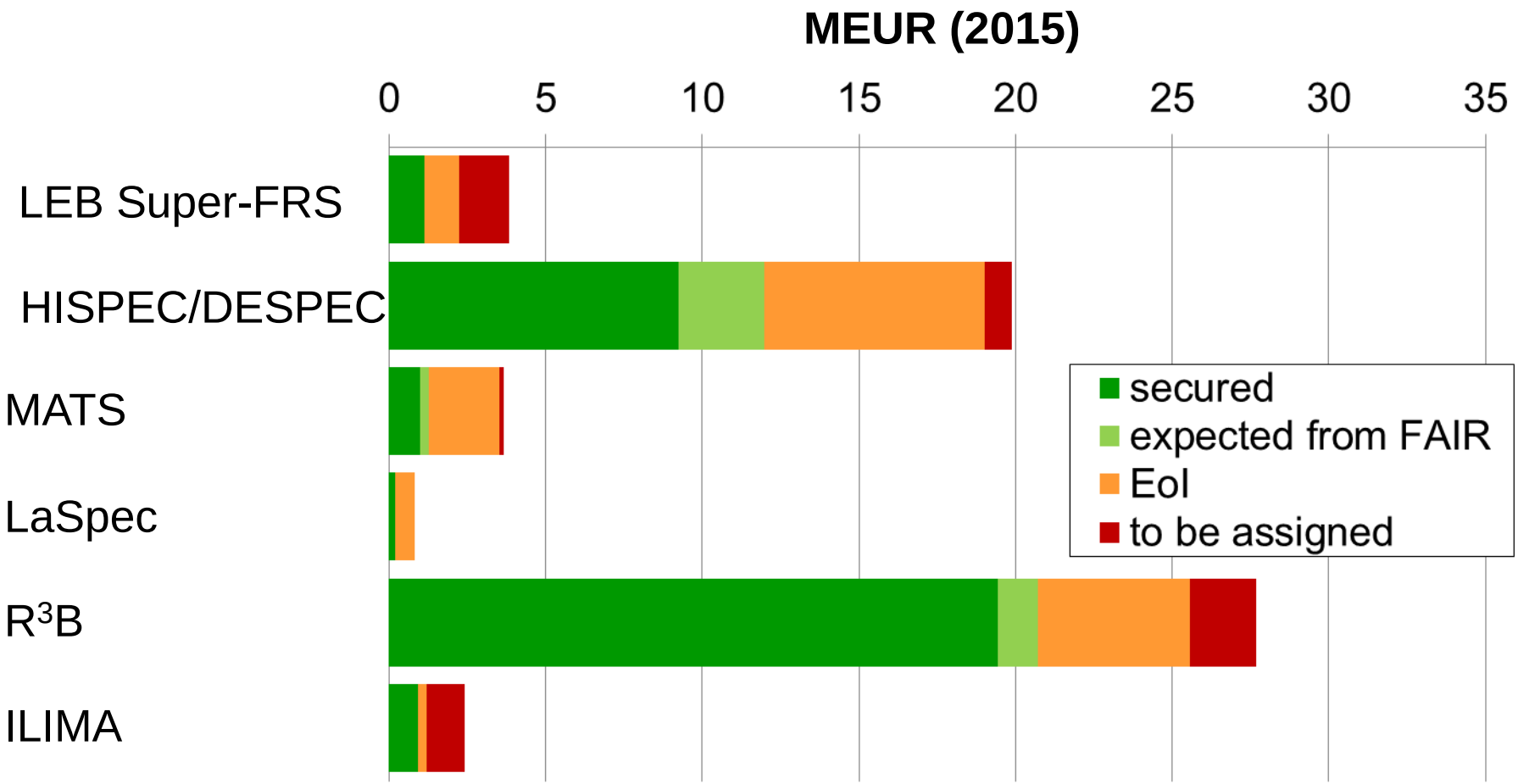
TDRs expected (18) (submission profile – January 2015)			
2015	2016	2017	2018
15	3	0	0

NUSTAR - TDR Status



~50% of TDRs define ~70% of construction costs for NUSTAR.

Status of NUSTAR experiment funding



Life could be so easy, but....

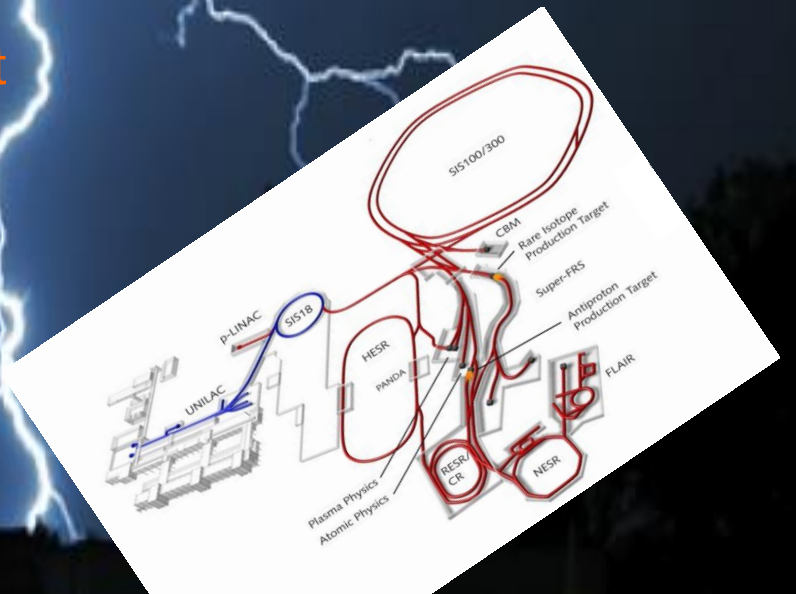
FAIR in Great Danger

Possibly 200 M€ cost overrun for Construction!

Years of additional Time Delay before Operation!

Increasing Attacks from other Science Communities!

⟶ BMBF launched another evaluation of FAIR Science, Infrastructure and Management



FAIR Evaluation

Date: 16.-18. Feb. 2015

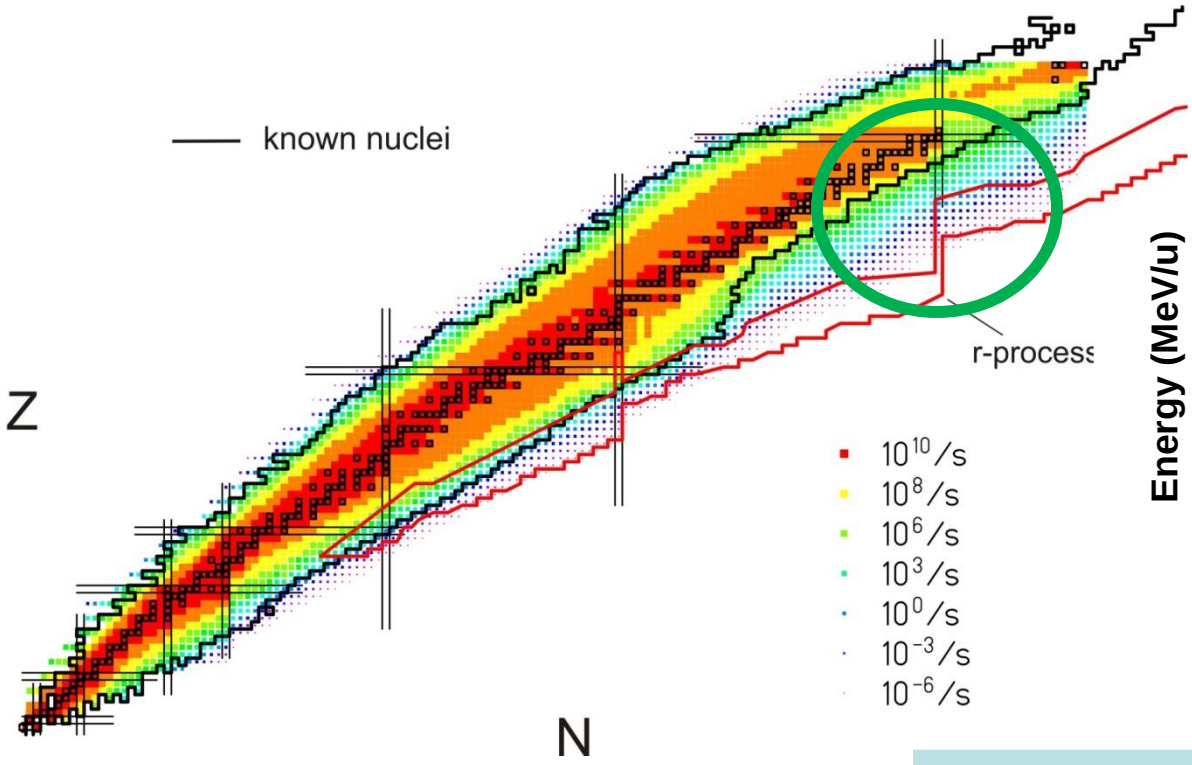
Committee: R. Heuer + 6 scientists (R. Krücken for NUSTAR) + 6 managers

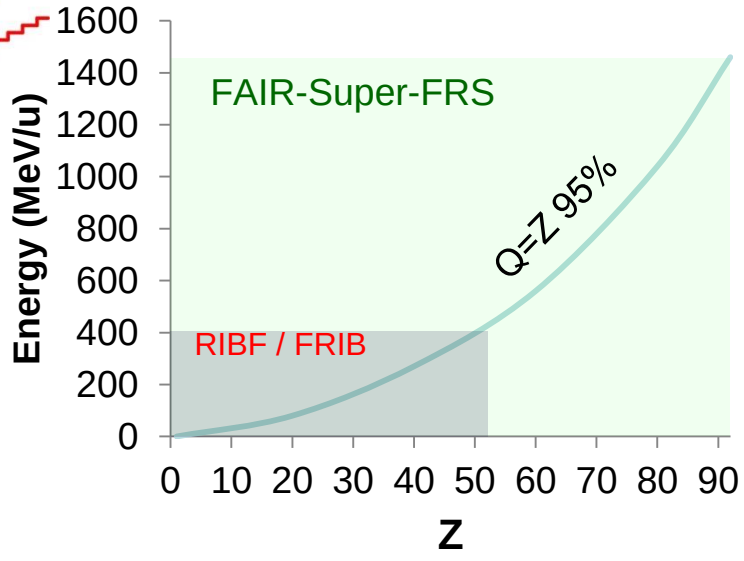
Basis: Written reports + presentation and discussions

Results: -FAIR Science continues to be top-notch
-NUSTAR ranks top
-Status of project seen very critical
-Concrete recommendations in document released on Feb. 25 to Management Boards of FAIR and GSI and Staatssekretär G. Schütte
-FAIR project shall be continued, but...*cost ceiling, new management*,...

Next steps: -Discussion and decisions at GSI Aufsichtsrat on March 10
-Discussion and decisions at FAIR Council on March 11

Uniqueness and Competitiveness





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

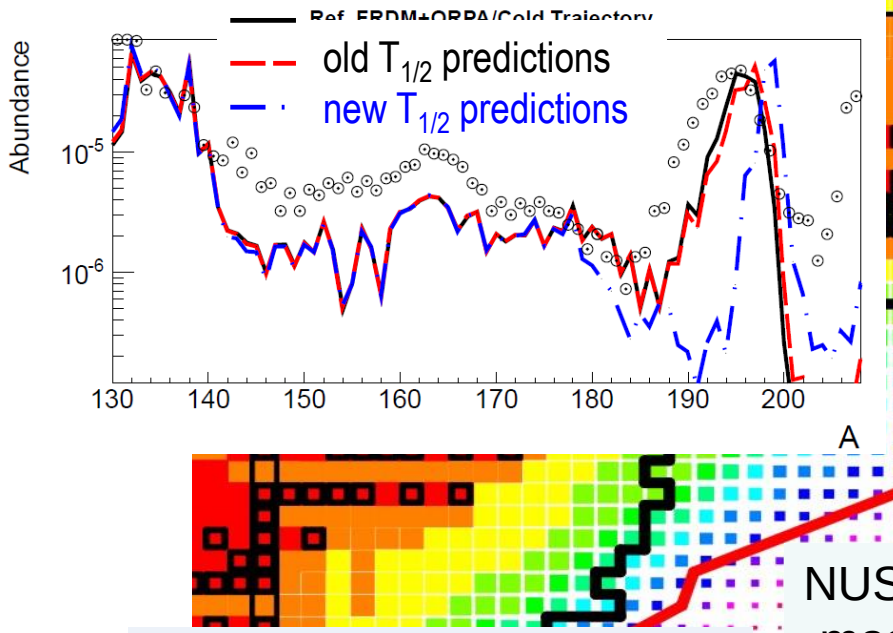
Facility	U beam int. per spill at production target
previously at GSI	1...2x10^{9}
after the SIS18 upgrade at GSI	8x10^{9}
commissioning phase SIS100	2x10^{10}
final full intensity with SIS100	3x10^{11}

Highlights of the initial Phase – 1 programme

- Understanding the 3rd r-process peak by means of comprehensive measurements of masses, lifetimes, neutron branchings, dipole strength, and level structure along the N=126 isotones;
- Equation of State (EoS) of asymmetric matter by means of measuring the dipole polarizability and neutron skin thicknesses of tin isotopes with N larger than 82 (in combination to the results of the first highlight);
- Exotic hypernuclei with very large N/Z asymmetry.

The N=126 Physics case

Previous GSI measurements
contradict earlier lifetime predictions!
→ Mass abundances not understood!



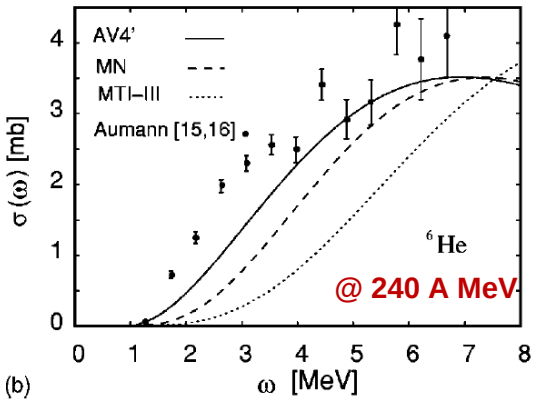
Mass abundances depend
on the detailed structure
of N=126 nuclei around the
3rd r-process waiting point

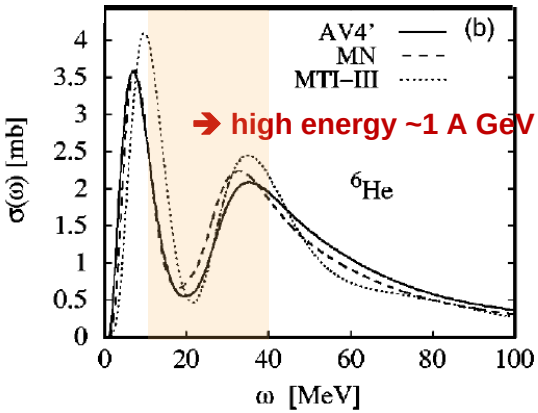
NUSTAR aims to measure:
-masses
-β-lifetimes
-neutron-branchings
-strength distributions
-level structure

Important unique NUSTAR-LEB experiment

Phase 1 Physics with R3B setup

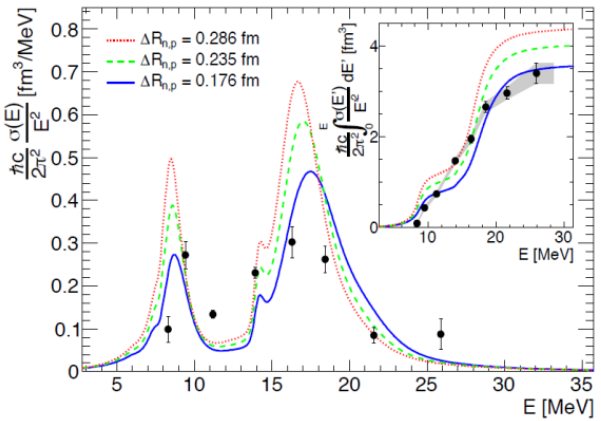
- core vs. neutron skins & halos → density / asymmetry





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

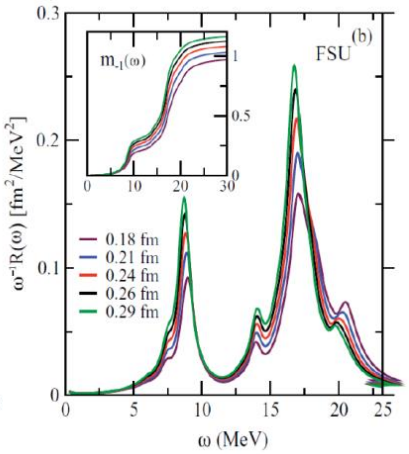
- access to EoS (e.g. neutron star) & low lying E1 strength (r-process)



$$\alpha_D = \frac{\hbar c}{2\pi^2}\int_0^\infty \frac{\sigma(E)}{E^2}dE$$

D. Rossi et al.
PRL **111** (2013) 242503

skin thickness **^{68}Ni**
0.175(21) fm



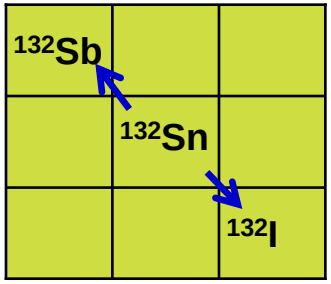
Pb chain &
N=126 isotones

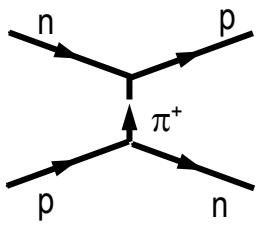
~1 A GeV →
bare ions
Fragment
identification

J. Piekarewicz, PRC **83** (2011) 034319

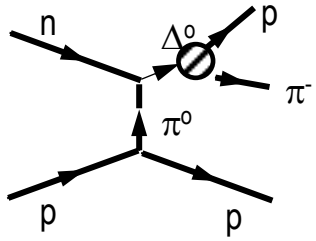
Phase 1 Physics with high-resolution spectrometer

Isobaric charge exchange reactions



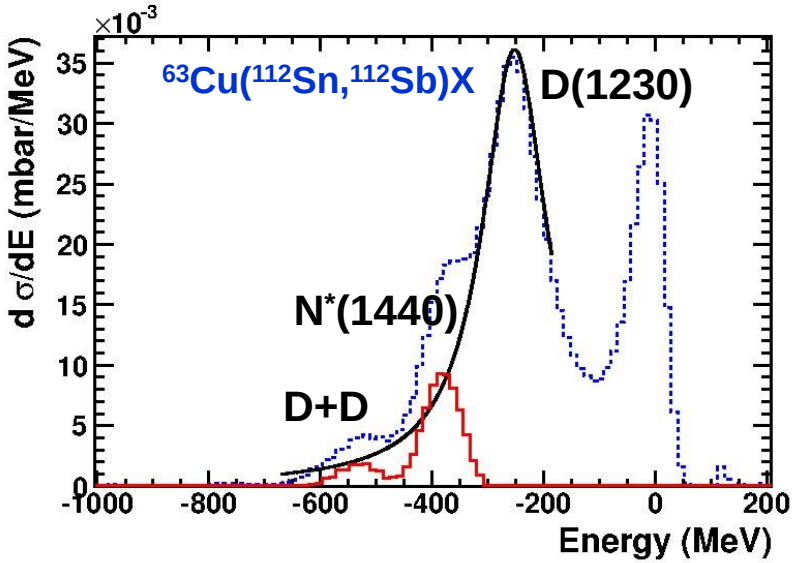


quasi-elastic



inelastic

Relativistic neutron-rich projectiles (>600 MeV/u)
High-resolving power spectrometer
→ Pilot experiments with stable beams at FRS/GSI in 2017+
→ Experiments with asymmetric nuclear beams at Super-FRS/FAIR

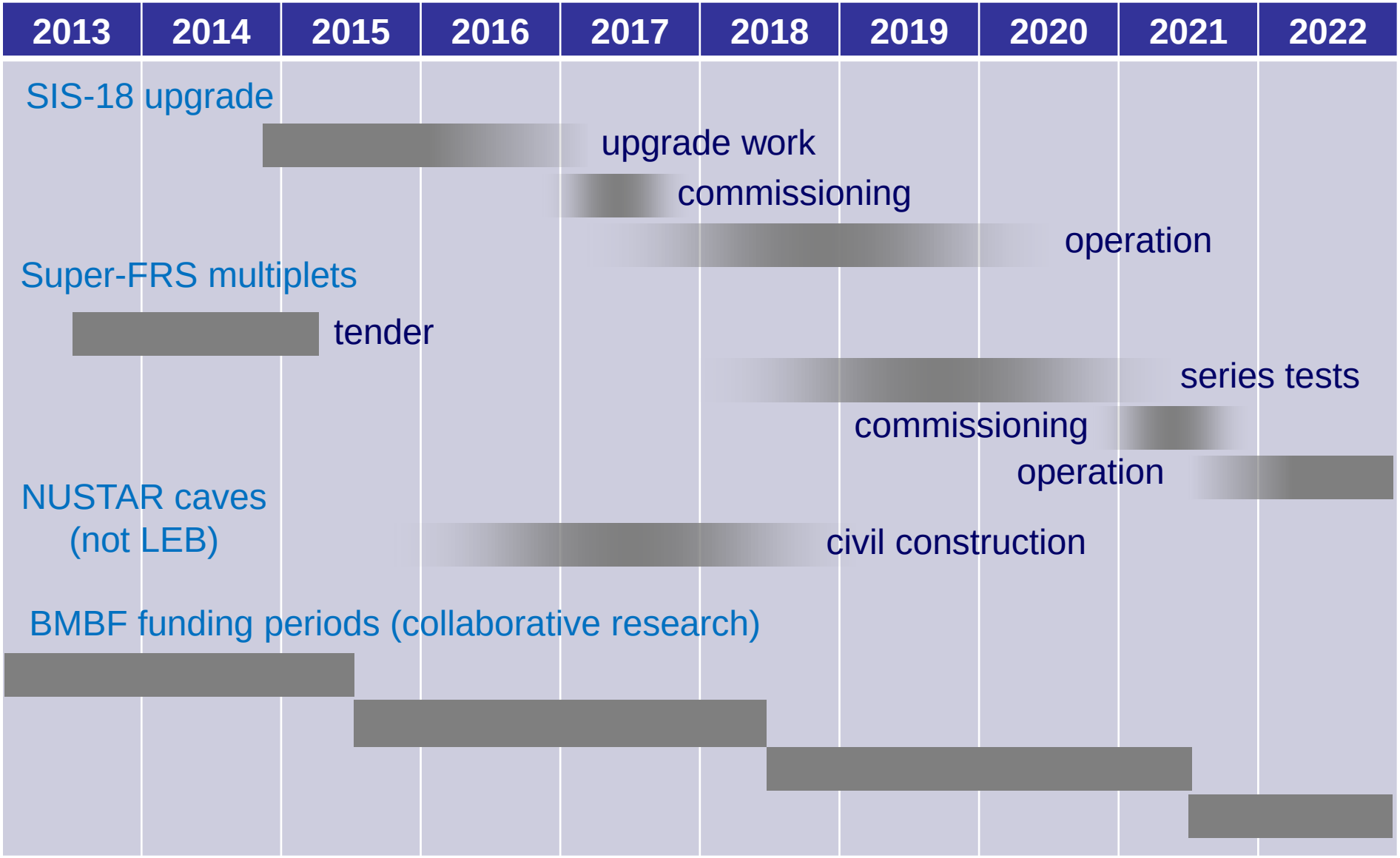


The momentum recoil induced by the pion emission proves the excitation of the resonances

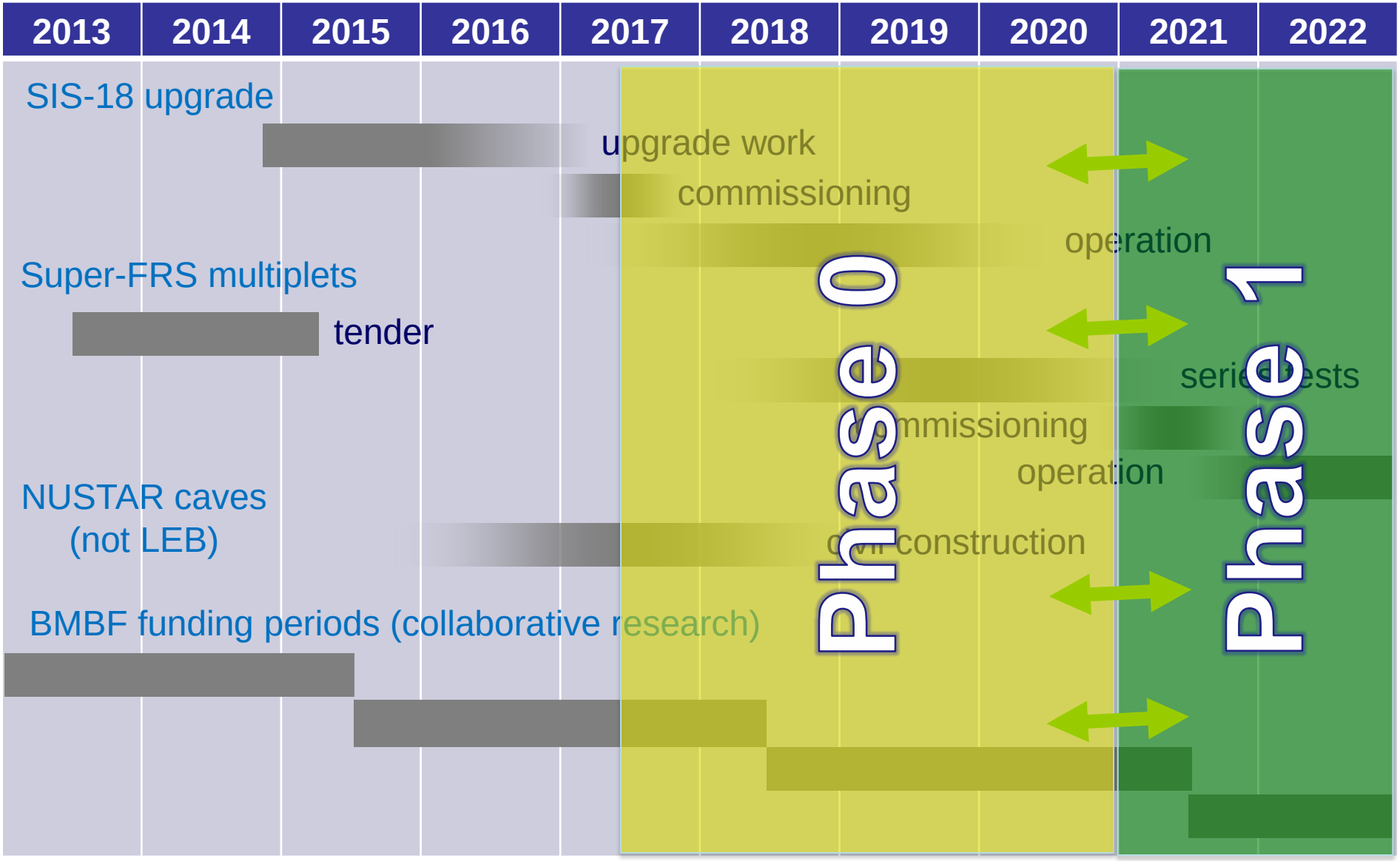
Physics case

- ✓ Nuclear Structure Physics with the excited nucleon.
- ✓ In-medium baryon resonances.
- ✓ Role of nucleon excitations in massive neutron stars.
- ✓ Constraining the symmetry energy s(n,p)/s(p,n)

Joining Time Lines



Initial NUSTAR Phases



Beam Time at GSI

Current planning:

2015 Break for SIS-18 upgrade and shielding enforcement and UNILAC renovation.
Q3-4: UNILAC operation (no call, but internal disc. and PAC 17.4.)

2016 Break for SIS-18 upgrade and shielding enforcement, UNILAC operation under discussion

2017: Q2-3: SIS-18 commissioning, Q4: SIS-18 operation starts, mainly FAIR preparation and experiment commissioning

2018: 4-5 months, FAIR preparations and experiment programme

2019: 5-6 months, FAIR preparations and experiment programme

2020: 5-6 months, FAIR preparations and experiment programme

Agreed by BMBF and GSI management

Current readiness of NUSTAR experiments

Modularized Start Version (MSV)		Phase 0	Phase 1
1.2.1	LEB Super-FRS		
1.2.2	HISPEC/DESPEC	√	√
1.2.3	MATS	√	√
1.2.4	LaSpec	√	√
1.2.5	R^3B	√	
1.2.6	ILIMA	√	
Beyond MSV			
1.2.8	ELISe		
1.2.9	EXL	√	
New experiments			
1.2.10	Super-FRS physics	√	√
1.2.11	SHE	√	√

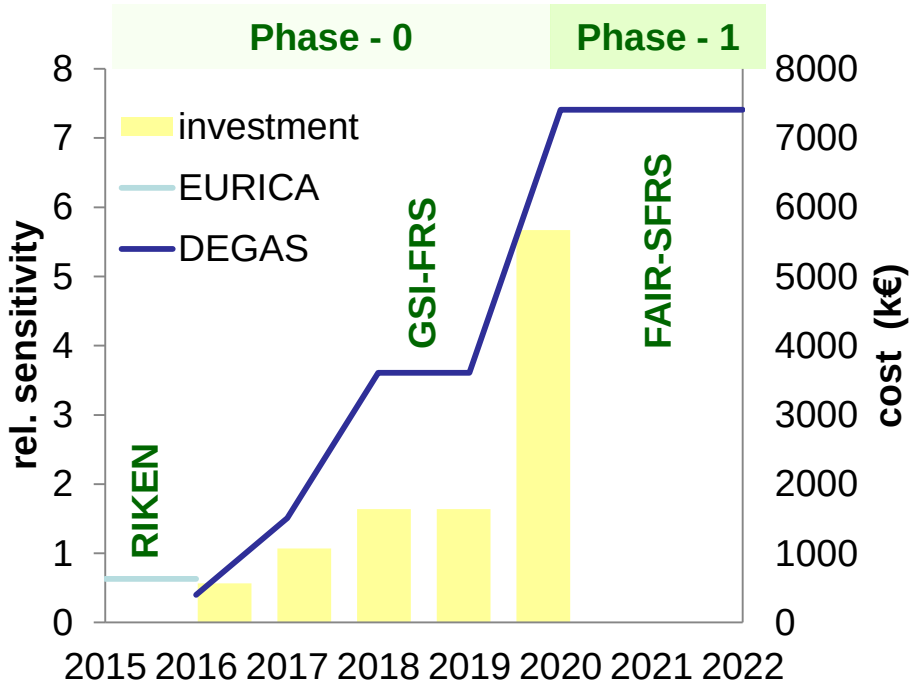
Concluding remarks

- NUSTAR has an excellent science case.
- The case will still be valid in 202x for NUSTAR/Super-FRS@FAIR.
- The situation for LEB building has to be resolved soon.
- The critical path is the readiness of Super-FRS.
- The NUSTAR equipment/end stations will be ready well in time for Super-FRS beams.
- NUSTAR has an intermediate plan, and pursues an evolutionary approach: perform unique and exciting pilot experiments at GSI with the available new equipment for FAIR (phase 0). → **Topic for session on Friday**
- Storage-ring activities exhibit world-unique features and must be strengthened.

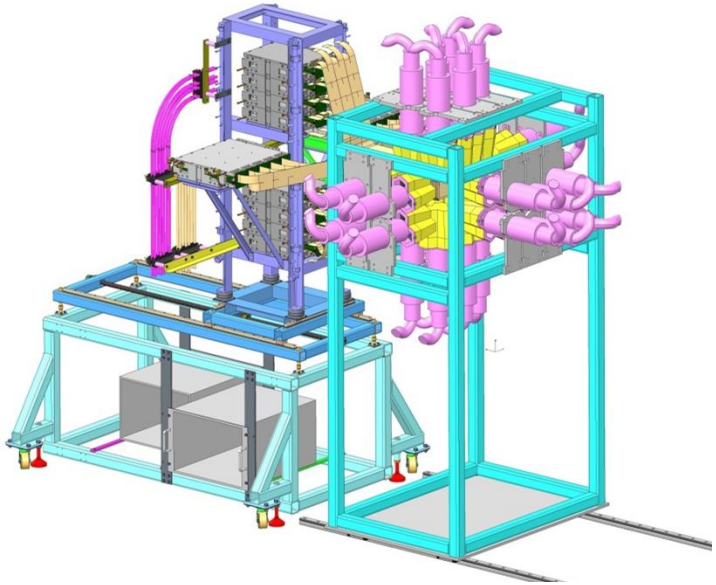
NUSTAR - Phases

- **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^3B spectrometer)
- **Phase 4**
  - Major new investments and upgrades for all experiments

Work packages and funding: DEGAS array



DEGAS array

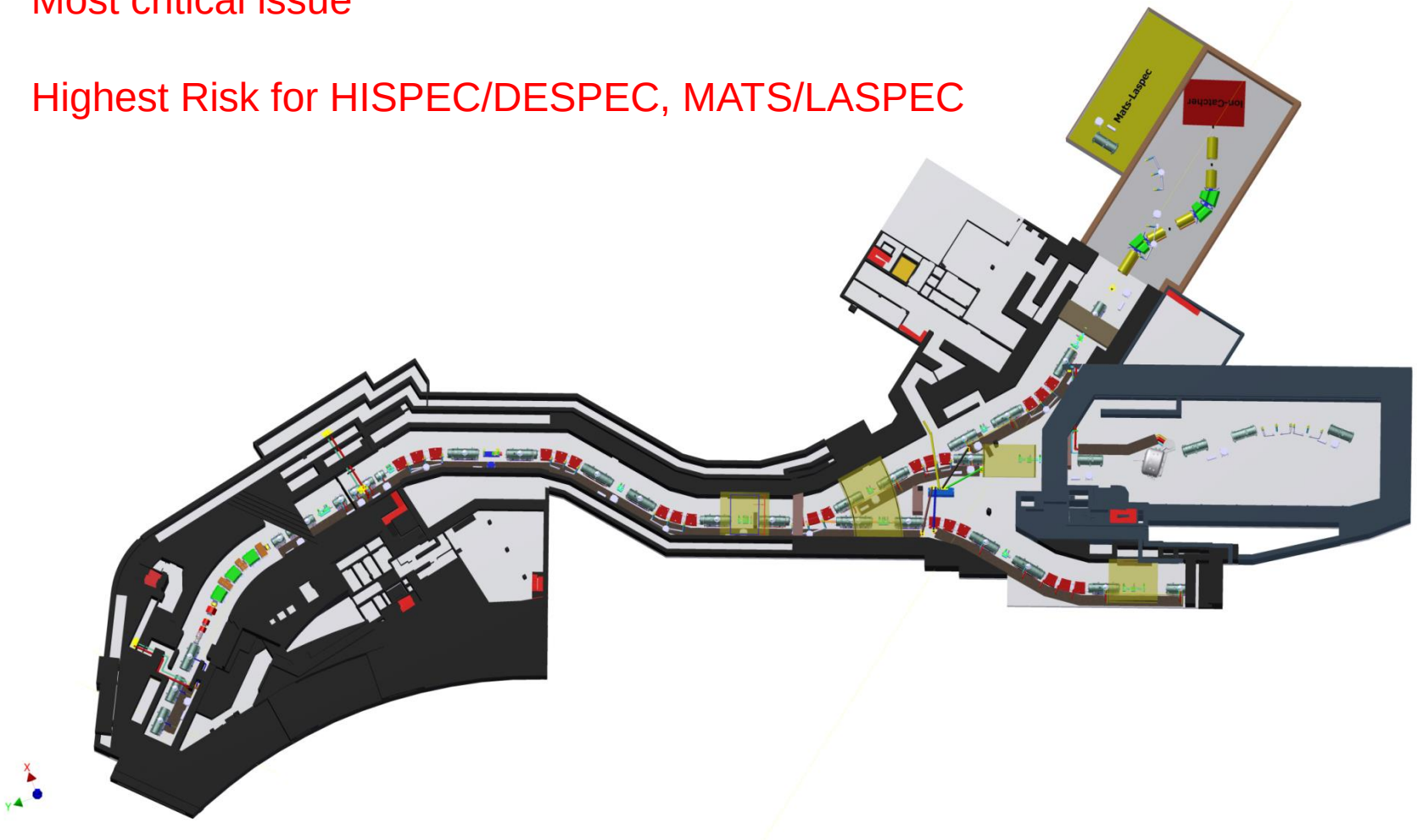


- The predecessor of DEGAS, namely EURICA is running currently in RIKEN.
- An intermediate version is planned for experiments at GSI from 2017 onwards.
- The full version shall be available once FAIR is operational.
- The course of construction is mainly determined by the availability of funding.

Low Energy Branch Building

Most critical issue

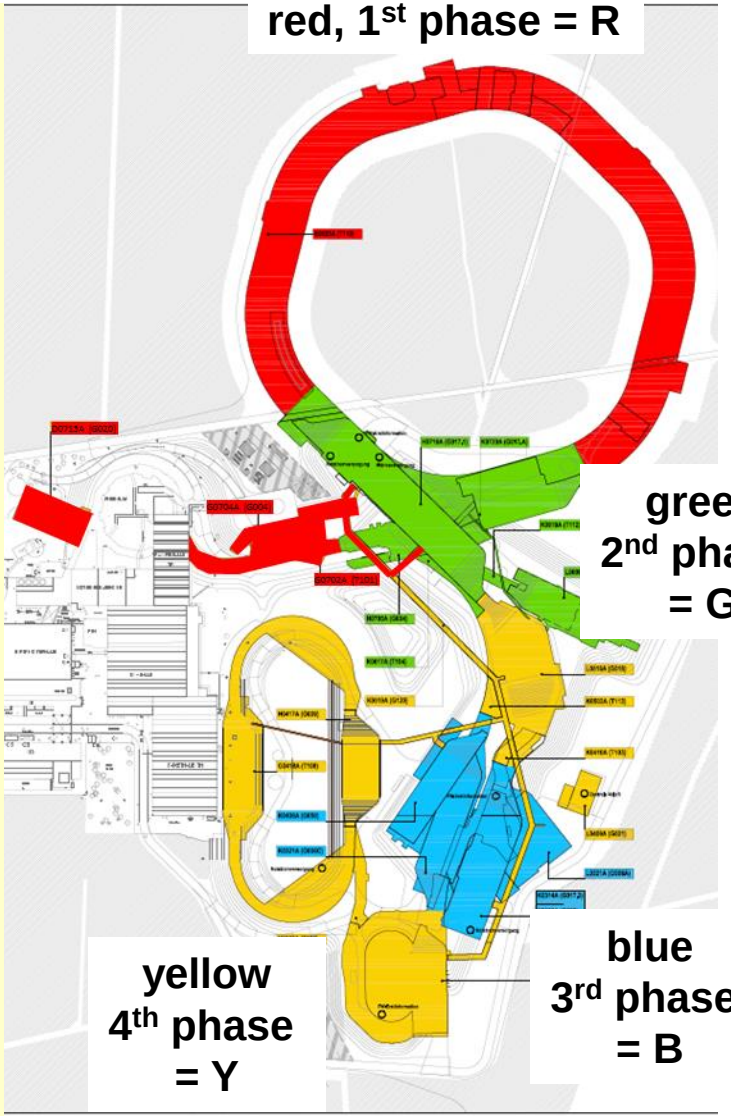
Highest Risk for HISPEC/DESPEC, MATS/LASPEC



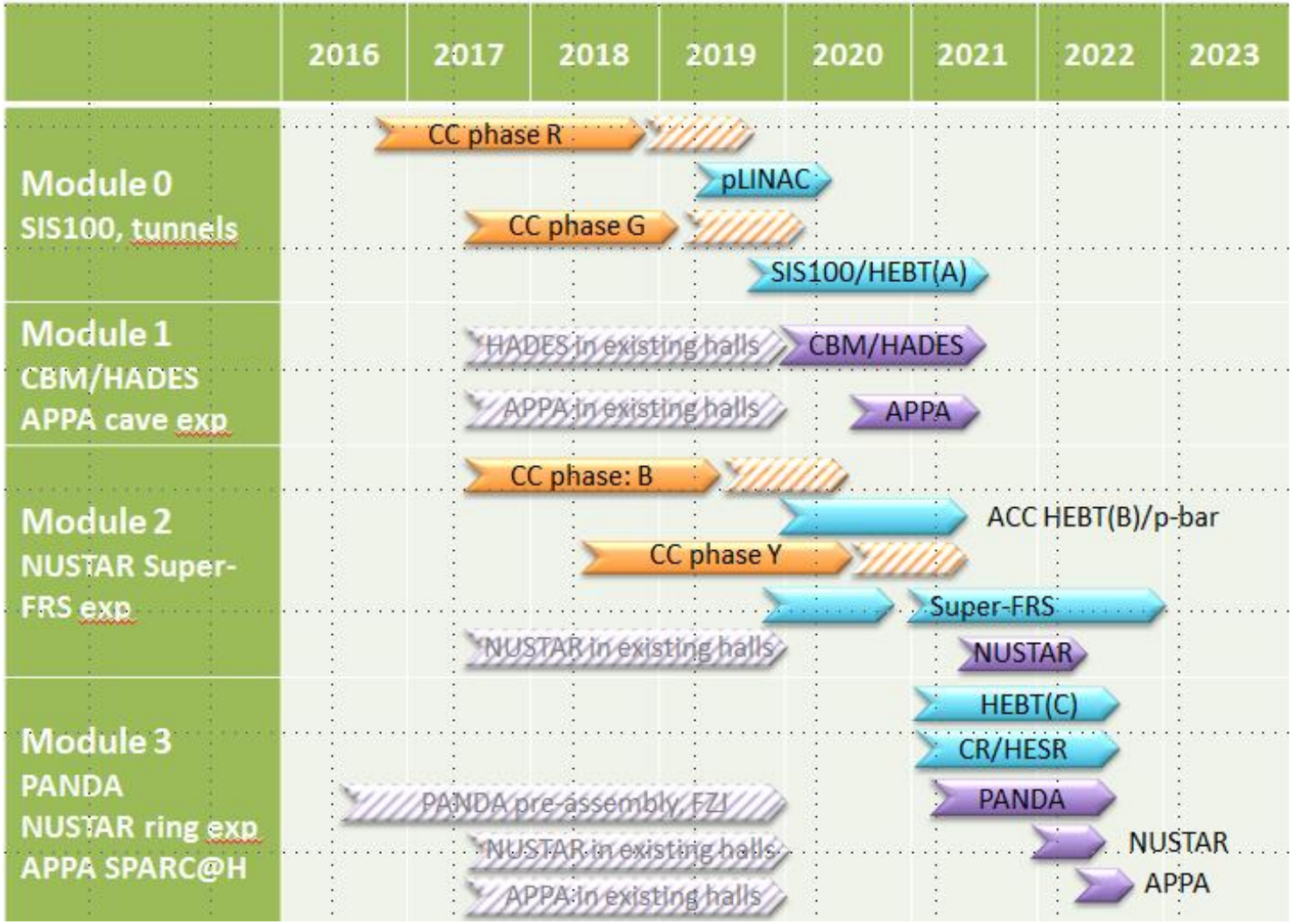
FAIR Construction – Latest “Scenario 2”

- Scenarios based on a combination of
  - CC estimated end of construction in sections build in 4 phases
  - ACC and EXP estimates of installation times
  - ½ year overlap for first installation allowed

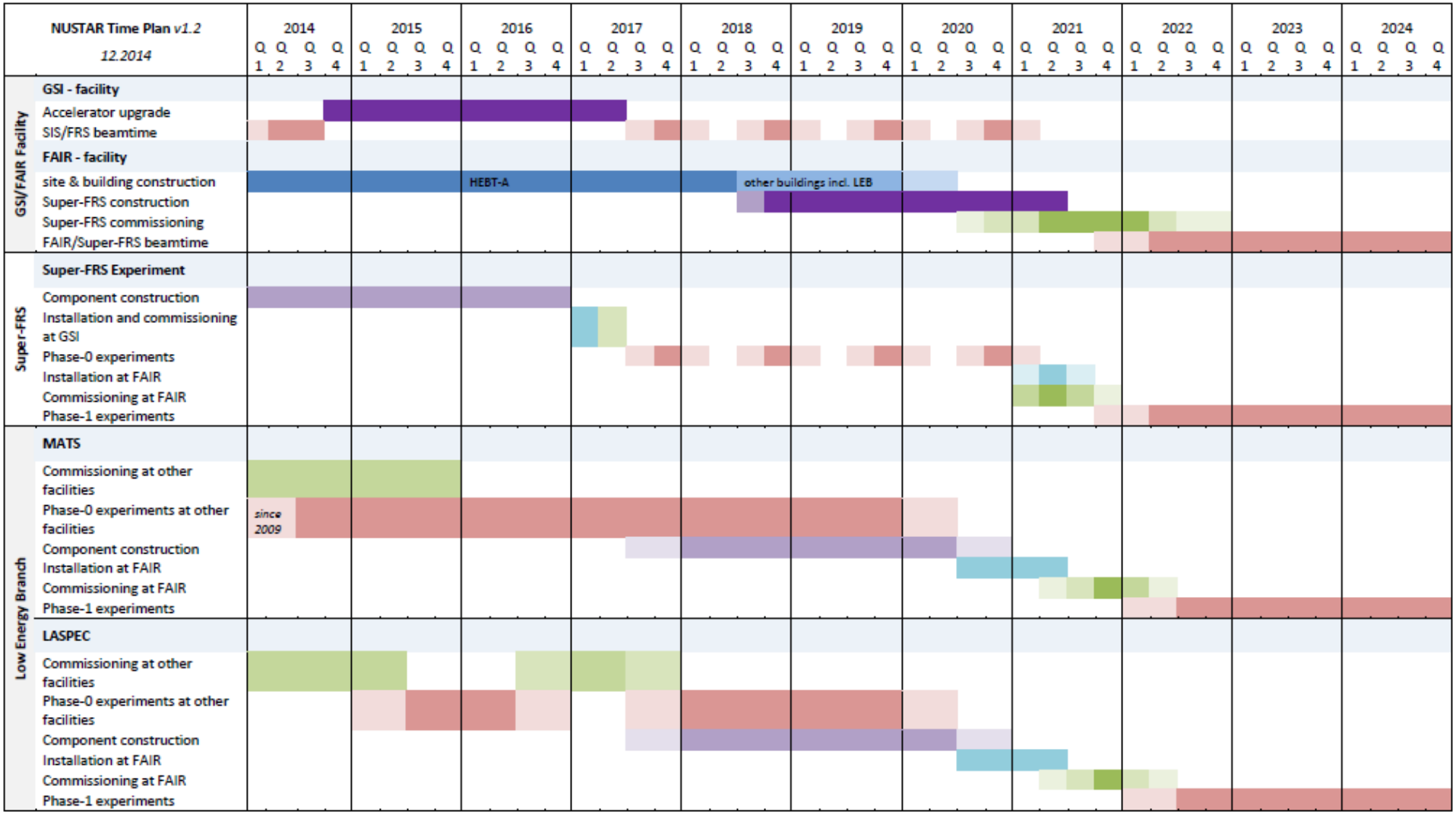
- Scenario 2:
  - Assuming that the presented CC schedule can be modified such that
  - the CC sections of the 2nd (B) and 3rd (G) phase can be interchanged in time
  - the connection between SIS18 and cross-bldg (SIS100) can be realised in the new 2nd phase (G)
  - New sequence: red (R), green incl. connection (G), blue (B) and finally yellow (Y)
  - The technical feasibility of this assumption has still to be evaluated



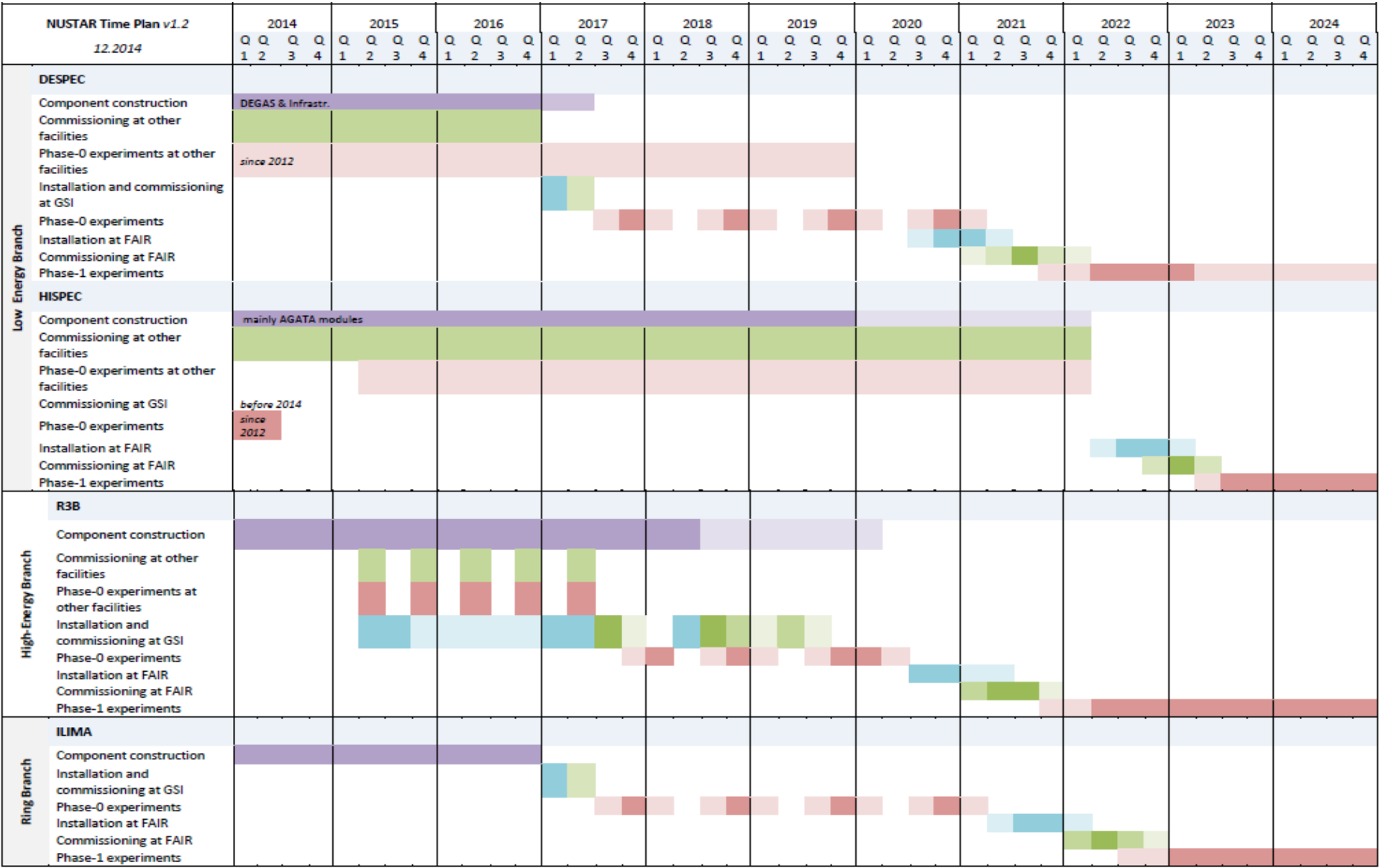
FAIR Timeline “Scenario 2”



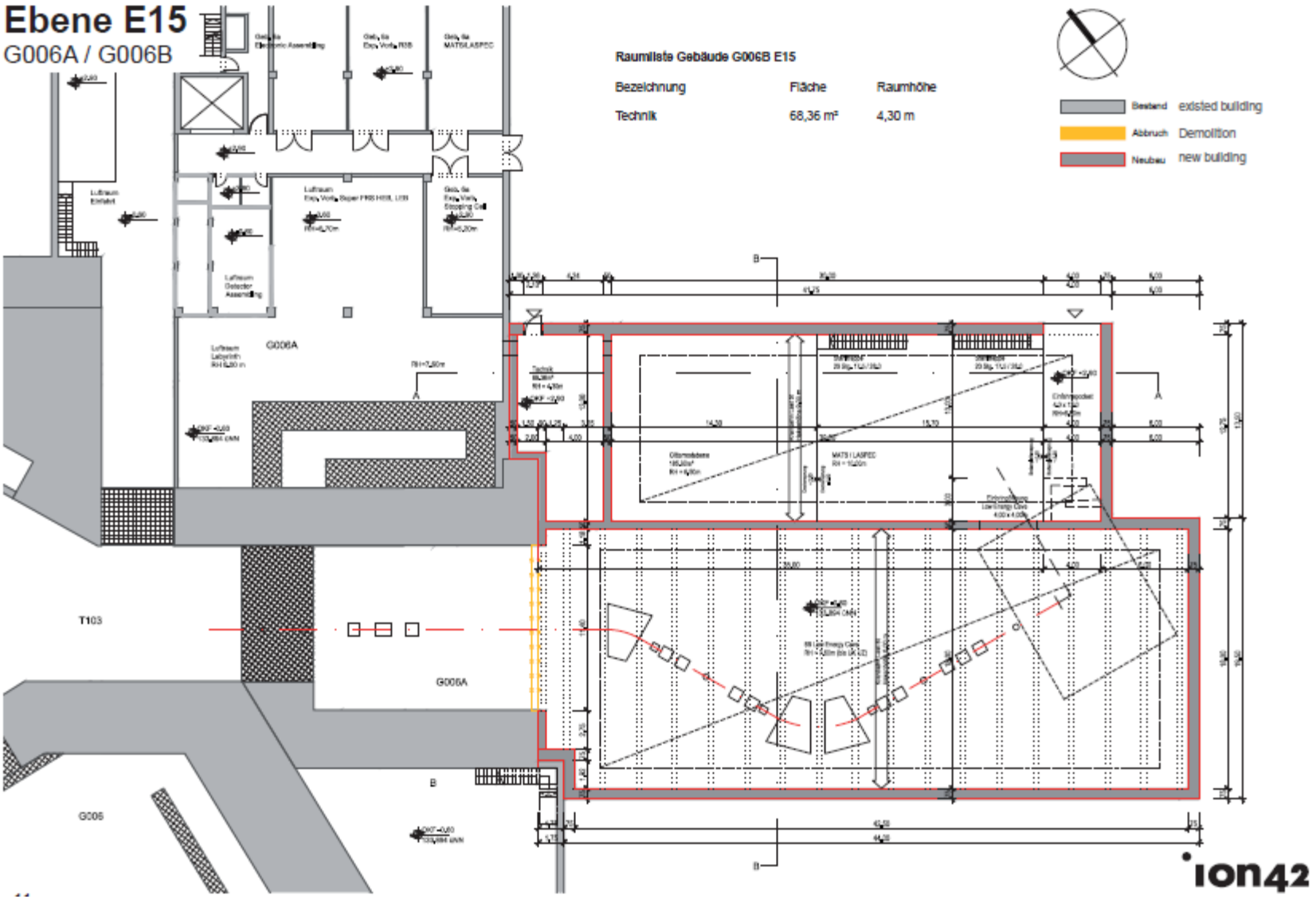
NUSTAR Time Line



NUSTAR Time Line



Low Energy Branch - architect study



Building issues - Costing

		Z-Bau	feasibility study 01/2014
	total cost KG 200 - 700		**8.265.925,00€**
KG 200	**preparing and development**		**100.000,00€**
KG 300	**Edifice**	4.189.000,00	**4.434.180,00€**
			3.825.765,00€
	Demolition		34.550,00€
	approx. 15% surcharge on cost calculation		573.865,00€
KG 400	**Edifice - Technical equipment**	3.604.000,00	**1.920.940,00€**
KG 500	**Outdoor facilities**		**582.660,00€**
KG 600	**Amenities and works of art**	101.500,00	**0,00€**
KG 700	**Ancillary costs**		**1.228.145,00€**

8.3 M€ in 2014 corresponds to
6.5 M€ in 2005!

Steps towards the LEB building

Perform 2nd. architect study (end of 2013) done

Inform/convince relevant funding agencies (early 2014) done

Find agreement with SPARC/FLAIR (2014) done

Form a consortium of funding agencies (2014)

Establish a funding roadmap (2014-2015)

Get agreement by FAIR Council and management (2015)

Plan building in detail (2016)

Apply for building permission (2016)

Build the LEB cave (2016-2017)

Install infrastructure and experiments (2018-2019)

Perform Day One experiment in 2019!!!