NUSTAR Technical Status

with a focus on NUSTAR ES/FS startup @ HEB

FAIR/GSI Research Retreat

18th-19th July 2023

H.M. Albers

Critical Path towards NUSTAR ES/FS

HE Cave ready	• Completion of High-Energy Cave TBI • Completion of relevant radiation safety infrastructure • Operating acceptance (Abnahme) awarded
S-FRS ready to deliver beam	• S-FRS beam delivery (M12) • Required SIS-18/SIS-100 beam parameters reached
Sub-collaboration specific infrastructure	• Platforms for detector subsystems at HE Branch focal planes • Experiment-specific media and other infrastructure
Detector systems ready	• Demonstrated readiness of NUSTAR setups • In-use setups commissioned during Phase-0
Expert resources available	• Expert resources (local + external) from collaboration required for installation and commissioning phases

NUSTAR
Early and First Science

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Risk: beam parameters not achieved

Low-impact scientific output

Critical Path towards NUSTAR ES/FS

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Risk: dependency on Common Fund (CF) established through NUSTAR MoU. Risk of non or late availability of CF. Risk of non-payment from communities no longer served in ES/FS

Mitigation: Bilateral discussions with funding agencies

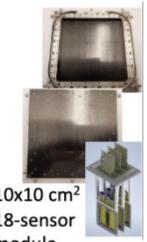
Buffer: No critical components with long lead times foreseen

Technical developments: R³B

R3B Target Recoil Tracker - Project Timeline for Stage 1 and 2

R&D and in-beam test of ALPIDE detectors is ongoing together with **ALICE** and AMBER collaboration

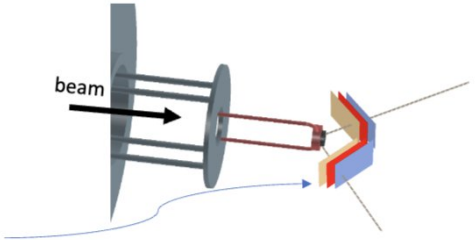
single-carrier boards



10x10 cm² 18-sensor module

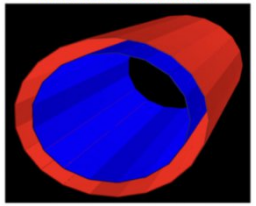
Stage 1

Modular conical arrangement using 18-ALPIDE station modules (recently designed by AMBER collaboration at CERN)



Stage 2

Barrel geometry based on ALPIDE modules optimised for thickness (ongoing R&D by AMBER and **NUSTAR** collaboration)



Present - Ongoing R&D

present

Autumn 2022

Utilised in Phase 0 experiments

2023/4
Stage 1
Two detector arms
Ready for in-beam tests

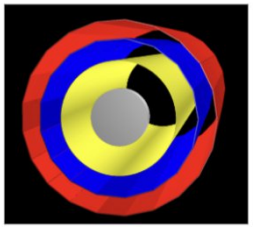
Utilised in FAIR experiments

Q1-2 2027
Stage 2
Full Barrel
Ready for in-beam tests

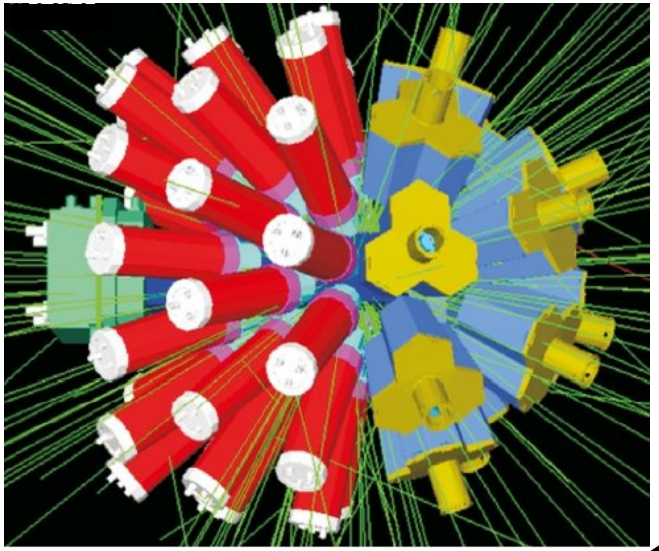
TDR expected 08/23

Far-Future Stage

A layer of fully flexible Silicon wafer (current R&D by ALICE) fitted inside the barrel geometry

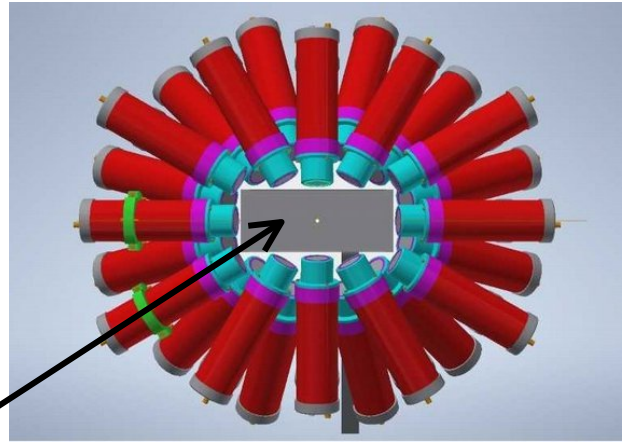


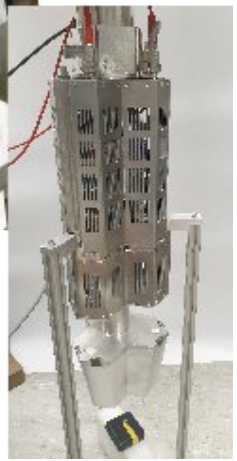
Technical developments: HISPEC/DESPEC

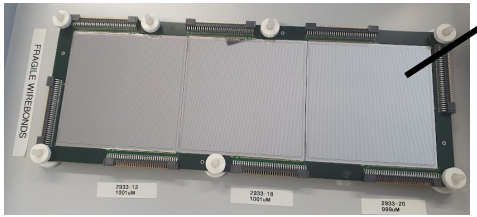


New DESPEC hybrid γ-ray array

- 12 DEGAS HPGes for **high-precision spectroscopy**
  + 36 FATIMA $LaBr_3$s for **fast-timing measurements**



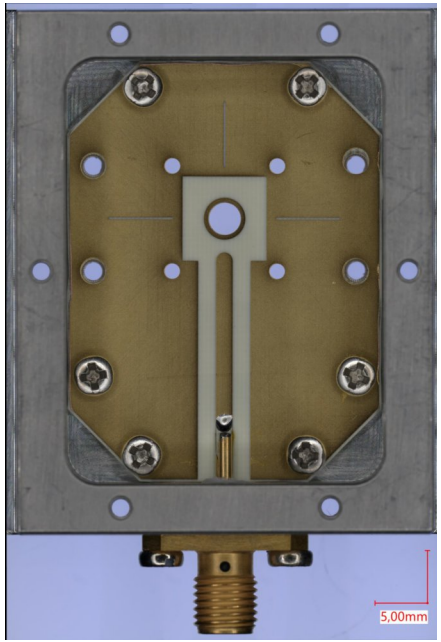




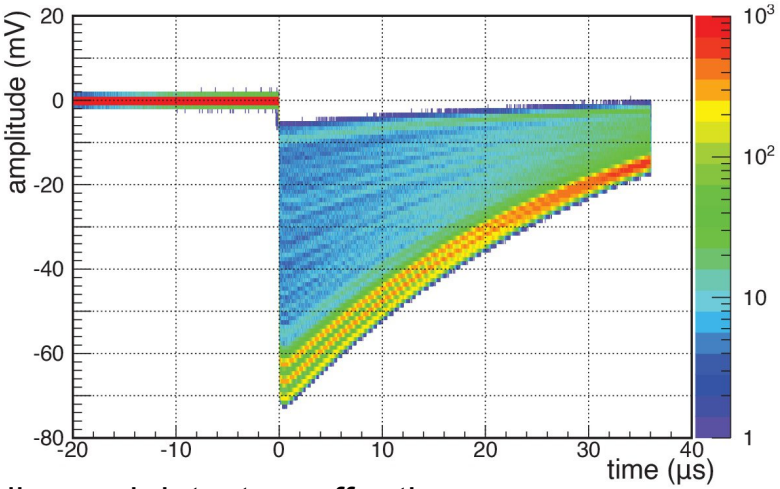
- Compatible with 'wide' 24x8-cm^2 AIDA Active Stopper + βPlast fast scintillators
- Improved efficiency compared with 2021 setup
- Plans for front-end improvement of TAMEX electronics for low-energy γ rays

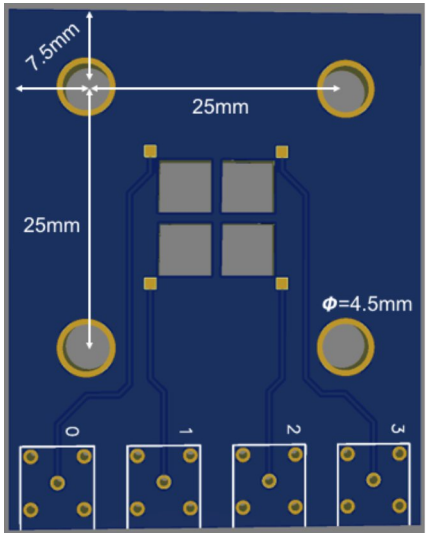
Technical developments: HISPEC/DESPEC

LISA: LIfetime measurements with Solid Active targets



wave forms recorded by high bandwidth oscilloscope

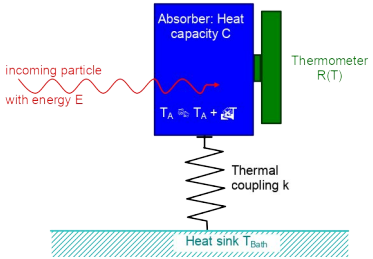




- diamond detectors offer the necessary energy resolution and radiation hardness
- sc-CVD diamond detectors testing in collaboration with GSI detector lab
- **triple-α source: energy resolution 0.8%**
- energy resolution sufficient for identification of one-proton removal events
- design and construction of 2×2×2 prototype
- ongoing optimization of charge sensitive pre-amplifiers and FEBEX4 DAQ system

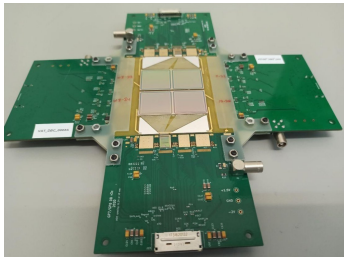
Technical developments: Super-FRS EC

Micro calorimeters for PID



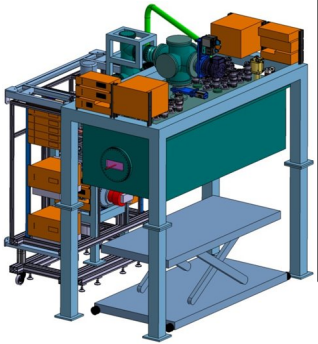
- Test at the FRS
- Design of an array with 4x4 crystals (active detector area 40x40 mm²)

Micro vertex detector for WASA@FRS



Test with off-line sources and with stable-ion beams: efficiency, tracking capability, IP measurement of nucleus-nucleus collisions

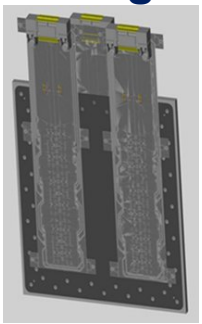
Cryogenic Stopping Cell



- GSI-FAIR In-Kind Contract signed
- First procurements completed, construction started
- Construction / assembly will be continued in 2024

Collaboration

Tracking detectors for EXPERT



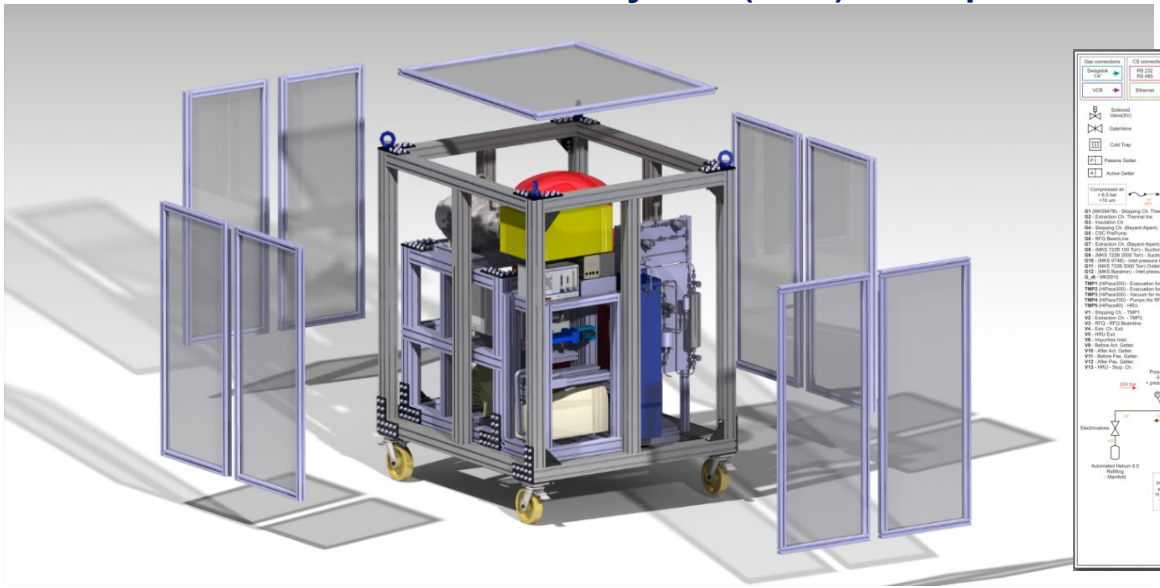
Tracking station with 18 ALPIDE detectors

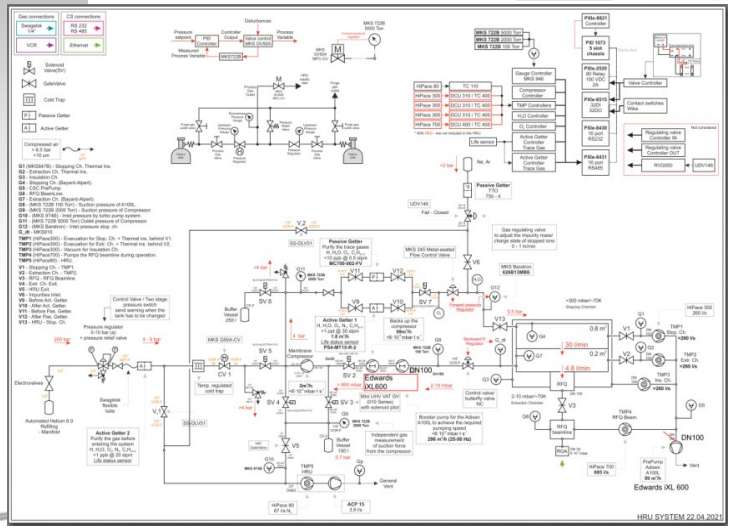
Tests with p-beams at COSY Jülich

- FOOT micro-strip detectors (combined R3B activity)
- ALPIDE tracking station (combined R3B activity)
- GADAST readout system

Technical developments: Super-FRS EC

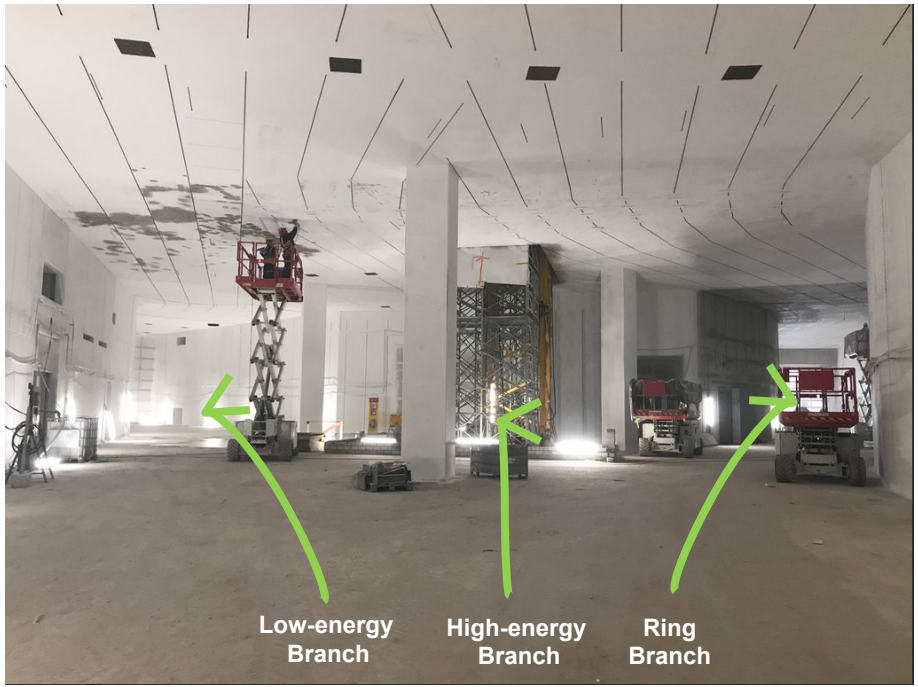
Helium Recovery Unit (HRU) for Super-FRS Cryogenic Stopping Cell

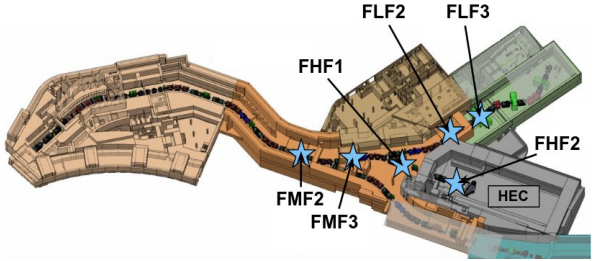




- Recovers >98% of (precious!) buffer gas He 6.0; purifies buffer gas at each cycle
- Final design report accepted; purchasing under way; test and assembly of first components will start in next weeks
- GSI engineering run in Q4 2023: test with beams

On-site construction update - April 2023





FHF1

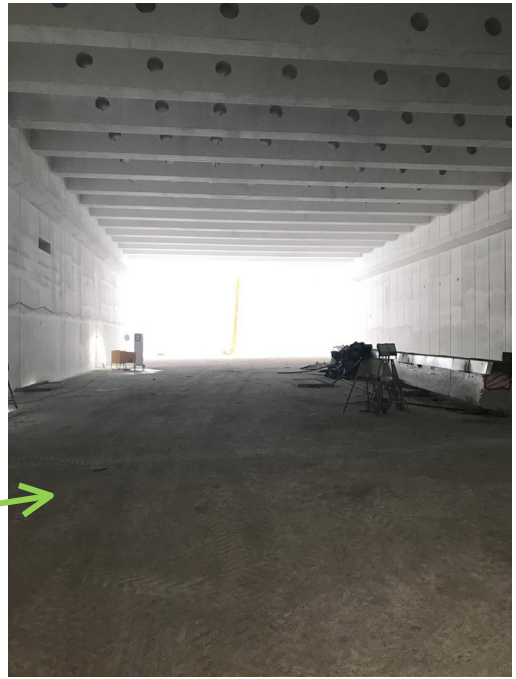
FLF2

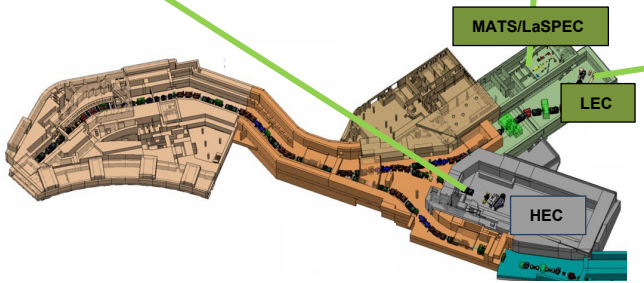
On-site construction update - April 2023

High-energy Cave

MATS/LaSPEC

Low-energy Cave





Status of TDRs

Sub-system	TDR #	name	status	
NUSTAR	2_01	LEB infrastructure	approved	
LEB infrastructure	2_02	Cryogenic Stopping cell	approved	
HISPEC/DESPEC	2_04	HISPEC/DESPEC infrastructure	approved	
NUSTAR	2_05	NUSTAR DAQ	approved	
HISPEC/DESPEC	2_07	Active target (India)	expected	11/2025
HISPEC/DESPEC	2_08	HYDE	expected	11/2025
HISPEC/DESPEC	2_09	LYCCA	approved	
HISPEC/DESPEC	2_10	Plunger	approved	
HISPEC/DESPEC	2_11	AIDA	approved	
HISPEC/DESPEC	2_12	DEGAS	approved	
HISPEC/DESPEC	2_13	FATIMA	approved	
HISPEC/DESPEC	2_14	BELEN	approved	
HISPEC/DESPEC	2_15	MONSTER	approved	
HISPEC/DESPEC	2_16	NEDA	approved	
HISPEC/DESPEC	2_17	DTAS	approved	
HISPEC/DESPEC	2_18	gSPEC	expected	**11/2023**
NUSTAR	2_19	MATS/LaSpec	approved	
R3B	2_21	GLAD	approved	
R3B	2_22	R3B tracking	approved	
R3B	2_24	CALIFA barrel	approved	
R3B	2_25	CALIFA fwd endcap	approved	
R3B	2_26	Si tracker	expected	**08/2023***
R3B	2_27	NeuLAND	approved	
R3B	2_28	R3B vacuum	approved	
R3B	2_29	R3B infrastructure	approved	
R3B	2_30	R3B spectrometer	expected	07/2024
R3B	2_32	ACTAF	approved	
ILIMA	2_33	ILIMA Schottky	approved	
ILIMA	2_34	ILIMA TOF detectors	approved	
ILIMA	2_35	ILIMA Heavy ion detector	approved	
HISPEC/DESPEC	2_37	Slowed down beam setup	expected	11/2025
Super-FRS Experiment	2_38	EXPERT	approved	
Super-FRS Experiment	2_39	Super-FRS Exp infrastructure	approved	
Super-FRS Experiment	2_40	Liquid hydrogen target	expected	07/2024
Super-FRS Experiment	2_41	(Ice target and tensor force)	expected	**08/2023***
Super-FRS Experiment	2_42	(future WASA)	expected	07/2025
R3B	2_43	HYDRA	expected	07/2024

*Funding available/secured

27	approved
0	submitted
3	expected
7	beyond “Day one”

Expected TDRs:

- gSPEC:
  - Grant request submitted
- Si tracker:
  - Funding granted by STFC
  - Re-design complete
  - TDR expected 08/23
- Ice-target and tensor force detection:
  - Funding available
  - TDR expected 08/23

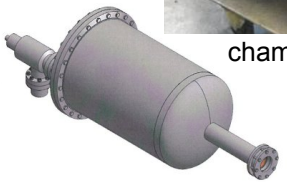
Status of re-procurement for Russian in-kind

Active target ACTAF2

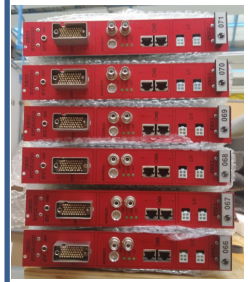
Status: **nothing delivered**

- ACTAF1 will be combined with parts of ACTAF2
- Electronics from ACTAF2 might need revision
- Revised vacuum and gas systems
- Support and alignment systems required
- 226 kEUR (2005) requested for full re-procurement

chamber at PNPI



NeuLAND HV



Status: **all modules and control boards delivered**

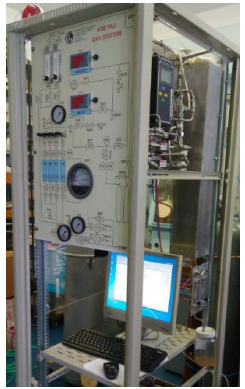
- Quality issue - repair required
- GSI EEL reverse engineering
- 31.4 kEUR (2005) requested for repair

Proton Arm Spectrometer (PAS)

Status: **nothing delivered**

- New design and (likely) TDR needed
- R3B investigating technical solutions
- 587 kEUR (2005) requested for full re-procurement

straw tubes at PNPI



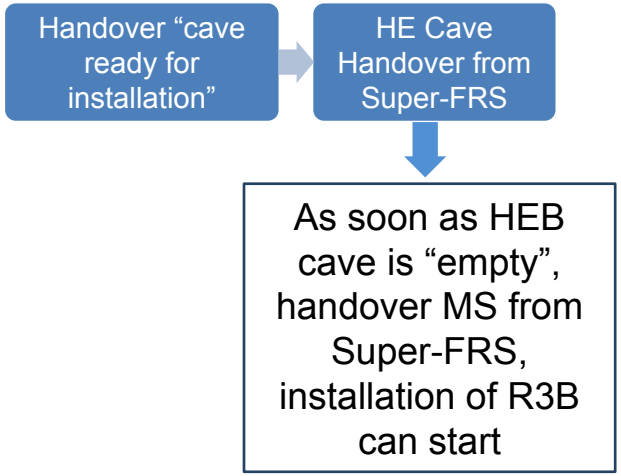
gas system for PAS at PNPI

NUSTAR Strategy towards FS

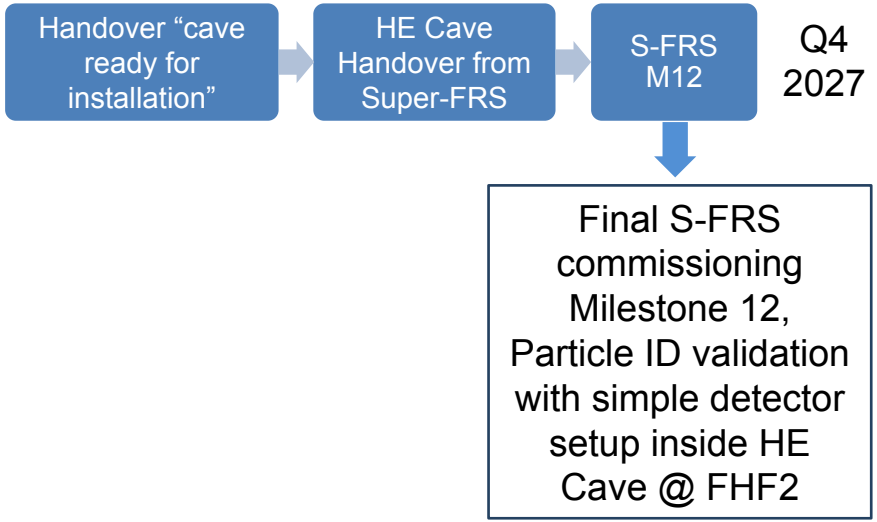
Handover “cave ready for installation”

As soon as building is ready for installation, some infrastructure items can be installed (limited due to work on Super-FRS)

NUSTAR Strategy towards FS



NUSTAR Strategy towards FS

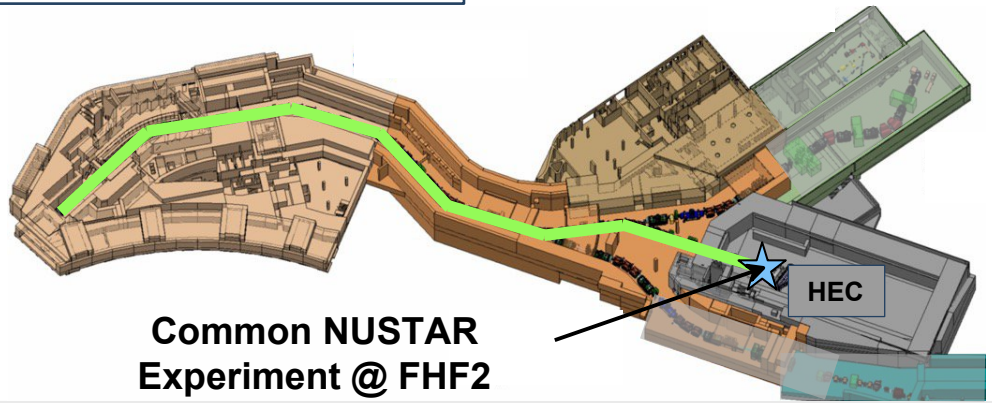


NUSTAR Strategy towards FS

Handover “cave ready for installation” → HE Cave Handover from Super-FRS → S-FRS M12 → Q4 2027 → Common NUSTAR experiment @ FHF2

Common NUSTAR experiment involving **ALL NUSTAR subcollaborations**. S-FRS settings and setup likely to overlap with M12

Simple, compact setup, fast results needed! NUSTAR collaboration to decide on the physics goal(s)



Common NUSTAR Experiment @ FHF2

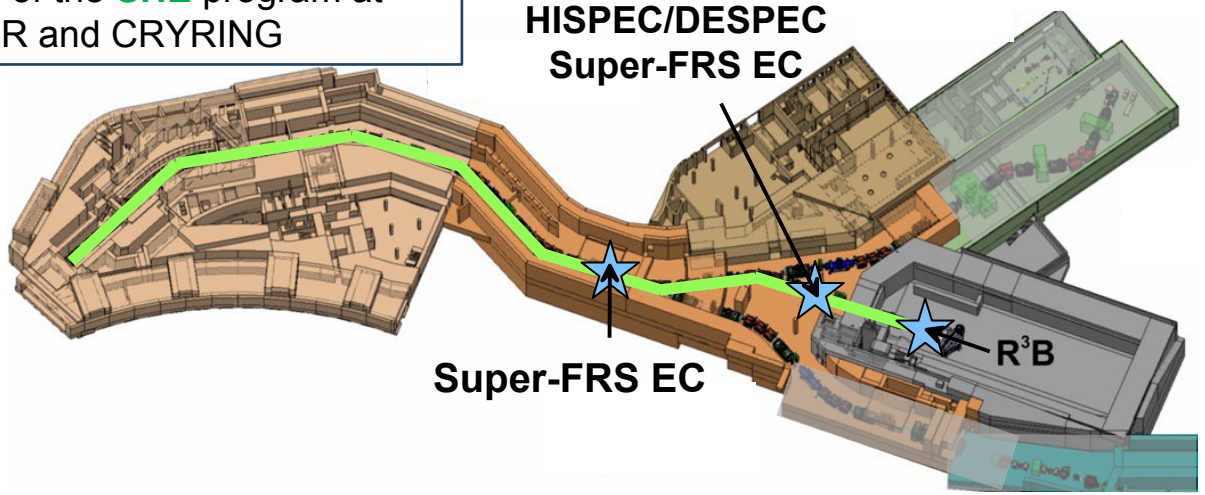
NUSTAR Strategy towards FS

Handover “cave ready for installation” → HE Cave Handover from Super-FRS → S-FRS M12 → Q4 2027 → Common NUSTAR experiment @ FHF2 → NUSTAR Early Science → NUSTAR First Science

NUSTAR ES and FS:
individual sub-collaborations **(Super-FRS EC, partial HISPEC/DESPEC and R3B)** running PAC-approved experiments at S-FRS focal planes, continuation of the **SHE** program at UNILAC and **ILIMA** at the ESR and CRYRING

Detailed installation timelines to be developed and refined in LCM workshops

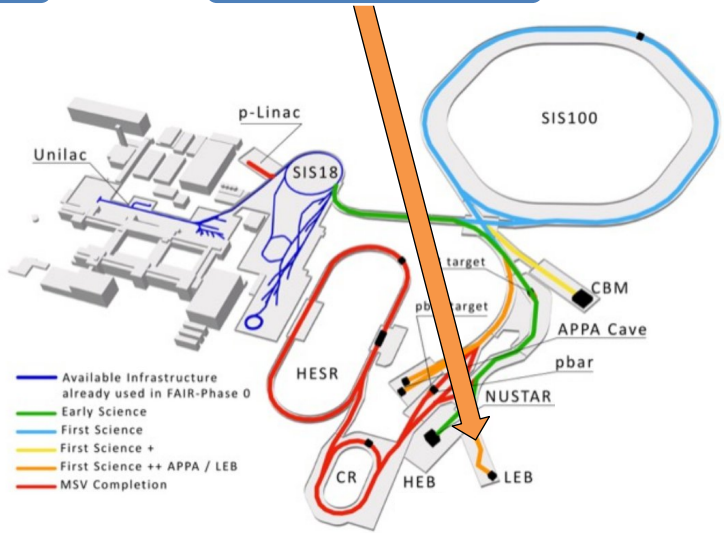
New “NUSTAR Technical Integration for ES” team planned



NUSTAR Strategy beyond FS (2028+)

Handover “cave ready for installation” → HE Cave Handover from Super-FRS → S-FRS M12 → Q4 2027 → Common NUSTAR experiment @ FHF2 → NUSTAR Early Science → NUSTAR First Science

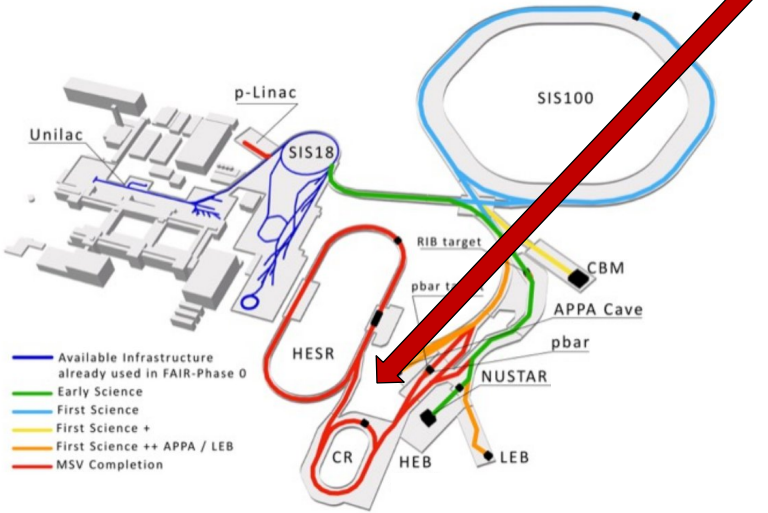
Funding decision on FS++ (Low Energy Branch) aimed for in **2025** → Low Energy Branch operation beginning **2030**



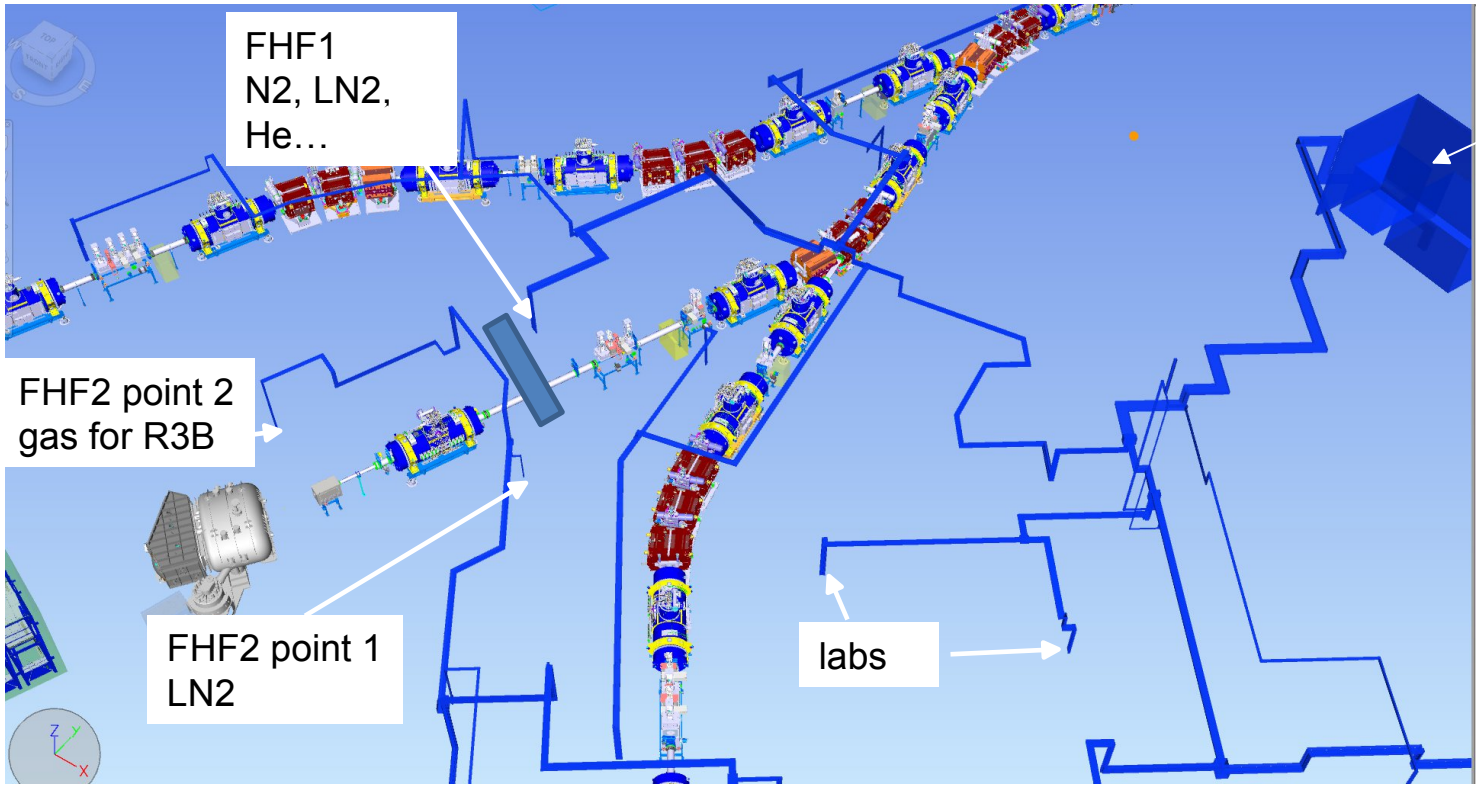
NUSTAR Strategy beyond FS (2028+)

Handover “cave ready for installation” → HE Cave Handover from Super-FRS → S-FRS M12 → Q4 2027 → Common NUSTAR experiment @ FHF2 → NUSTAR Early Science → NUSTAR First Science

Funding decision on FS++ (Low Energy Branch) aimed for in **2025** → Low Energy Branch operation beginning **2030** → Full MSVc (including rings) **2032**



Gas and LN2 planning for NUSTAR ES



Outside supply building: gas lager

Slide: S. Pietri

magnets of MSV are shown together with magnets of ES for clarity

Infrastructure at FHF1

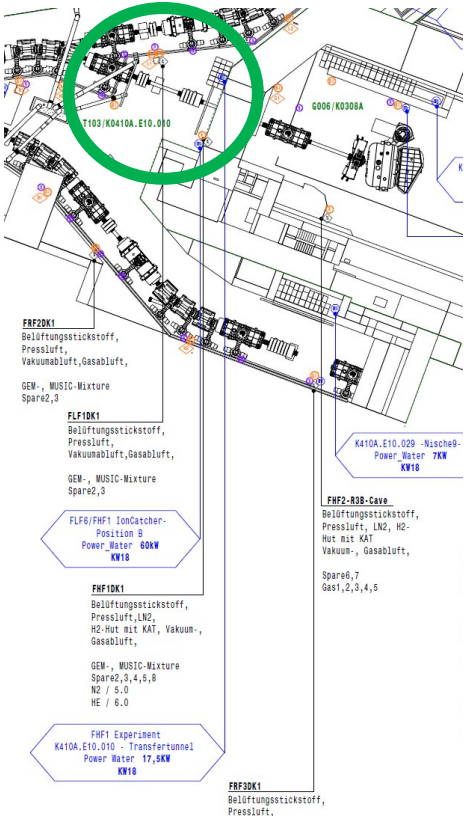
- FHF1 was always planned as Super-FRS focal plane for
  - high-intensity experiments
  - higher transmission
- Infrastructure planned since 2016+ for operation of Super-FRS EC Ion Catcher and gamma array at FHF1

LN2 Consumers NUSTAR

Position	Nr.	Location	Reqiured flow	Amount per day / week	Max allowed pressure at connection (bar)	Minimum require pressure at connection (bar)
R3B @FHF2	1	K0308A.E10.010 (G006)	300 l/h	2 m³/d	2	1,3
FHF1	2	K0410A.E10.010 (T103)	100 l/h	1 m³/d	2	1,3
LEB Cave @FLF3	3	L0317A.E10.010 (G006B)	300 l/h	2 m³/d	2	1,3
LEB Cave @FLF6	4	L0317A.E10.010 (G006B)	100 l/h	1 m³/d	2	1,3
Vorb. SFRS	5	L0321A.E10.007 (G006A)	100 l/h	1 m³/d	2	1,3
MATS/LaSpec	6	L0317A.E10.020 (G006B)	200 l/h	1-4 times per week 100-200l	free flow, no fix connection	1,0
Vorb. R3B	7	L0321A.E15.008 (G006A)	-	-	-	-
Vorb. Stopping C. / Ion C.	8	L0321A.E15.009 (G006A)	-	-	-	-
Vorb. H/Dspec	9	L0321A.E30.008 (G006A)	100 l/h	1 m³/d	2	1,3
FMF2	10	K410A.E10.010	-	-	-	-

Bemerkung: Der Durchfluss von 300 l/h wird entweder an Position Nr.1 oder an Position Nr.3 benötigt - nie gleichzeitig an beiden.

Stand: 07.02.2019



Slide: S. Pietri

NUSTAR input to the FAIR IT CDR (highlights)

User access Users should be able to access the GSI/FAIR computing resources via centrally managed Linux desktop PCs. The general availability of such terminals has proven very valuable in the past, and it is a must for operation of the spectrometer at the center of the NUSTAR experiments (FRs and Super-FRS). Indeed a strong link exist between the online analysis from detectors used in the experiment and the machine tuning of the spectrometers. To achieve this reliably standardized computer for operation are needed.

Table 26: Compute Requirements (in HEPSpec06).

	Early science configuration	Full MSV configuration
at the experiment	12,000	24,000
	0	0
	0	0
	0	0
anywhere in facility	10,000	10,000
at Green cube	120,000	300,000

Table 28: Storage Requirements (II —Processing).

		Early science configuration	Full MSV configuration
Raw Data	TB/year	5,000	5,000
	#years	5	5
	Bandwidth (MB/s)	10,000	10,000
Simulation	TB/year	500	500
	#years	5	5
	Bandwidth (MB/s)	1000	1000
Derived data	TB/year	1,250	1,250
	#years	5	5
	Bandwidth (MB/s)	10,000	10,000

Table 27: Storage Requirements (I —Data Taking).

		Early science configuration	Full MSV configuration
Experiment to GreenCube/RZ1	#fibers	192	192
	Bandwidth (MB/s)	500	500
Bandwidth to permanent storage	Peak (MB/s)	1000	1000
	Average (MB/s)	500	500
Permanent storage/year (TB/year)		5,000	5,000
Additional disk storage (TB)		500	500

Slide: S. Pietri

Personnel resources

- Personnel requirements for all FAIR pillars were collected and presented to the **O**perating **C**osts **W**orking **G**roup
  - Exp. Core (FTEs needed to operate experiments)
  - Exp. Operation (consumables related to operation of equipment)
  - Research (FTEs for experimental output, core group on site)

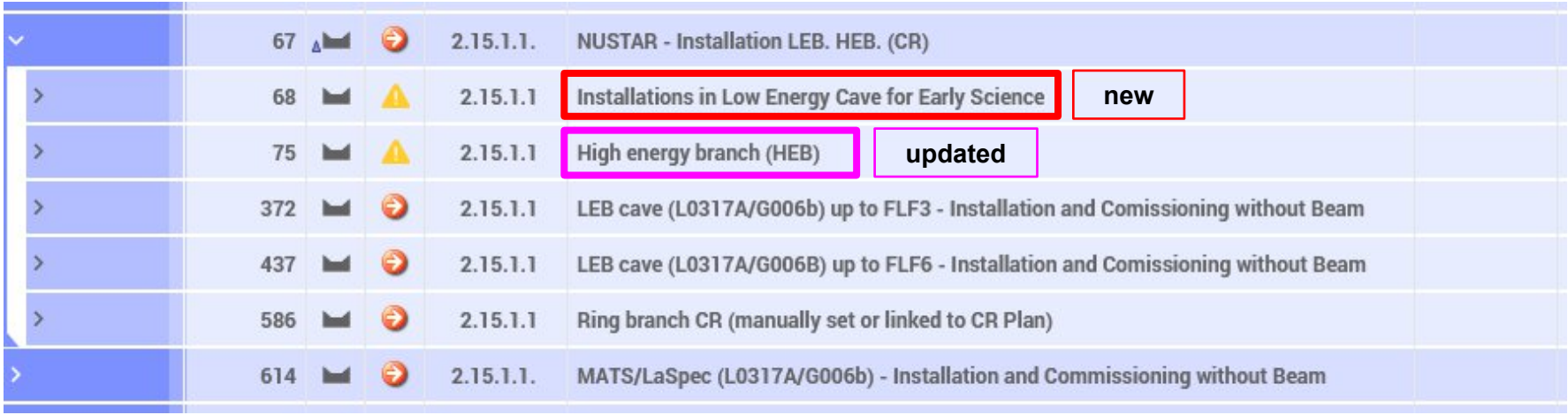
- A further iteration with updated estimates was made
  - Increased request compared to 2014
  - MSVc and IO considered
  - 40 fellows and associates included

- Outcome of the “Staging Review of the FAIR Project”

- Current NUSTAR personnel: 41 FTE

- Updated detailed request considering new staging and realistic perspective urgently needed. NUSTAR operation to begin in 2027. Request expected to be presented to AFC Q2 2024

Installation Planning – NUSTAR Status



67		2.15.1.1.	NUSTAR - Installation LEB. HEB. (CR)	
68		2.15.1.1	Installations in Low Energy Cave for Early Science	new
75		2.15.1.1	High energy branch (HEB)	updated
372		2.15.1.1	LEB cave (L0317A/G006b) up to FLF3 - Installation and Comissioning without Beam	
437		2.15.1.1	LEB cave (L0317A/G006B) up to FLF6 - Installation and Comissioning without Beam	
586		2.15.1.1	Ring branch CR (manually set or linked to CR Plan)	
614		2.15.1.1.	MATS/LaSpec (L0317A/G006b) - Installation and Commissioning without Beam	

- Project rebaselining **completed**
- **New block:** operation of the high-energy branch **requires installation of components in the low-energy Cave (e.g., cryo components, racks,...)**
- **HEB block:** updated to include installation of Super-FRS EC, HISPEC/DESPEC and R3B


Thank you