Design of LINAC-100 and LINAC-30 for new rare isotope facility project DERICA at JINR

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Contents:

- DERICA (Dubna Electron – Radioactive Ion Collider fAcility) project at JINR:
  motivation, physical aims, general structure and site
- LINAC-100 initial layout and beam dynamics
- LINAC-30 initial layout
- DERICA: possible collaboration
- Conclusions

What is at JINR (Flerov Lab.) today

JINR
114 Flerovium
FLNR
Dubna

Elements 102 - 108 and 113 - 118 were synthesized at FLNR JINR

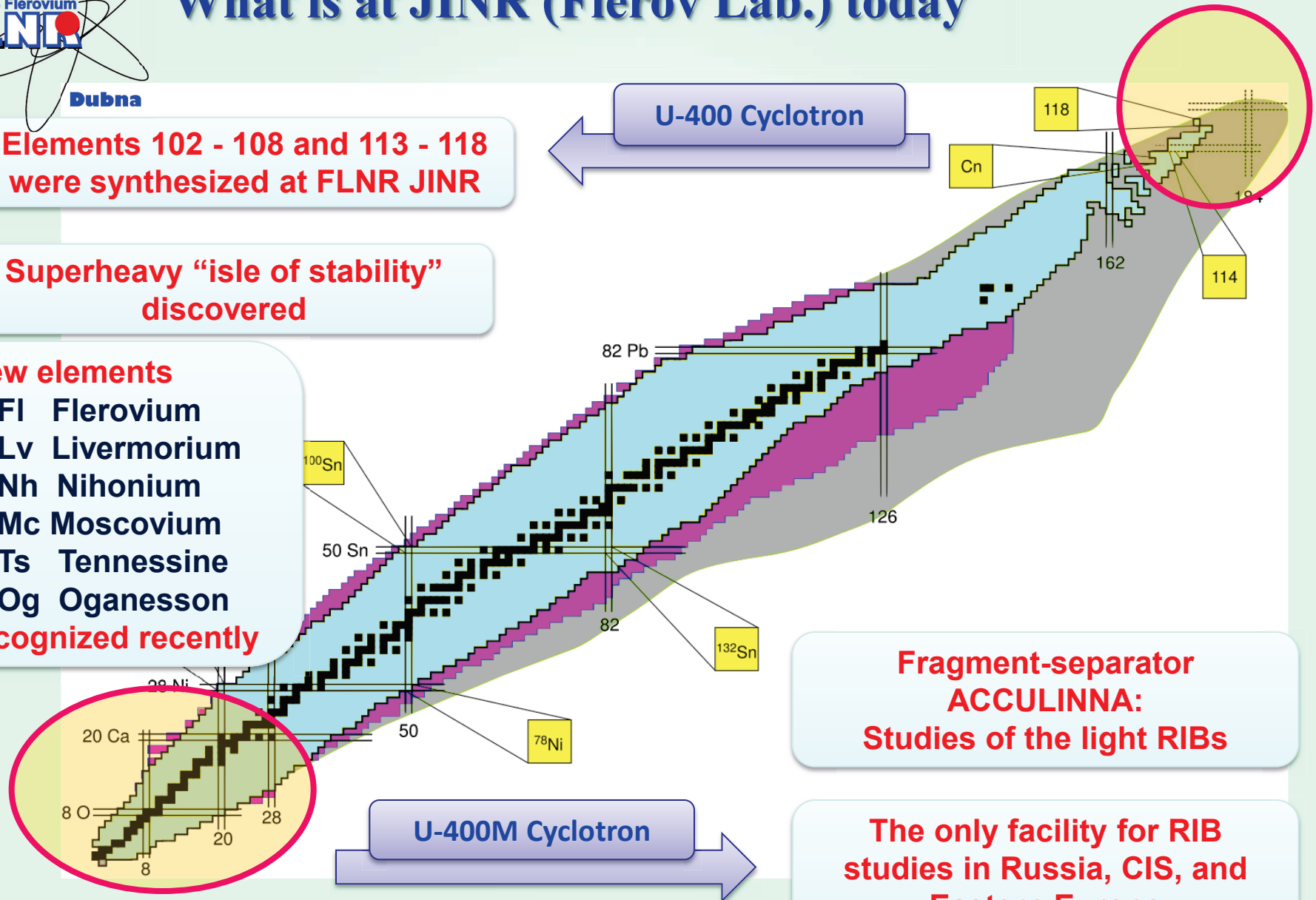
Superheavy "isle of stability" discovered

New elements

^{114}Fl Flerovium
^{116}Lv Livermorium
^{113}Nh Nihonium
^{115}Mc Moscovium
^{117}Ts Tennessine
^{118}Og Oganesson

recognized recently

U-400 Cyclotron



U-400M Cyclotron

Fragment-separator ACCULINNA: Studies of the light RIBs

The only facility for RIB studies in Russia, CIS, and Eastern Europe

JINR

114 Flerovium

FLNR

Dubna

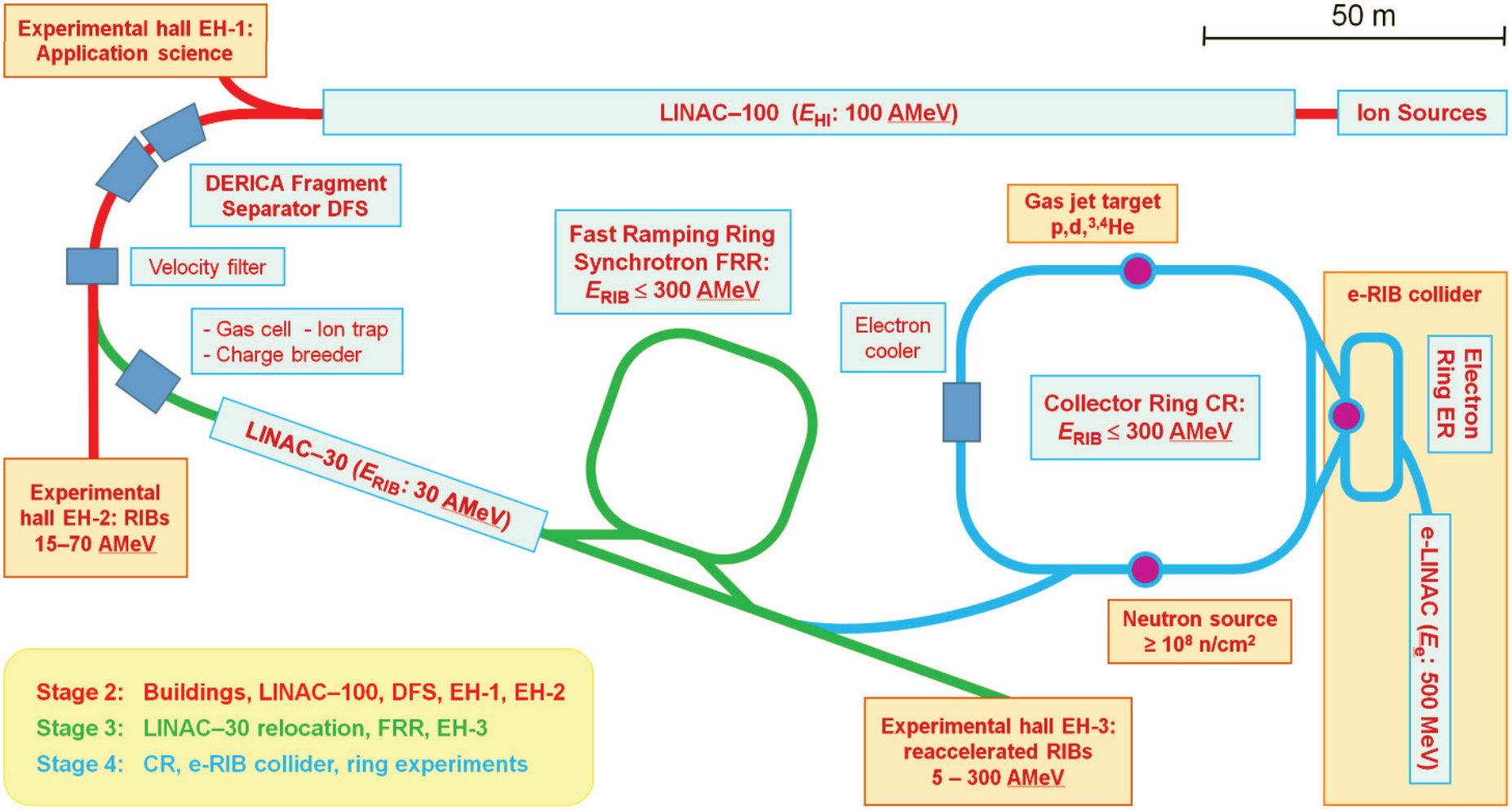
7-year planning prospects

"Factory of superheavy elements"
Stage: mounting of equipment
Investment: ~55 M€

Facility based on ACCULINNA-2 fragment-separator
Stage: first experiments in 2018
Investment: ~10 M€

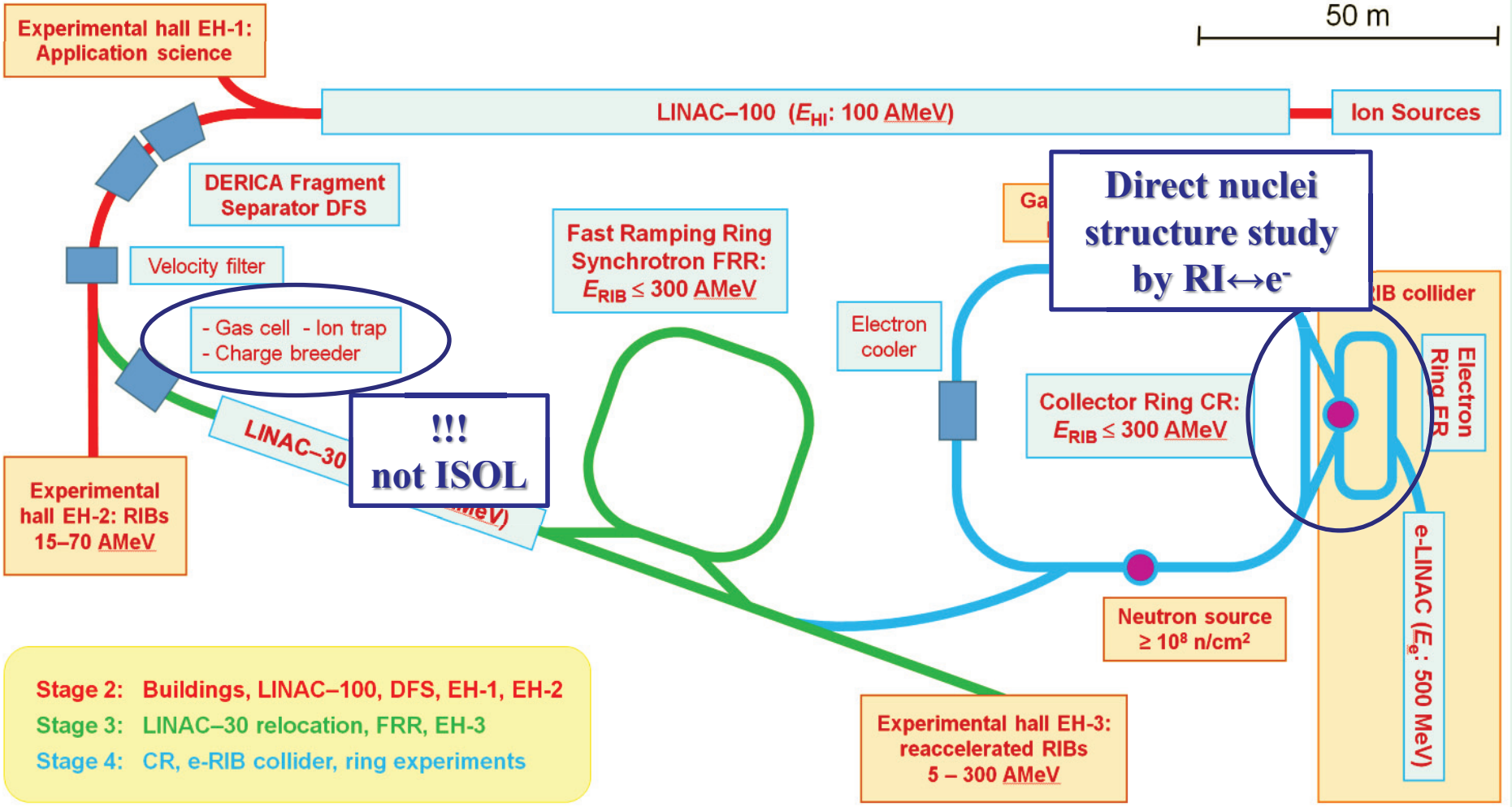
DERICA - Dubna Electron – Radioactive Ion Collider fAcility – project of RIB-factory for rp-process study

General layout



DERICA - Dubna Electron – Radioactive Ion Collider fAcility – project of RIB-factory for rp-process study

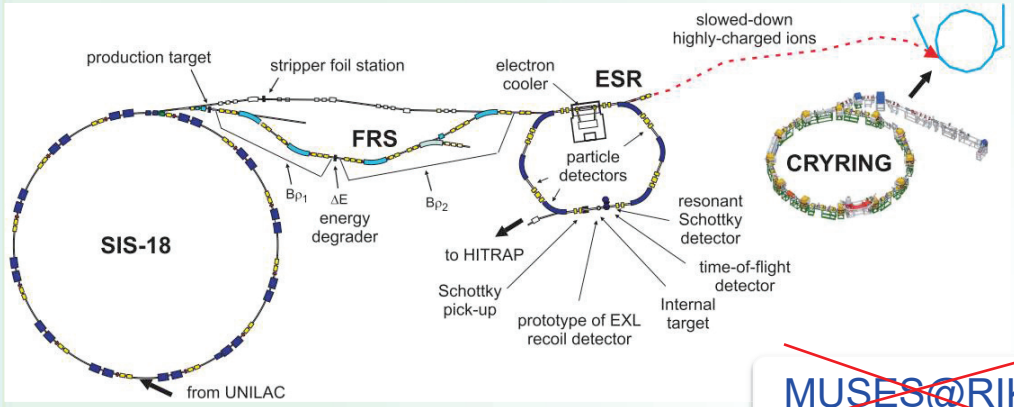
General layout

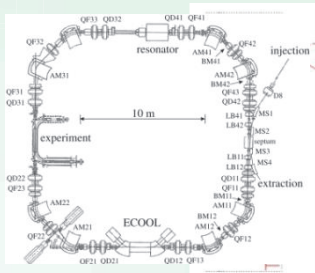


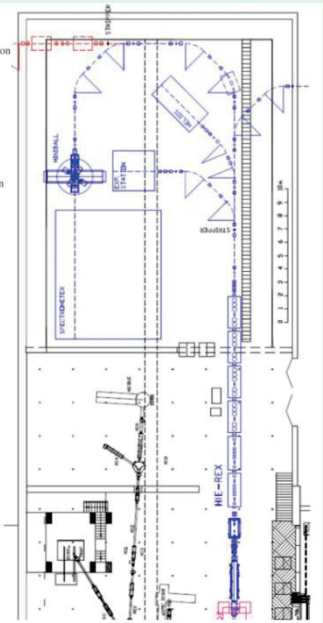
Why it has happened this way?

~~TSR/ISOLDE@CERN~~

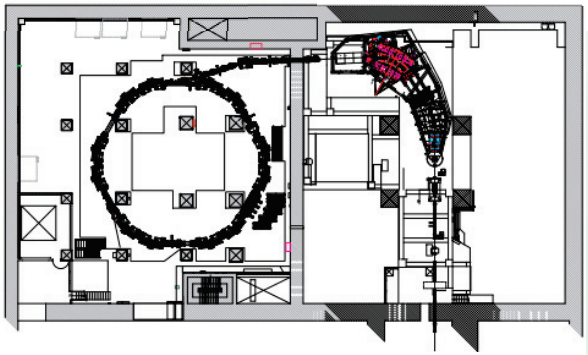
~~ELISe/NESR@FAIR~~ → ESR/CRYRING@GSI



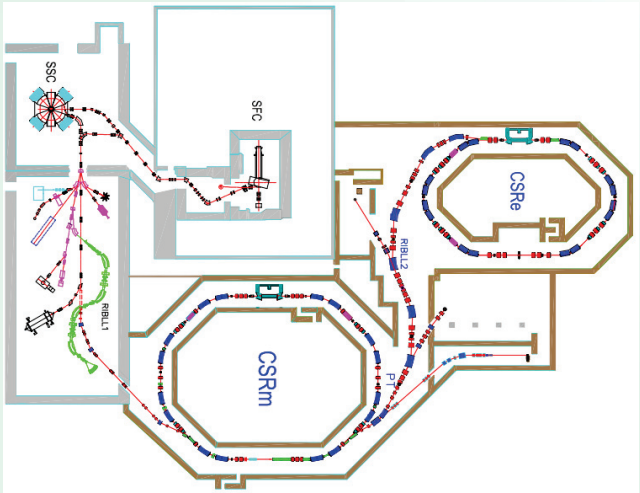




~~MUSES@RIKEN~~ → RI-Ring@RIKEN



~~HIRFL-CSR@Lanzhou~~ → HIAF



Not in sale

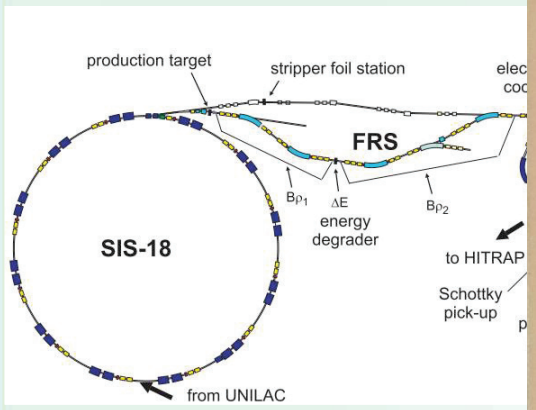
– A lot of ring projects – serious interest to the topic

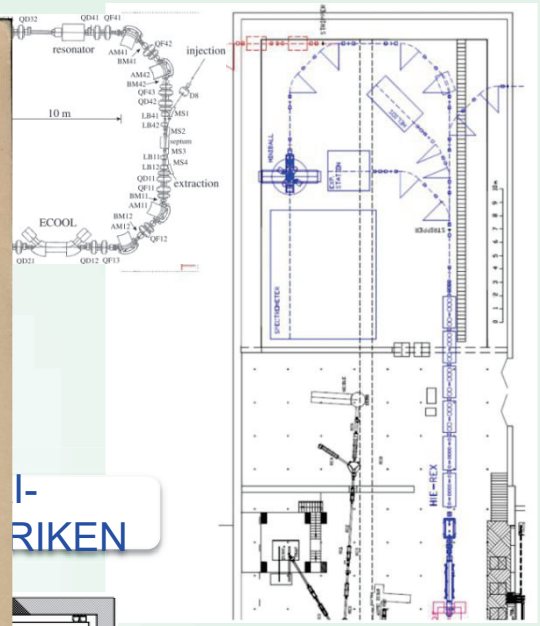
– All the ring projects with e-collider abilities were cancelled or indefinitely postponed

Why it has happened this way?

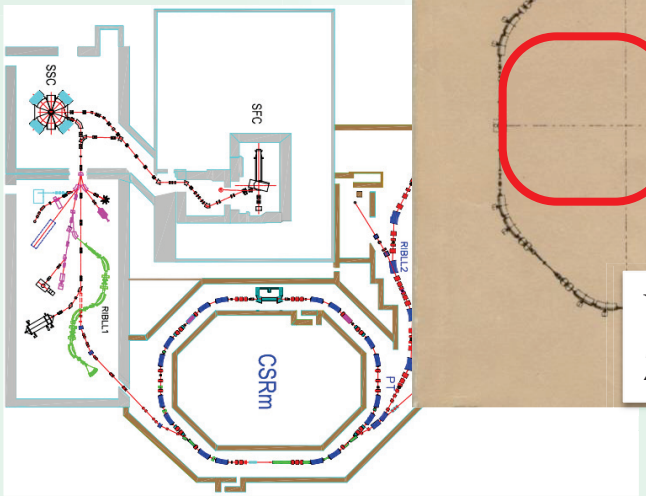
~~TSR/ISOLDE@CERN~~

~~ELISe/NESR@FAIR~~





~~HIRFL-CSR@Lanzhou~~



Yu.Ts. Oganessian *et. al.*,
Z. Phys. A341 (1992) 217

Not in sale

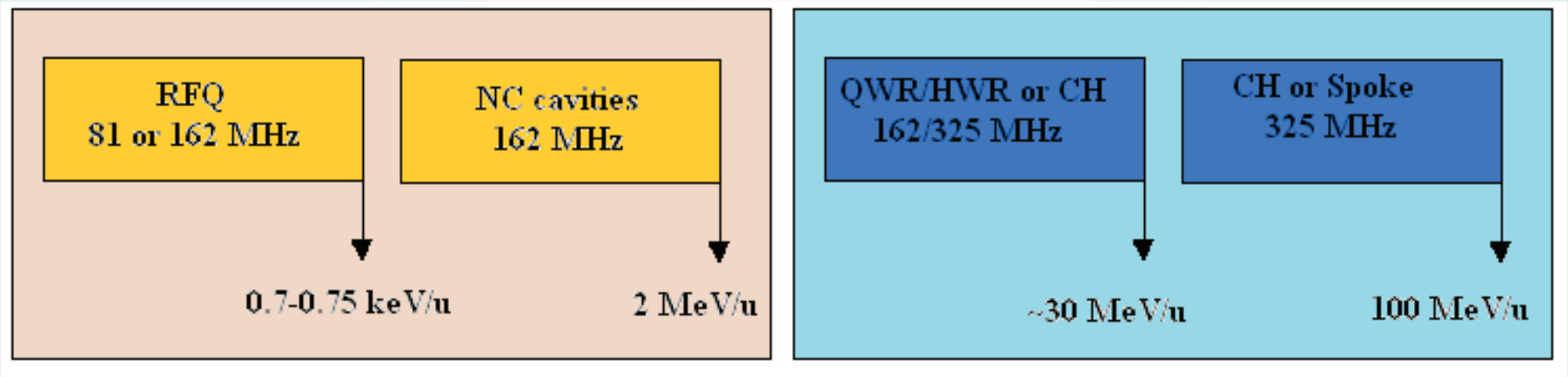
– serious interest to the

– All the ring projects with e-collider abilities were cancelled or indefinitely postponed

- **DERICA site**


Stage 1
location at
ACCULINNA-2
U400M +
ACCULINNA-2
200 м
FLNR
JINR border
Possible DERICA
location
140x230 m²
U400+SHE
SHE factory
construction

•LINAC-100 initial layout and beam dynamics



First version of DERICA's driver LINAC-100 general layout

The supposed primary beams in the LINAC-100 accelerator. The most available charges of Bi and U correspond to modern capacities of the intensive cryogenic ECR sources.

Ion	*A*/*Z*	*I*, pμA
$^{11}B^{2+}$	5.5	> 10
$^{18}O^{3+}$	6.0	> 10
$^{20,22}Ne^{4+}$	5.5	> 8
$^{32,36}S^{6+}$	6.0	> 5
$^{36}Ar^{6+}$	6.0	> 5
$^{40,48}Ca^{7+}$	6.0	> 5
$^{56,64}Ni^{11+}$	5.8	> 5
$^{86}Kr^{15+}$	5.7	5
$^{132}Xe^{22+}$	6.0	5
$^{160}Gd^{27+}$	5.9	5
$^{209}Bi^{37+}$	5.65	4
$^{238}U^{40+}$	5.95	~ 0.8*

Base parameters of LINAC-100 RFQ both for 81 and 162 MHz

Operating frequency, MHz	**162.5**	**81.25**
Input energy, keV/u	**16.9**	**16.3**
Output energy, keV/u	**612**	**614**
Max modulation	**1.4**	**1.9**
Aperture, mm	**3.2**	**4.4**
Transmission, %	**> 98**	**99.8**
Synchr. Phase, grad.	**-90 … -30**	**-90 … -30**
Voltage, kV	**100**	**100**
Input beam emittance, mm*mrad	**200**	**200**
Length, cm	**600**	**600**

Base parameters of LINAC-100 RFQ both for 81 a

54 MHz ???

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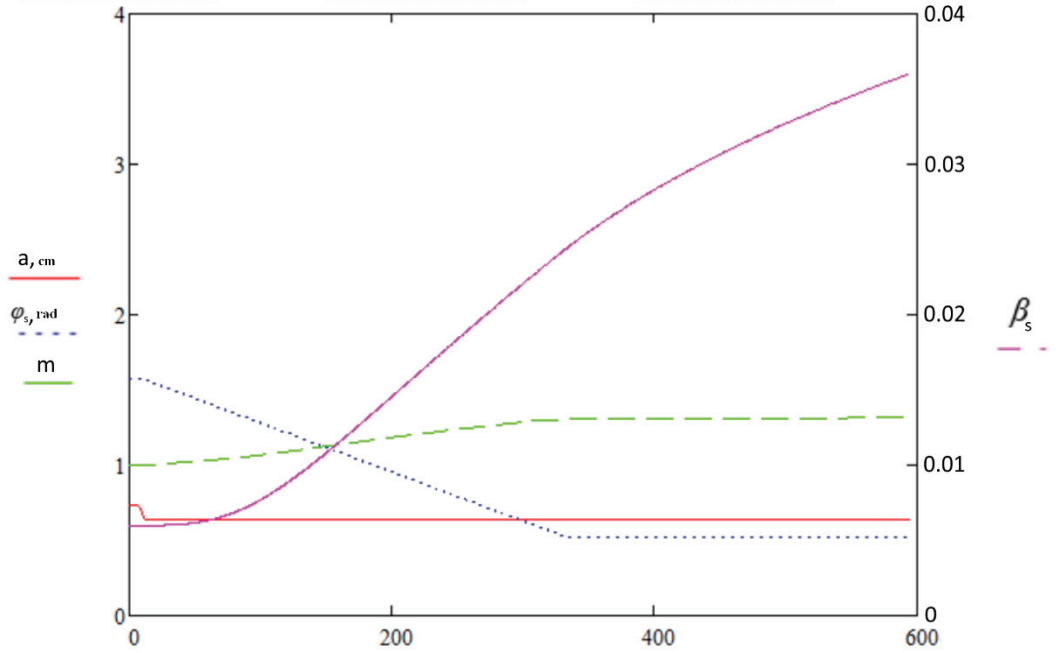
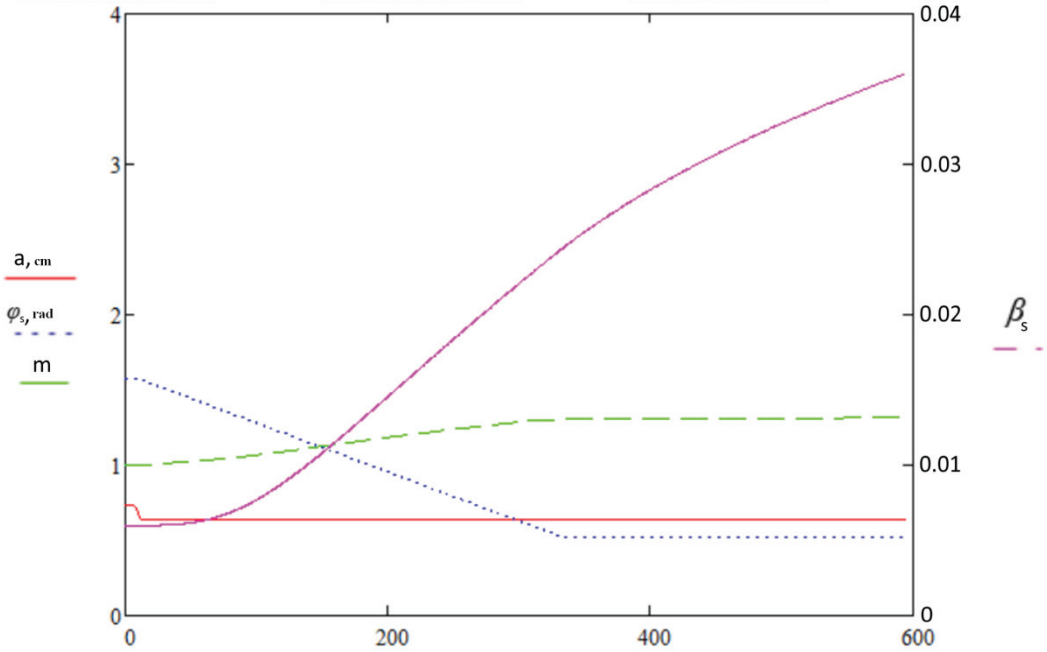
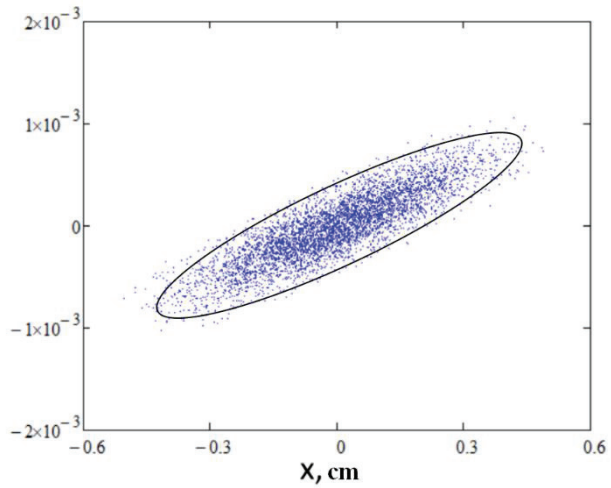
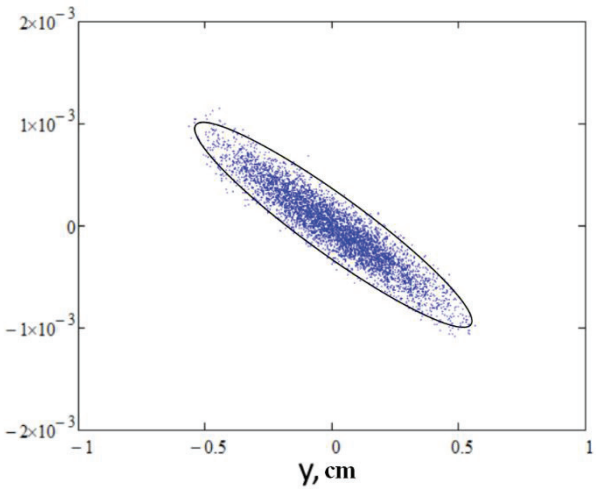


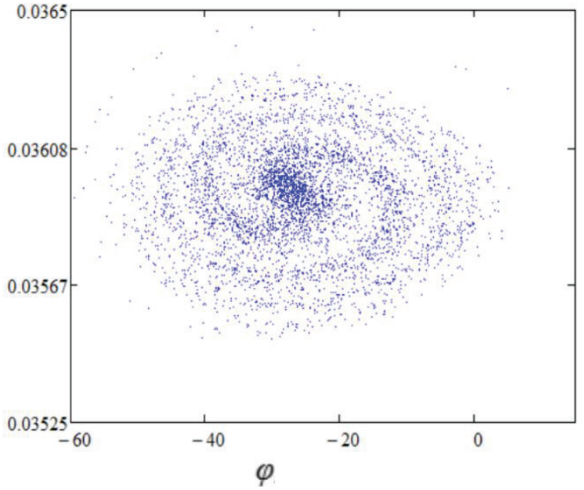
f=162.5 MHz

f=81.25 MHz



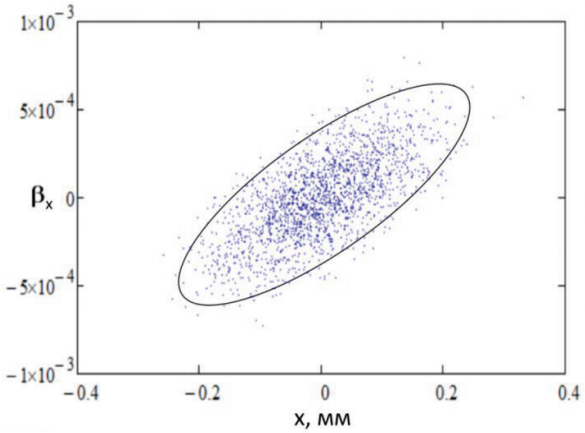

2×10⁻³
1×10⁻³
0
−1×10⁻³
−2×10⁻³
−0.6
−0.3
0
0.3
0.6
x, cm

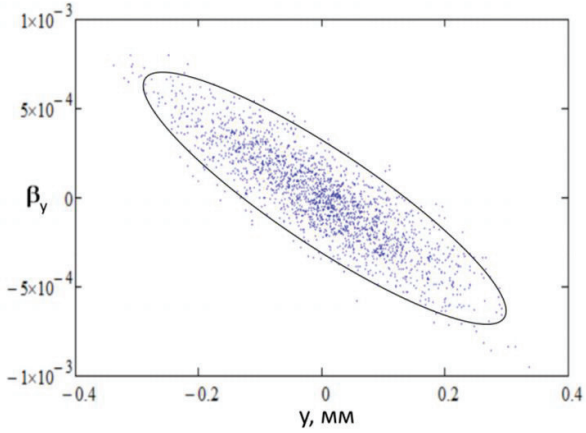

2×10⁻³
1×10⁻³
0
−1×10⁻³
−2×10⁻³
−1
−0.5
0
0.5
1
y, cm

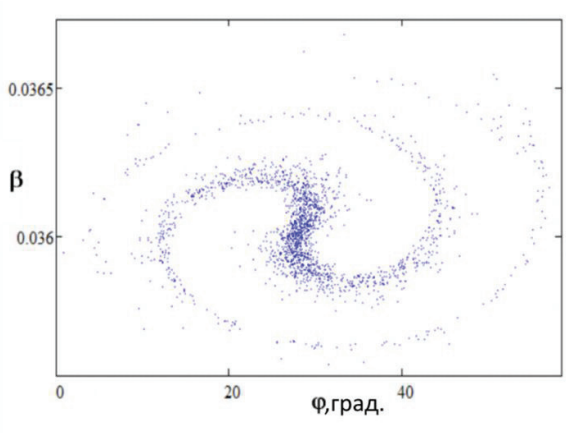

0.0365
0.03608
0.03567
0.03525
−60
−40
−20
0
φ

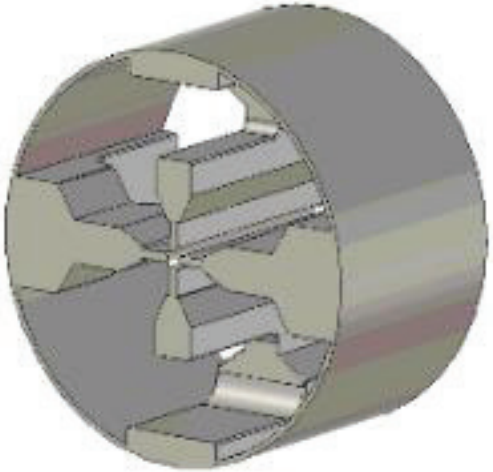
4
0.04
0
200
400
600

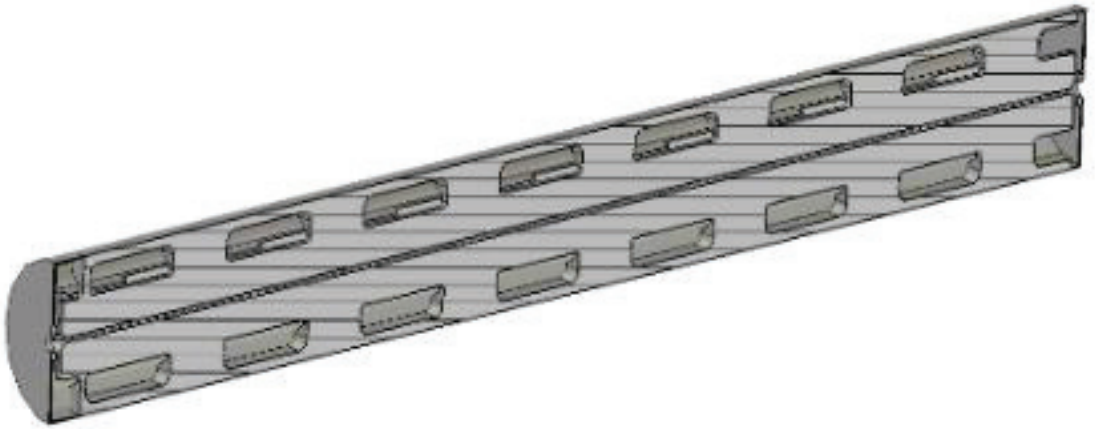

4
0.04

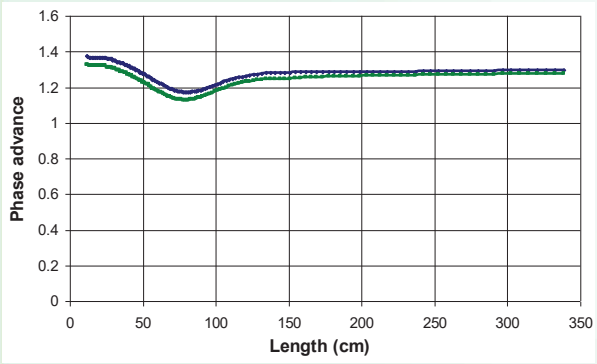

1×10⁻³
5×10⁻⁴
βx
0
−5×10⁻⁴
−1×10⁻³
−0.4
−0.2
0
0.2
0.4
x, мм

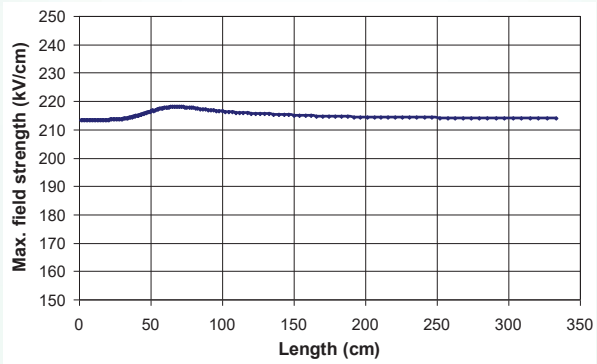

1×10⁻³
5×10⁻⁴
βy
0
−5×10⁻⁴
−1×10⁻³
−0.4
−0.2
0
0.2
0.4
y, мм

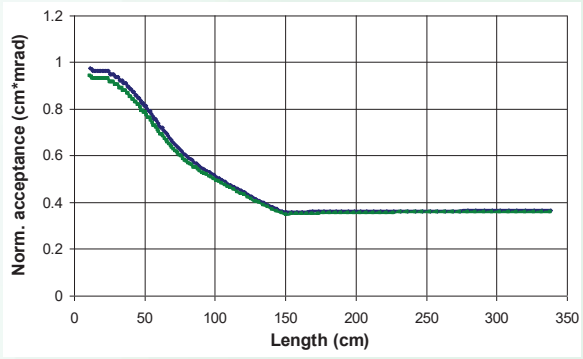

0.0365
β
0.036
0
20
40
φ,град.









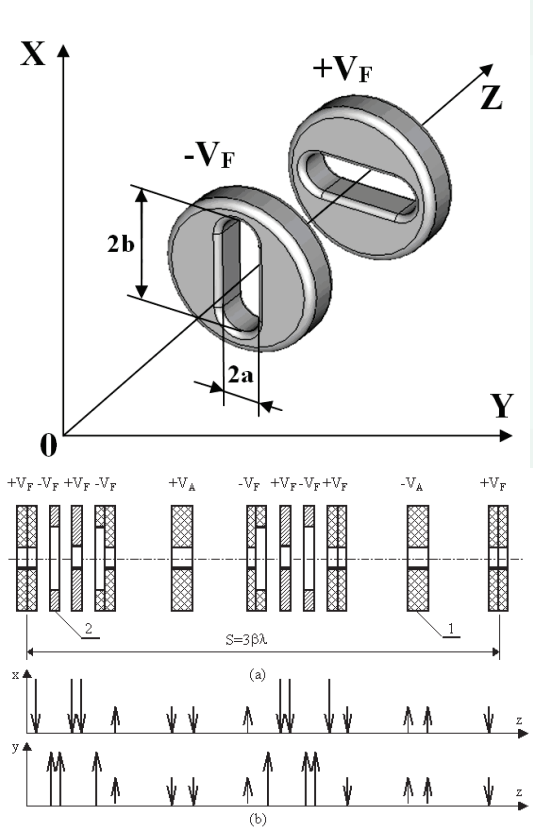


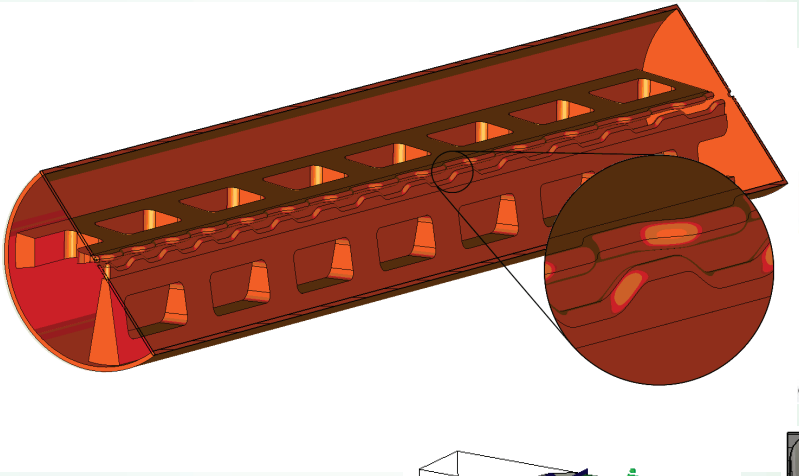
The design of RFQ cavity will based on the CW segmented-vane RFQ [V.A. Andreev, G. Parisi. Proc. Of PAC'93, 3124-3126 (1994)] developed by the joint team of MEPhI, ITEP, GSI and HIM: [S. Polozov et al., Proc. of HB'16, 188-190 (2016); S. Polozov et al., Proc. of RuPAC'16, 267-269 (2016); S. Polozov et at., Proc. of IPAC'17, 1333-1336 (2017)]

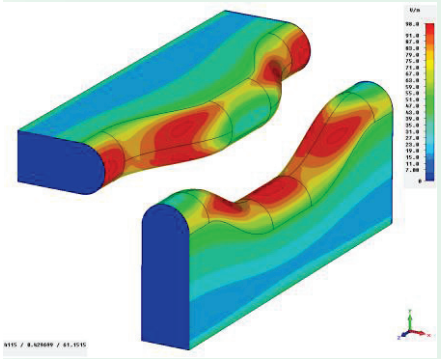
Normal conducting cavities for intermediate energies

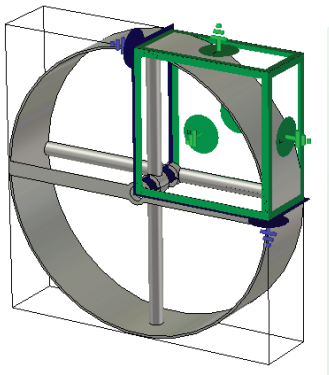
As known, the intermediate energy band (after RFQ and up to 2.0-2.5 MeV/u) has some difficulties both for the beam dynamics and the RF efficiency of the accelerating cavities.

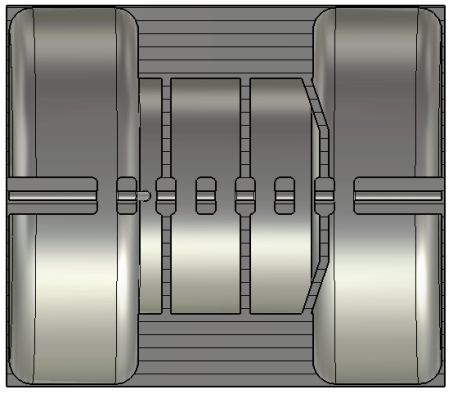
RF Crossed Lenses / modified electrode form RFQ / 3-cell or 5-cell CH/IH cavities ?







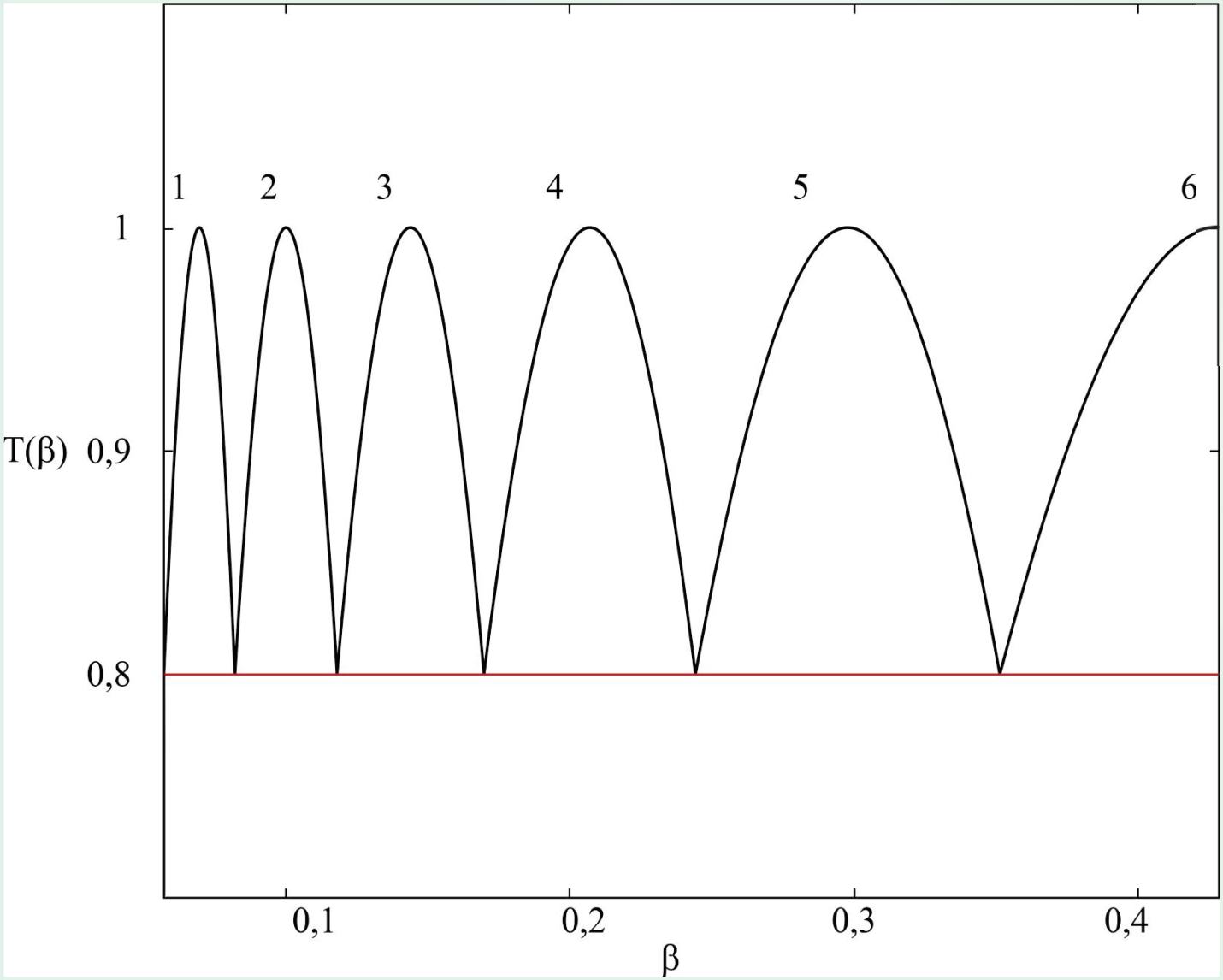




A.I. Balabin, G.N. Kropachev NIM A, 459, 87-92 (2001).

A.S. Plastun, A.A. Kolomiets Proc. of LINAC'12, 41 – 43 (2012).

*High energy linac part: SC cavities **



BEAMDULAC-SCL code simulations

5 groups

156 cavities

140 m

*** Current SRF activities in Russia: S.M. Polozov, Tua2wc02**

Group	1	2	3	4	5	6
W_{in}, MeV/u	1.5	3.16	6.59	13.78	29.24	63.8
β_{in}	0.056	0.08	0.12	0.170	0.244	0.351
β_g	0.069	0.01	0.144	0.207	0.298	0.428
W_{out}, MeV/u	3.16	6.59	13.78	29.24	63.8	100.0
β_{out}	0.082	0.12	0.170	0.244	0.351	0.428
T, %	20	20	20	20	20	20
f, MHz	162	162	162	324	324	324
φ_{inj}, deg	–30	–30	–30	–30	–27	-20
U, MV	0.52	1.5	2.7	3.0	6.0	9.5
E, kV/cm	2	4	5.1	7.83	10.9	11.93
N_{gap}	4	4	4	4	4	4
L_{cav}, m	0.257	0.37	0.532	0.383	0.551	0.796
B_{sol}, T	3.1	4.5	5.5	6	7	7.5
L_{sol}, m	0.2	0.2	0.2	0.2	0.2	0.2
L_{per}, m	0.657	0.77	0.932	0.783	0.951	1.196
N_{per}	22	16	18	36	40	24
K_T, %,	100	100	100	100	100	100

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Injection energy should be increased

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φ_{inj}, deg	–30					
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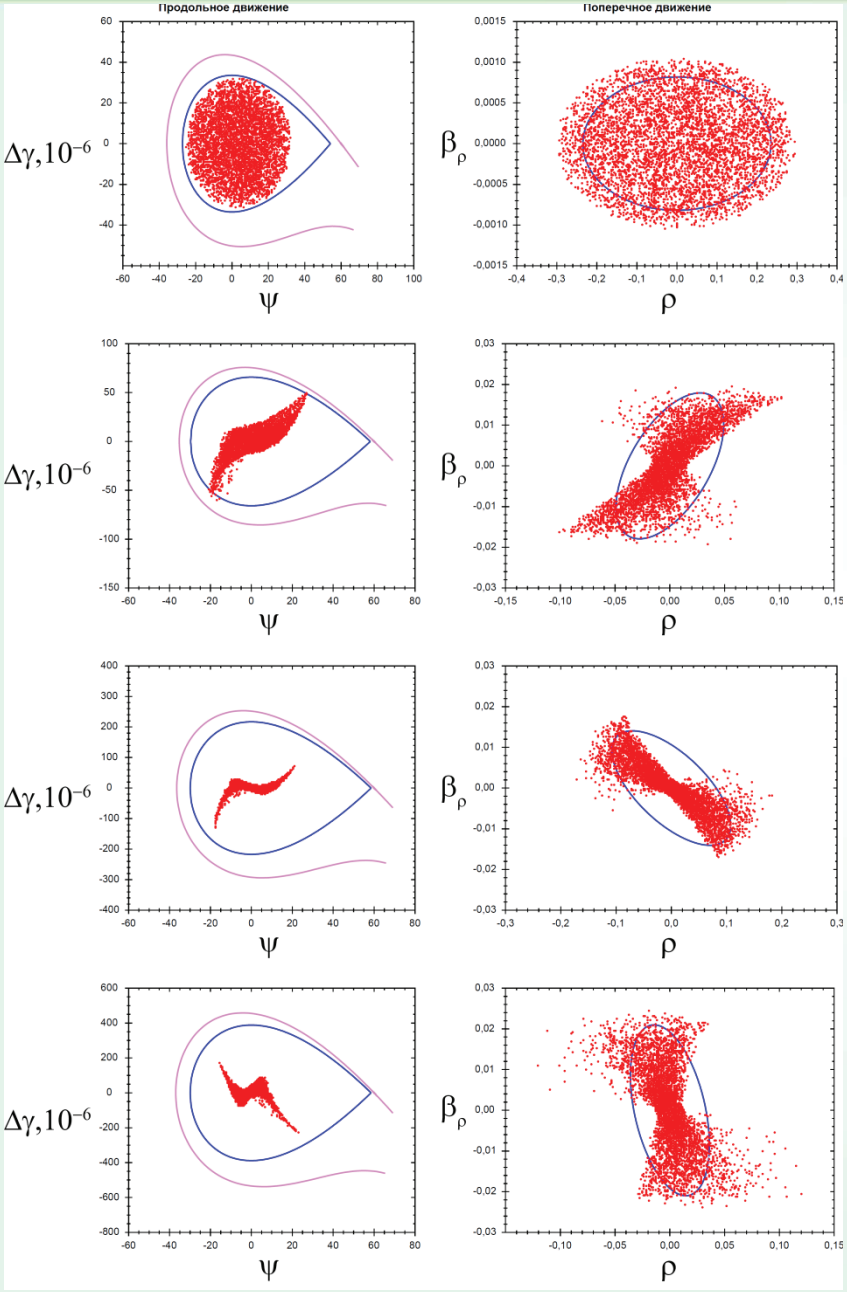
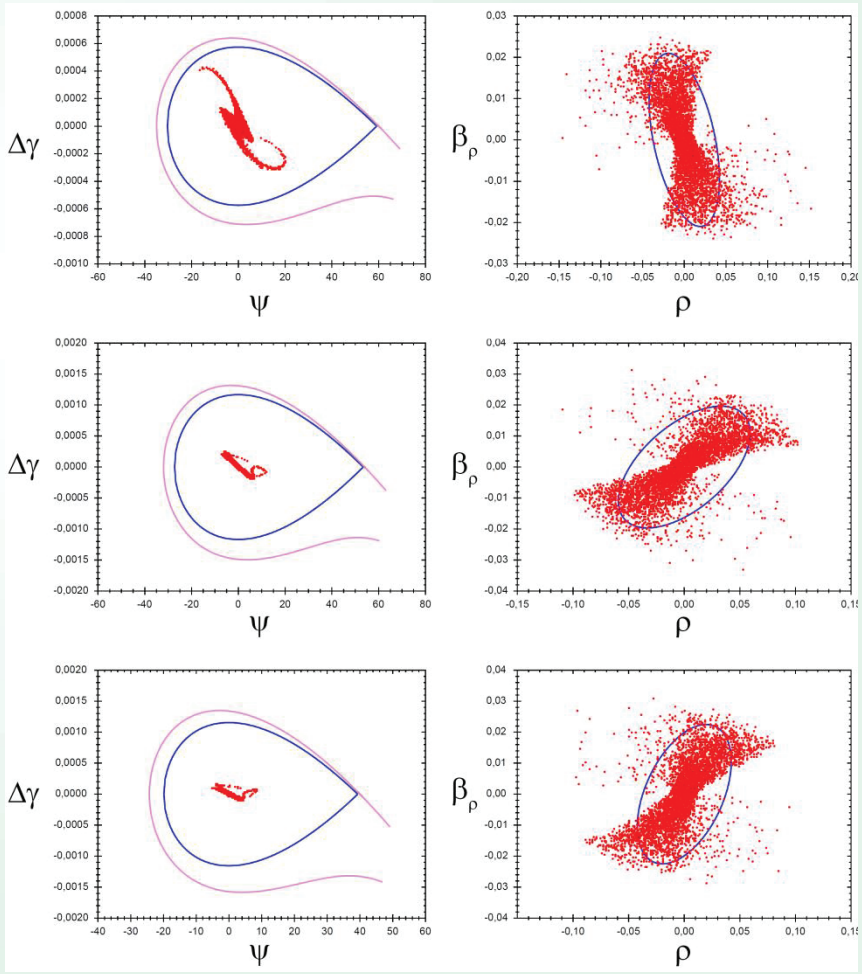
N_{gap}	4	4	4	4	4	4
L_{cav}, m	0.257	0.37	0.532	0.383	0.551	0.796
B_{sol}, T	3.1				7	7.5
L_{sol}, m	0.2				0.2	0.2
L_{per}, m	0.657	0.77	0.932	0.783	0.951	1.196
N_{per}	22	16	18	36	40	24
K_T, %,	100	100	100	100	100	100

Injection energy should be increased

Stripper is necessary


Продольное движение
Поперечное движение
Δγ,10⁻⁶
ψ
β_ρ
ρ


Δγ
ψ
β_ρ
ρ

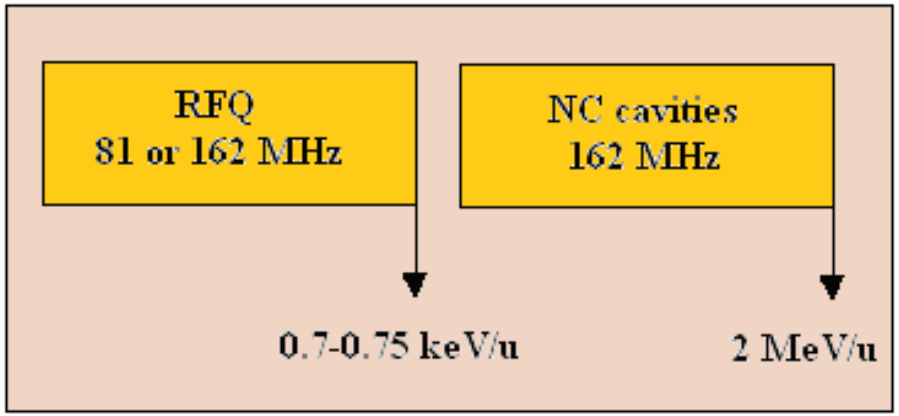
•LINAC-30 initial layout: ions

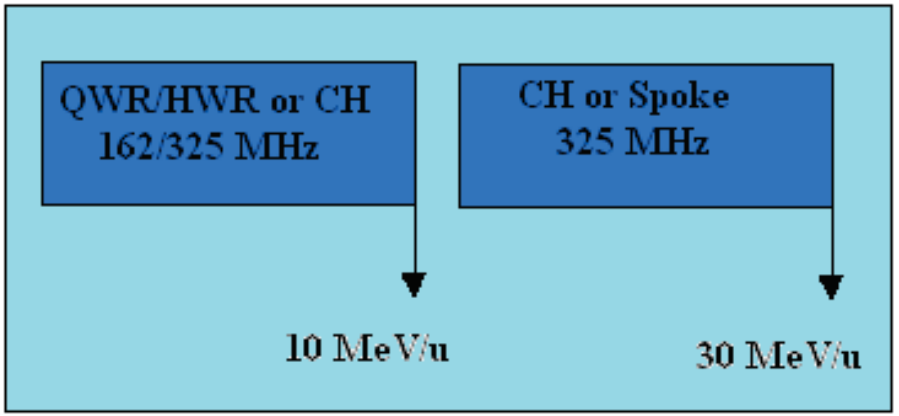
Representative secondary radioactive isotopes for LINAC-30

Ion	Possible *A*	Charge	*A/Z* band
B	8 – 19	5+	1.6 – 3.8
O	13 – 24	8+	1.63 – 3.0
Ar	31 – 46	16+	1.94 – 2.88
Sn	100 – 132	38+	2.63 – 3.47

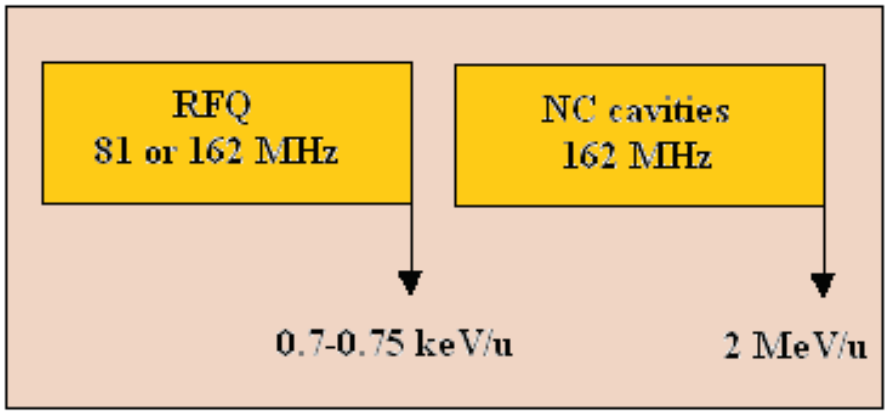
A/Z=1.6 – 3.8 !!!

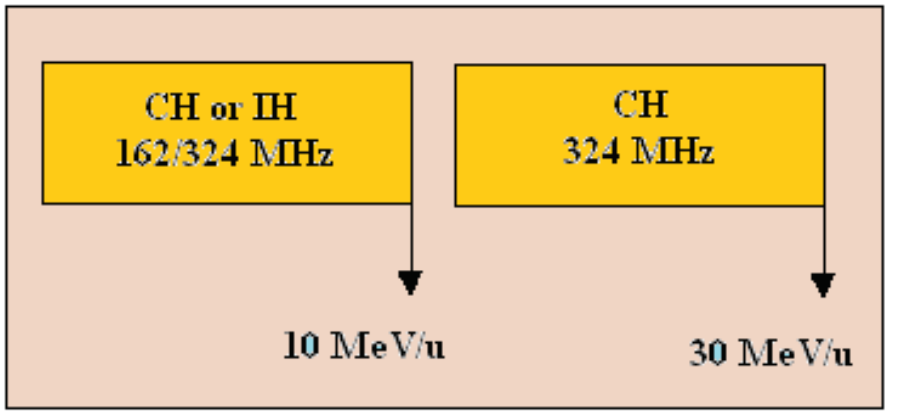
•LINAC-30 initial layout



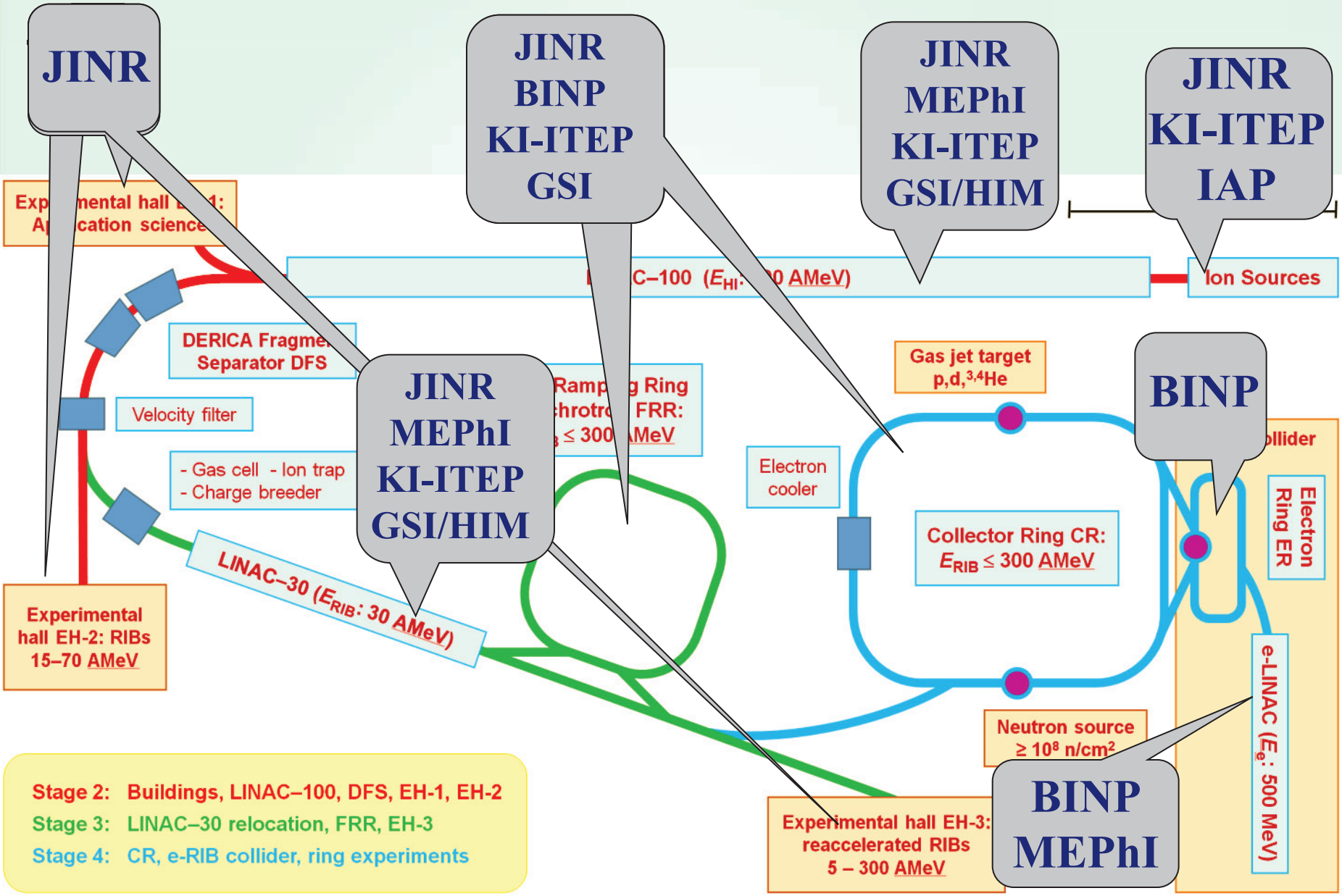


OR ???





•DERICA: possible collaboration (accelerators)



•Conclusions

-DERICA: **D**ubna **E**lectron – **R**adioactive **I**on **C**ollider f**A**cility is the new ambitious RIB project form Russia

-The project aims, DERICA's possible site and the general layout are initially defined

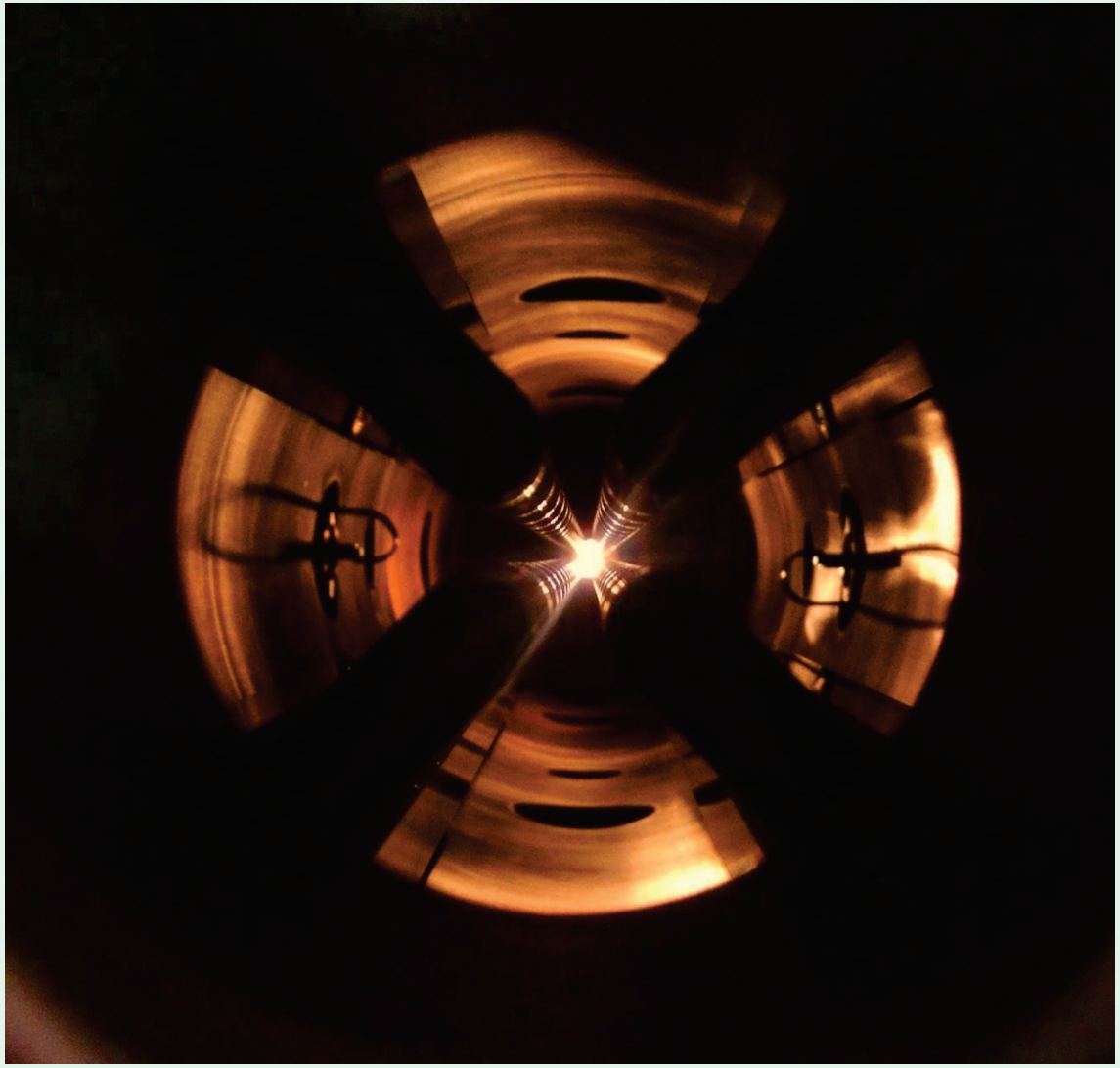
-LINAC-100 design and beam dynamics simulations are started

-LINAC-30: normal conducting or superconducting?

-SRF program is under start

-We are open for new collaboration

Thank You for attention !



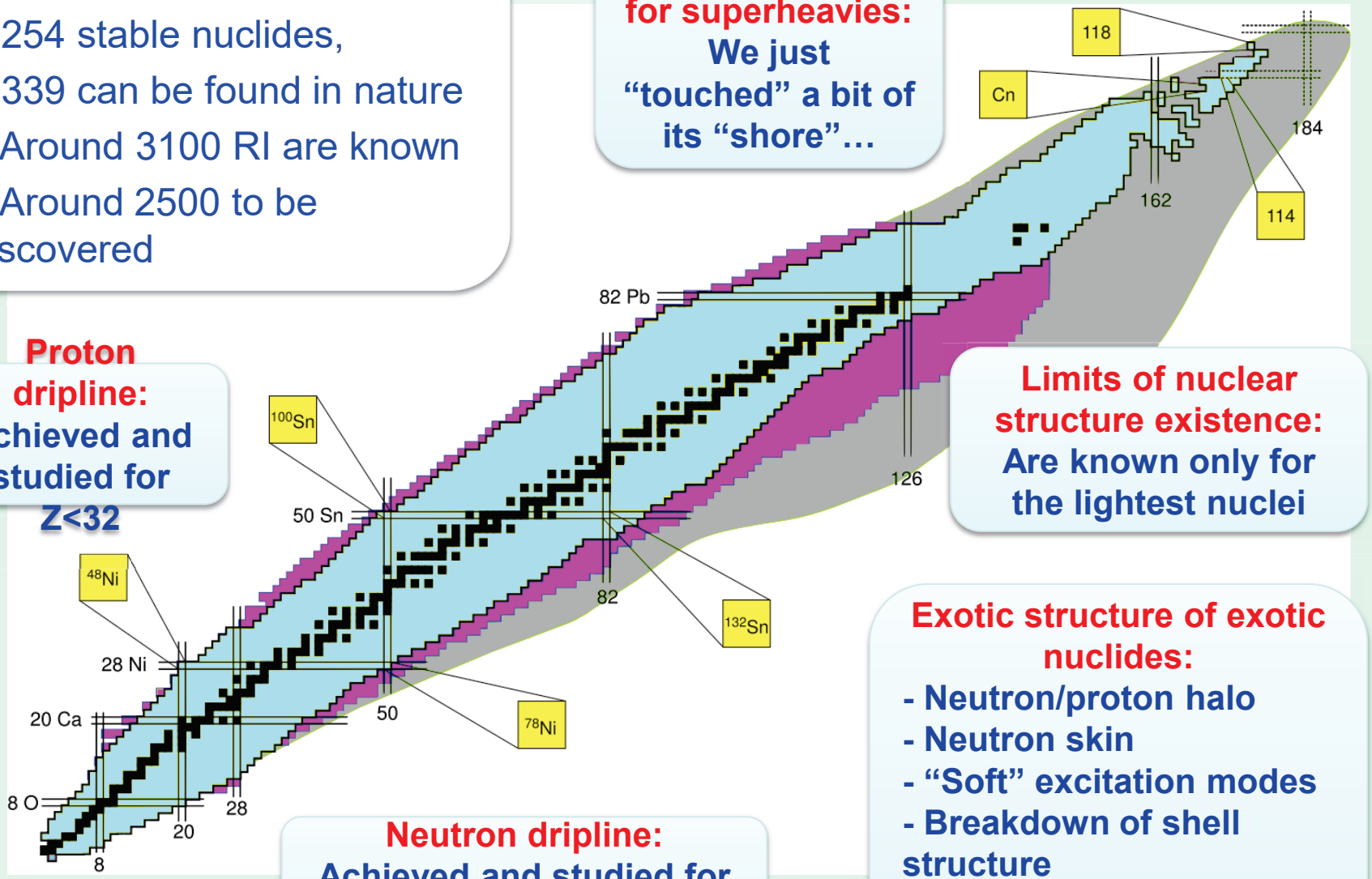
A number of additional slides

Radioactive Ion Beam (RIB) physics

The map of nuclides

- 254 stable nuclides,
- 339 can be found in nature
- Around 3100 RI are known
- Around 2500 to be discovered

"Isle of stability" for superheavies: We just "touched" a bit of its "shore"…



Proton dripline: Achieved and studied for Z<32

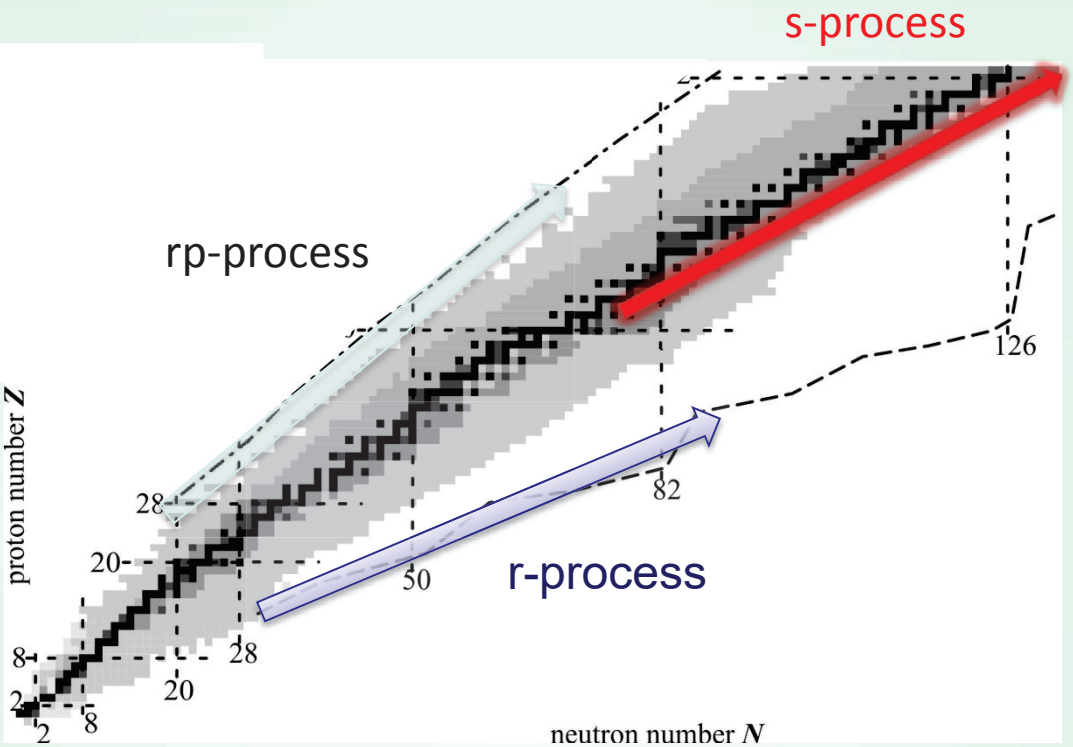
Limits of nuclear structure existence: Are known only for the lightest nuclei

Exotic structure of exotic nuclides:

- Neutron/proton halo
- Neutron skin
- "Soft" excitation modes
- Breakdown of shell structure
- New "magic numbers"

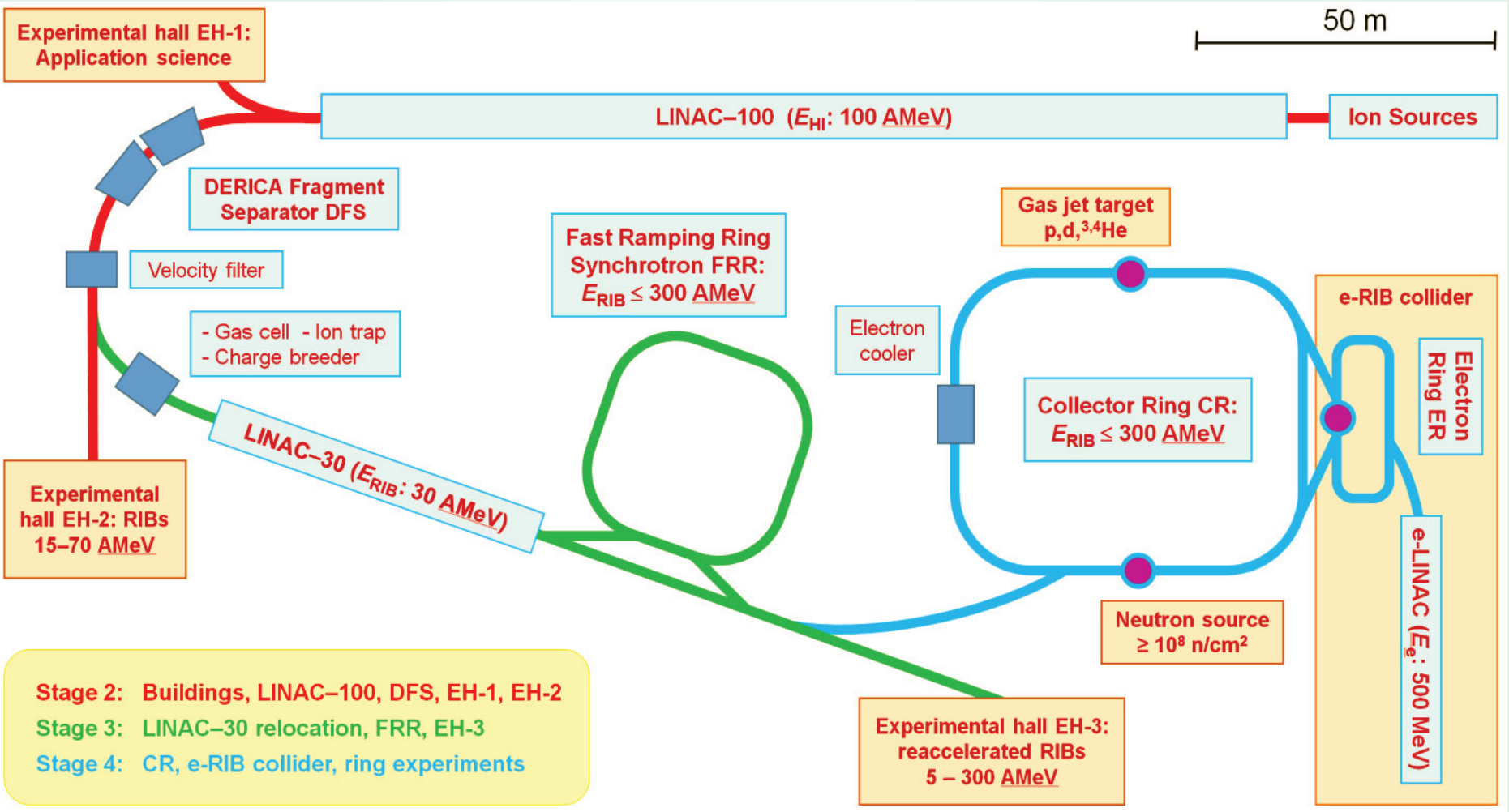
Neutron dripline: Achieved and studied for N<20

Motivation – Applications to nucleosynthesys



- Hydrostatic burning – slow process
- Explosive burning – rapid processes
- Where does it take place?
- Every day observed violent events in space are produced by rp-processes
- Element abundance in space is connected with r-processes
- No quantitative understanding until the driplines are studied in details

DERICA general layout



- # DERICA Stages

Stage 0: the scientific agenda is fully formulated, the technical concept is formed, required R&Ds are carried out.

Stage 1: equipment of the {gas cell - ion trap - ion source/charge breeder} system; experiments with stopped RI in the electromagnetic traps; construction and commissioning of LINAC-30.

Stage 2: LINAC-100 construction and commissioning; applied studies with high-intensity stable-ion beams; DFS construction and commissioning;

Stage 3: gas cell construction; system {gas cell - ion trap - ion source/charge breeder} is relocated to DFS; LINAC-30 is relocated to the DFS; FRR construction and commissioning;

Stage 4: CR and ER construction and commissioning; experiments can be performed at three independent experimental locations of the CR ring.

Stage #: LINAC-100 energy upgrade (150-100 MeV).