Multi Purpose Detector to study heavy-ion collisions at NICA collider

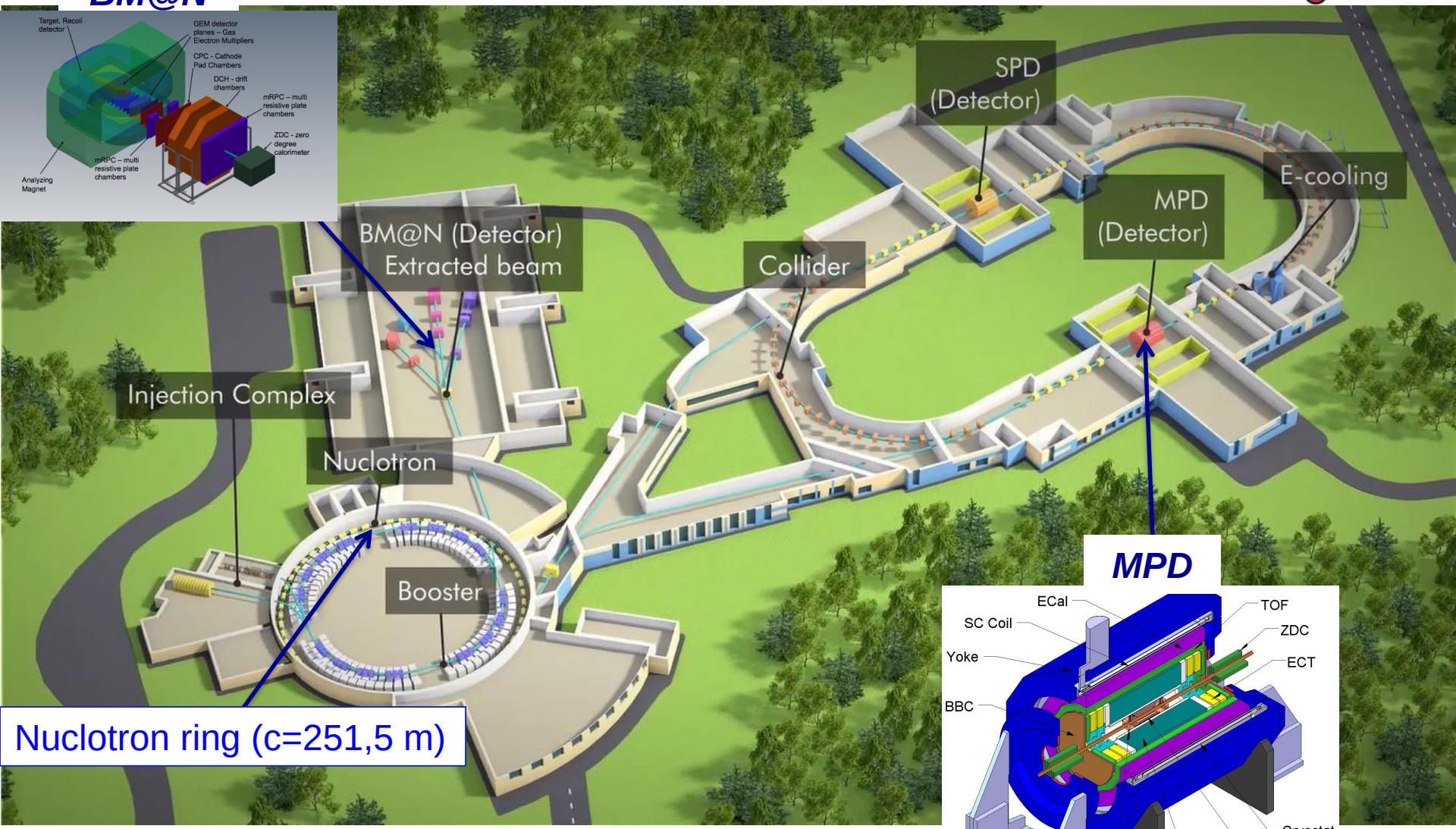
V.Kekelidze,

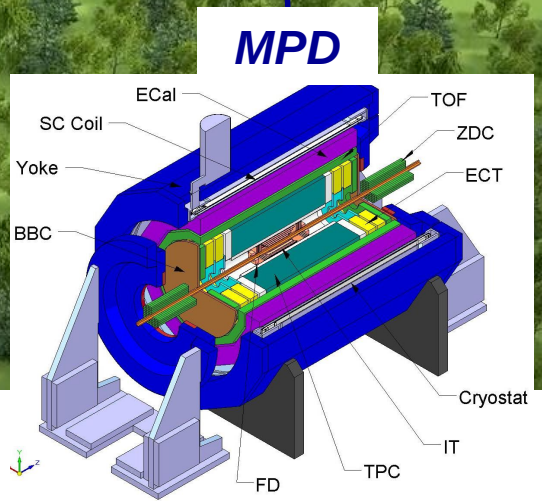
Joint Institute for Nuclear Research, Dubna

Venezia 2018 Quark Matter

May 13-19,

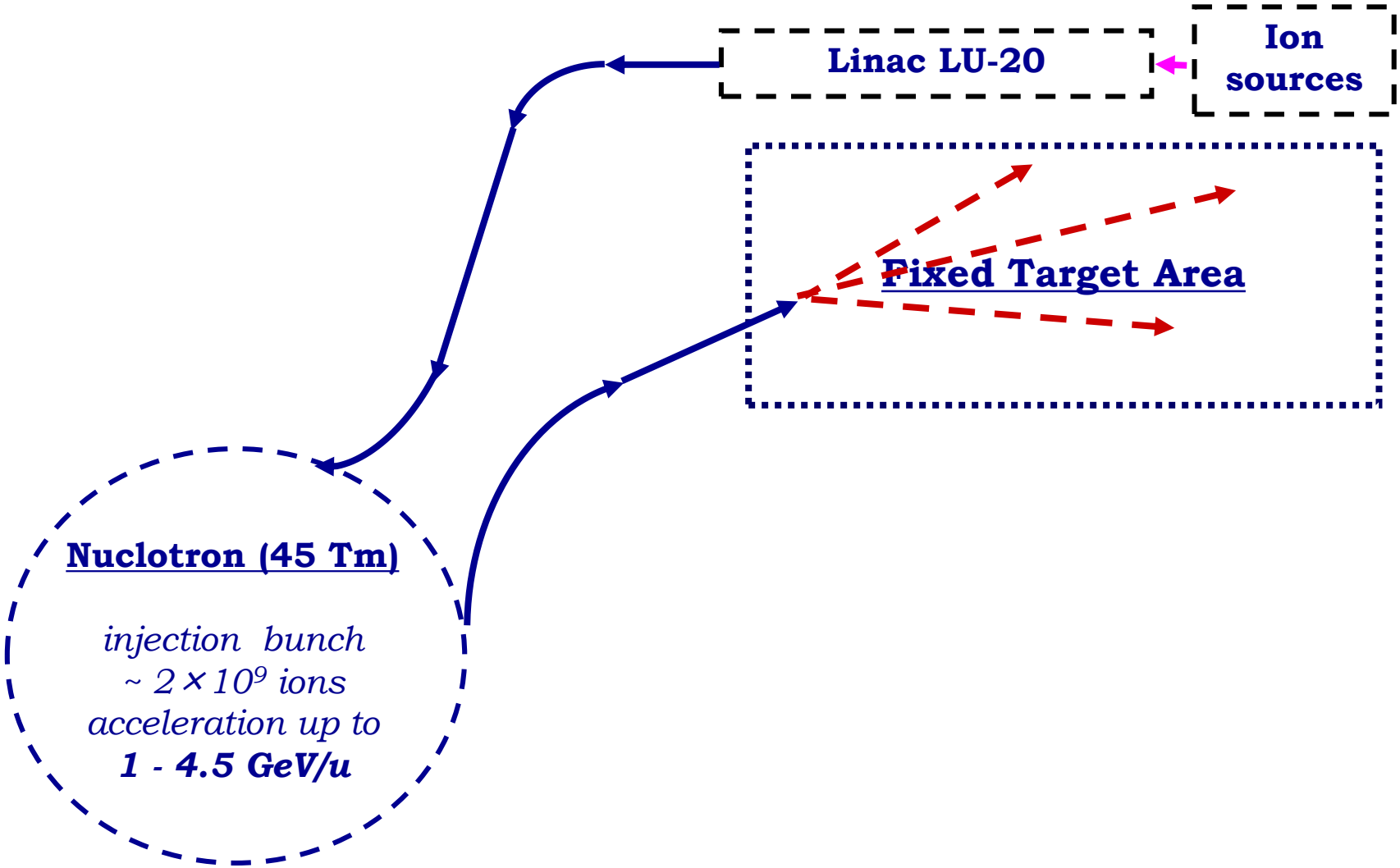
basic facility



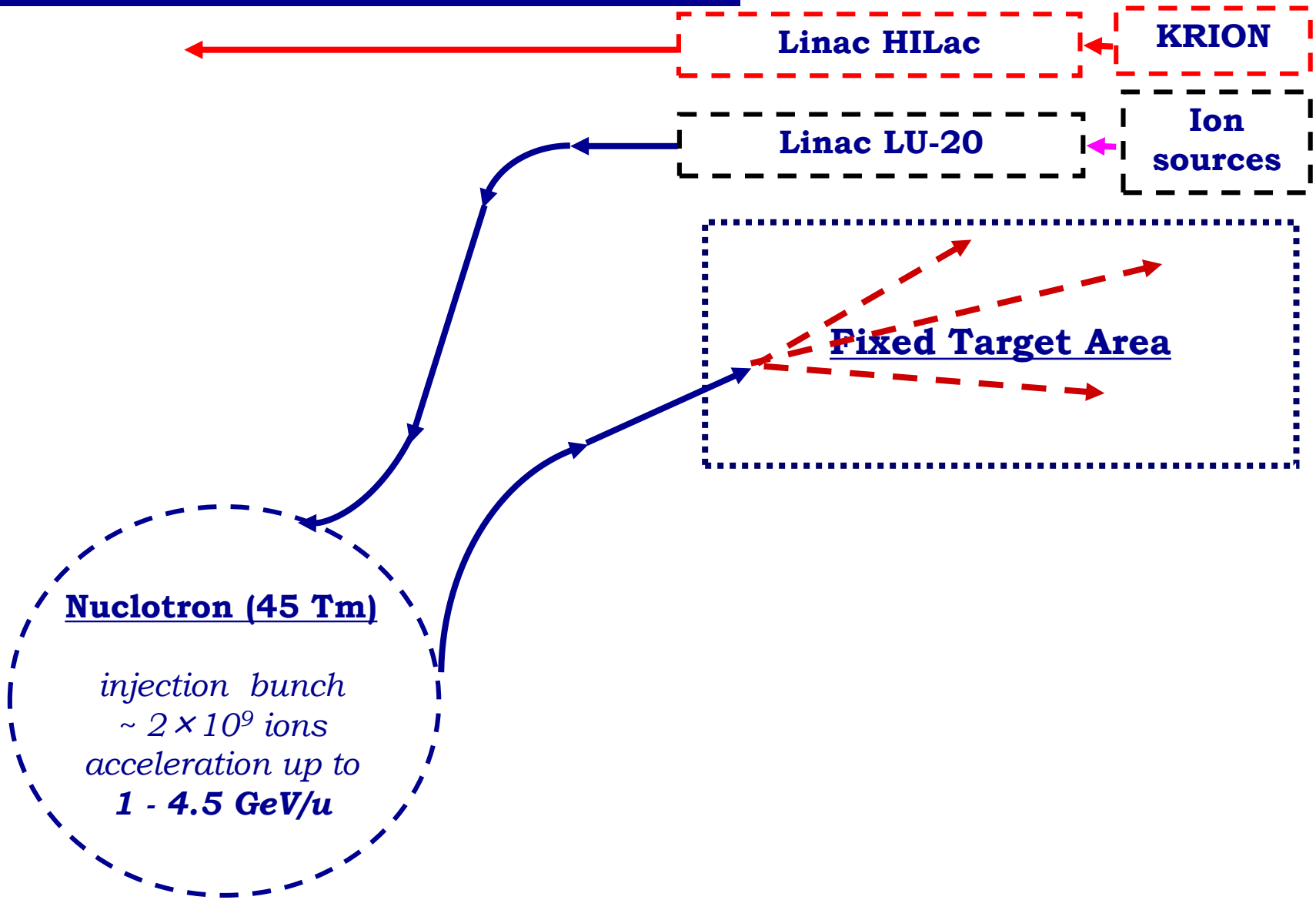


NICA
accelerator complex

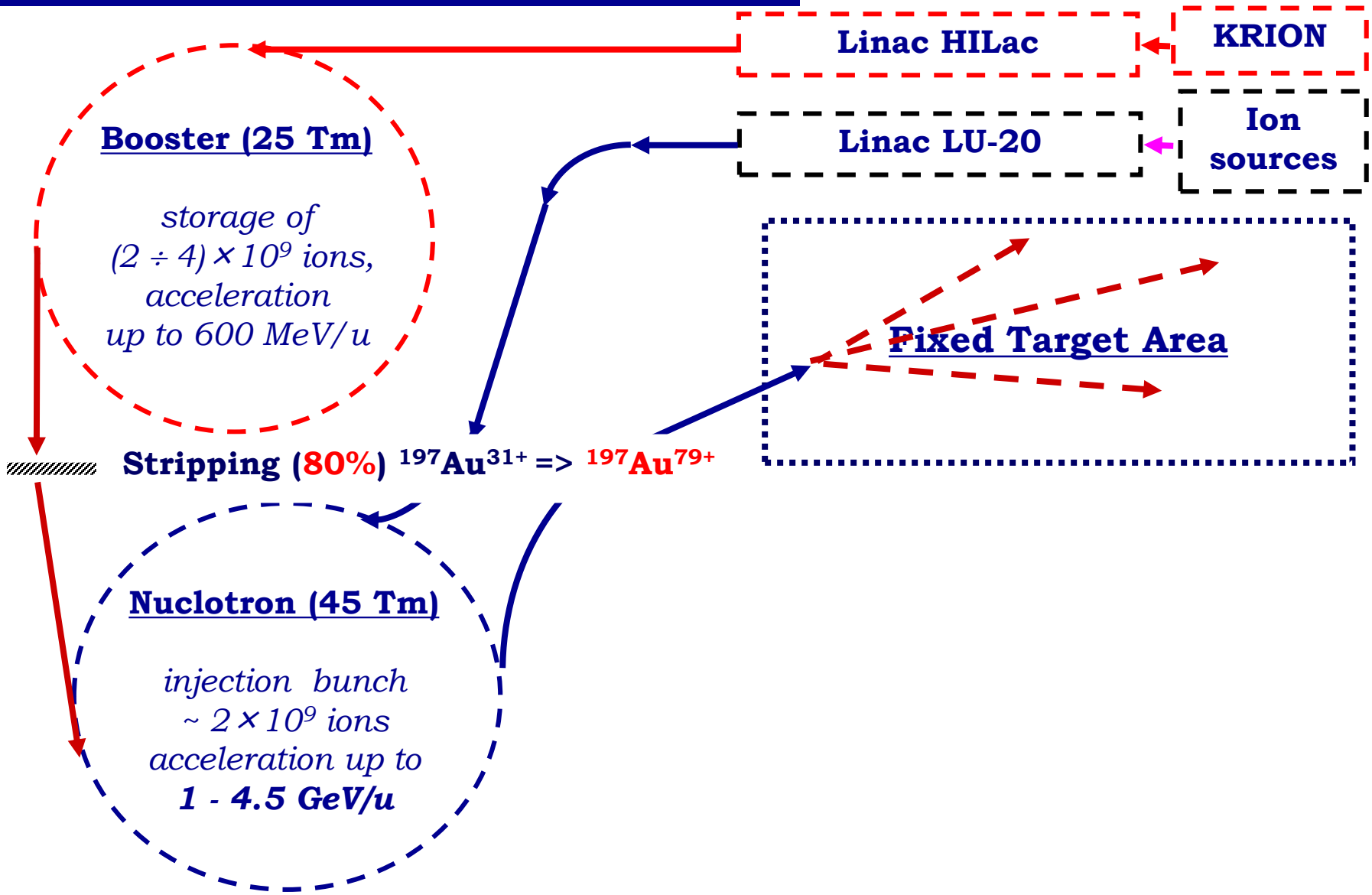
Structure and Operation Regimes



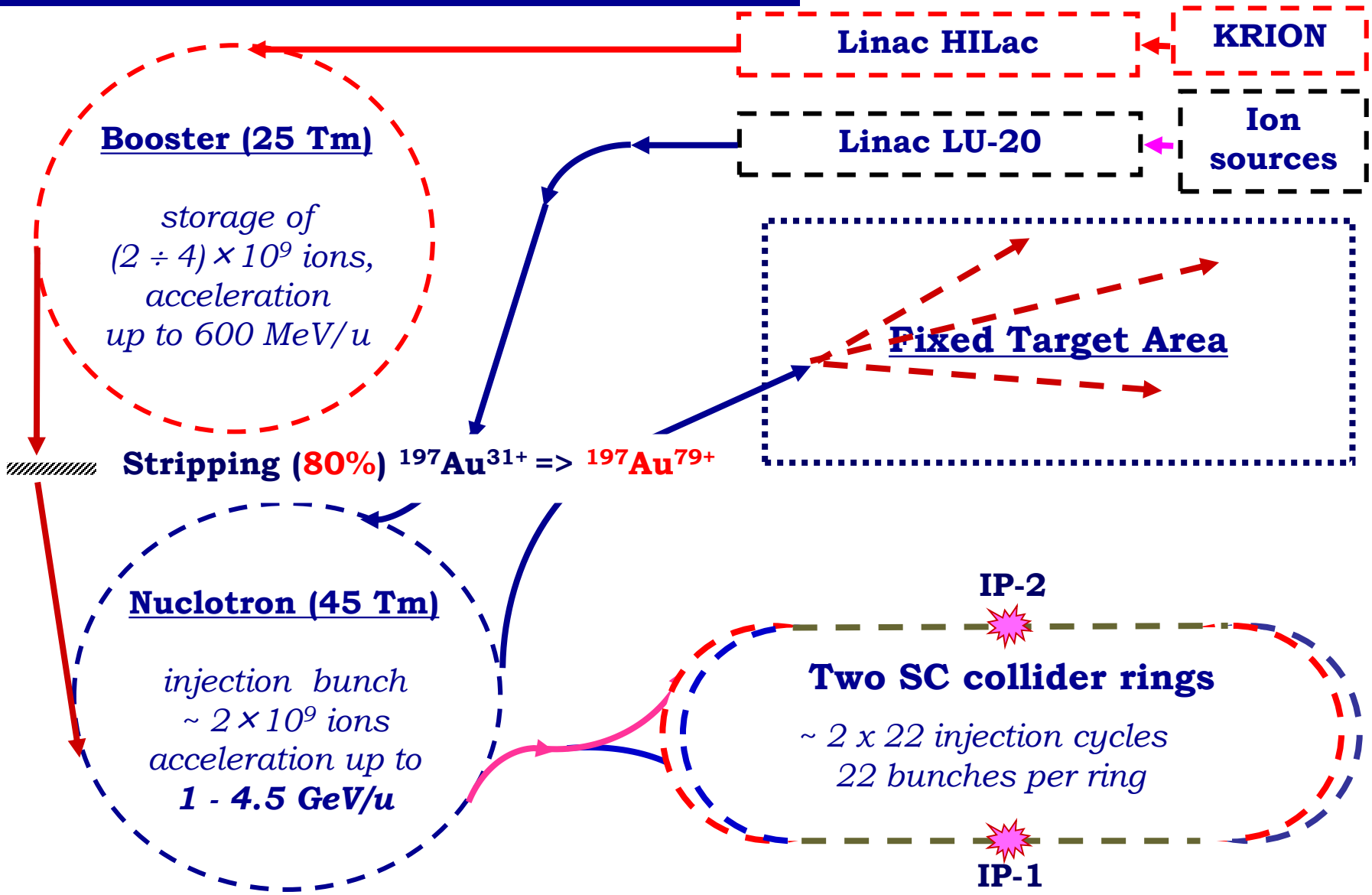
Structure and Operation Regimes



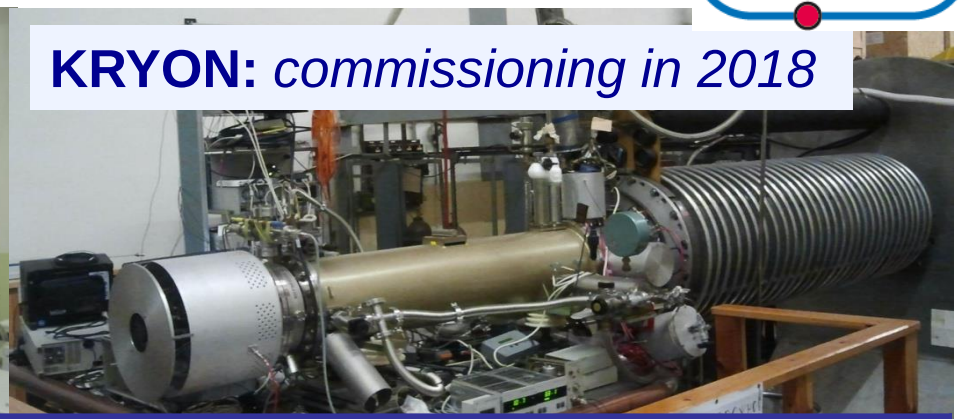
Structure and Operation Regimes



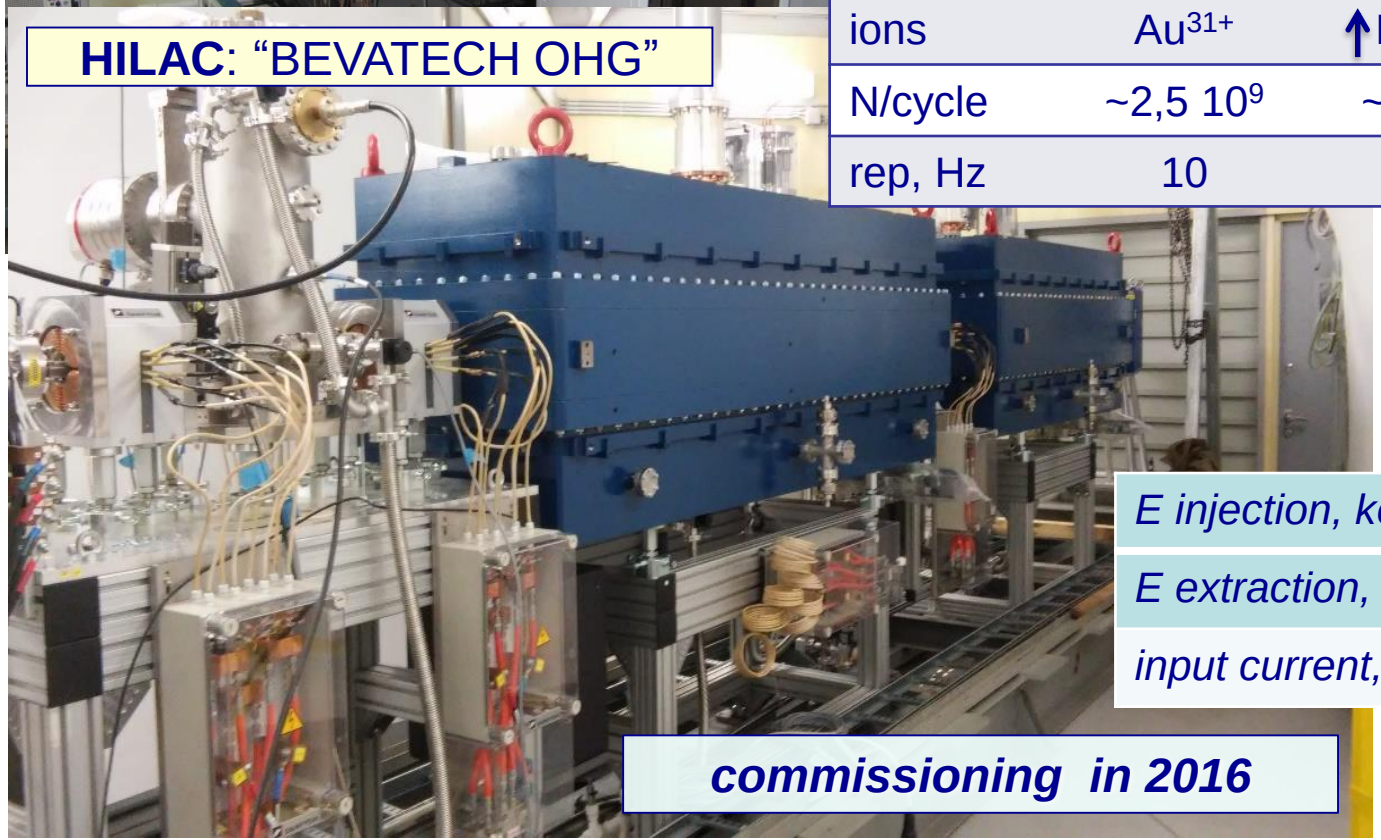
Structure and Operation Regimes



Injection Complex



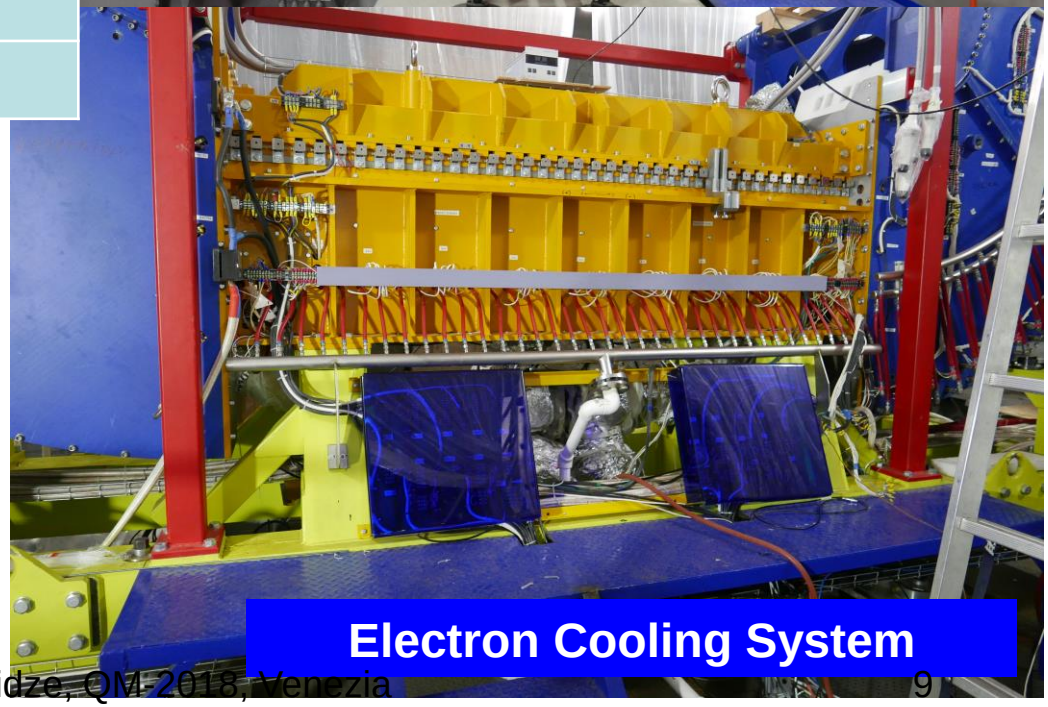
Source	Kryon-6T	SPI	Douplasmatron
ions	Au^{31+}	↑H,↑D	H^+, D^+
N/cycle	~2,5 10^9	~510^{11}	~5 10^{12}
rep, Hz	10	0,2	1,0



E injection, keV/amu	**17**
E extraction, MeV/amu	**3.24** (A/Z=6)
input current, mA	up to **10**

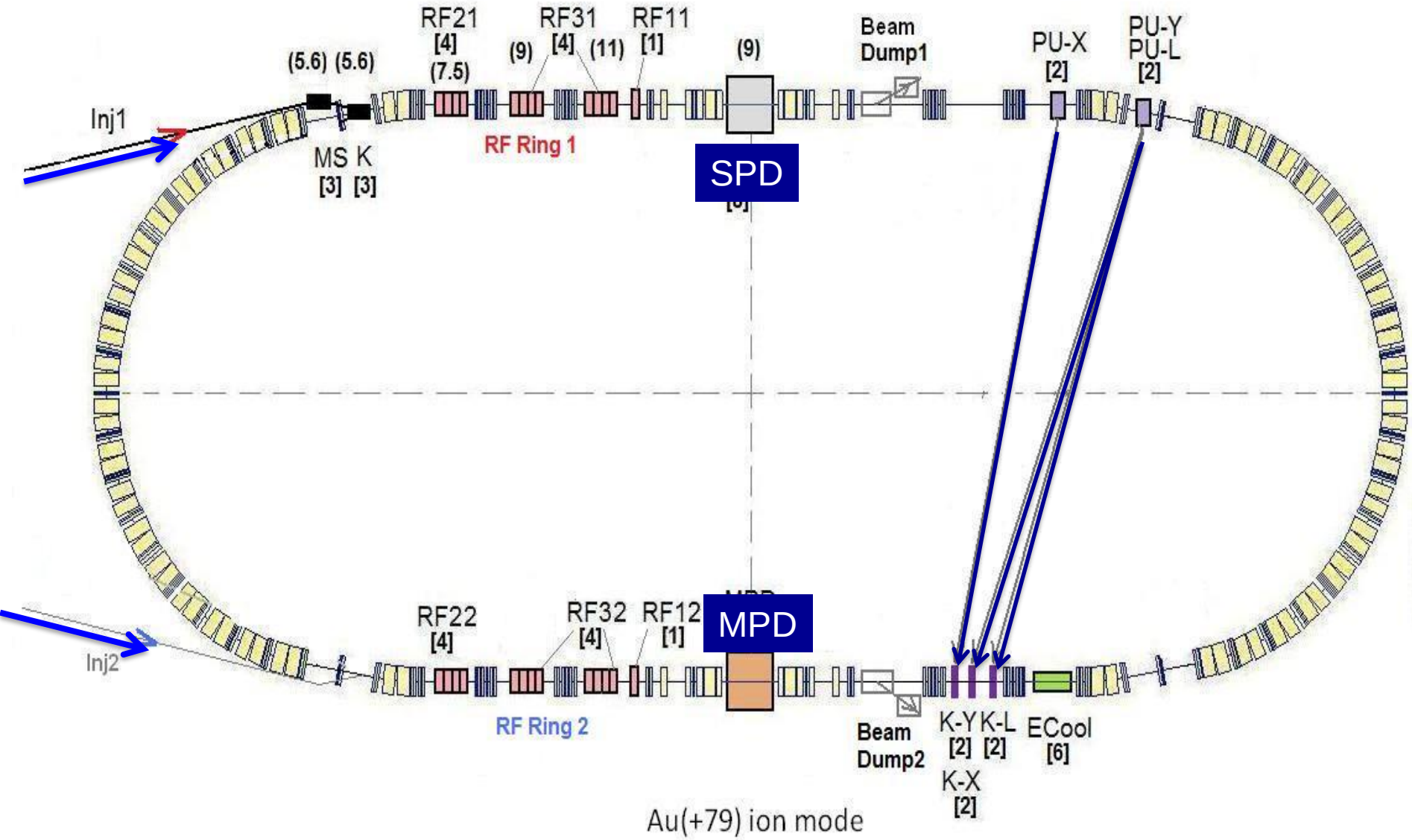
Booster – *commissioning in 2018*

parameter	**value**
Ion types	A/Z $\leq$ 3
injection energy, MeV/u	3.2
maximum energy, MeV/u	600
magnetic rigidity, T m	1.6 – 25.0
circumference, m	210.96
vacuum, Torr	10^{-11}
*intensity, **Au** ions/pulse*	1.5 10^{9}
RF range, MHz	0.5 -2.53



Collider structure

45 T*m, **11,0** *GeV/u for* ***Au^{79+}***



Collider *parameters*

parameter	value		
circumference, m	503,04		
structure	FODO, 12 sectors		
bunch number	22		
bunch length, m	0,6		
β –function at IP, m	0,35		
ring acceptance, p mm mrad	40		
E in the c.m.s. for $_{197}A^{79+}$, GeV/u	**4,0**	**8,0**	**11,0**
ion number in bunch	$2{,}0\ 10^{8}$	$2{,}4\ 10^{9}$	$2{,}3\ 10^{9}$
momentum spread, Dp/p	$0{,}55\ 10^{-3}$	$1{,}15\ 10^{-3}$	$1{,}5\ 10^{-3}$
beam emittance, p mm mrad	1,1/0,95	1,1/0,85	1,1/0,75
luminosity, $cm^{-2}\ s^{-1}$	**$0{,}6\ 10^{25}$**	**$1{,}0\ 10^{27}$**	**$1{,}0\ 10^{27}$**
time life of luminosity, s	160	460	1 800

SC Magnets for NICA & SIS-100/FAIR workshop at VBLHEP

(bld. 217) was put in operation (full configuration) ***in Nov. 2016***

> 80% of the Booster magnets are fabricated & tested

Civil Construction bld.17

> 5000 piles are already pressed in
> 20k m³ concrete works are done
metal constructions – in progress

Aug 2017

readiness for equipment installation in the MPD Hall - 2018

NICA heavy ion collisions program in 2021-2023

Physics objectives

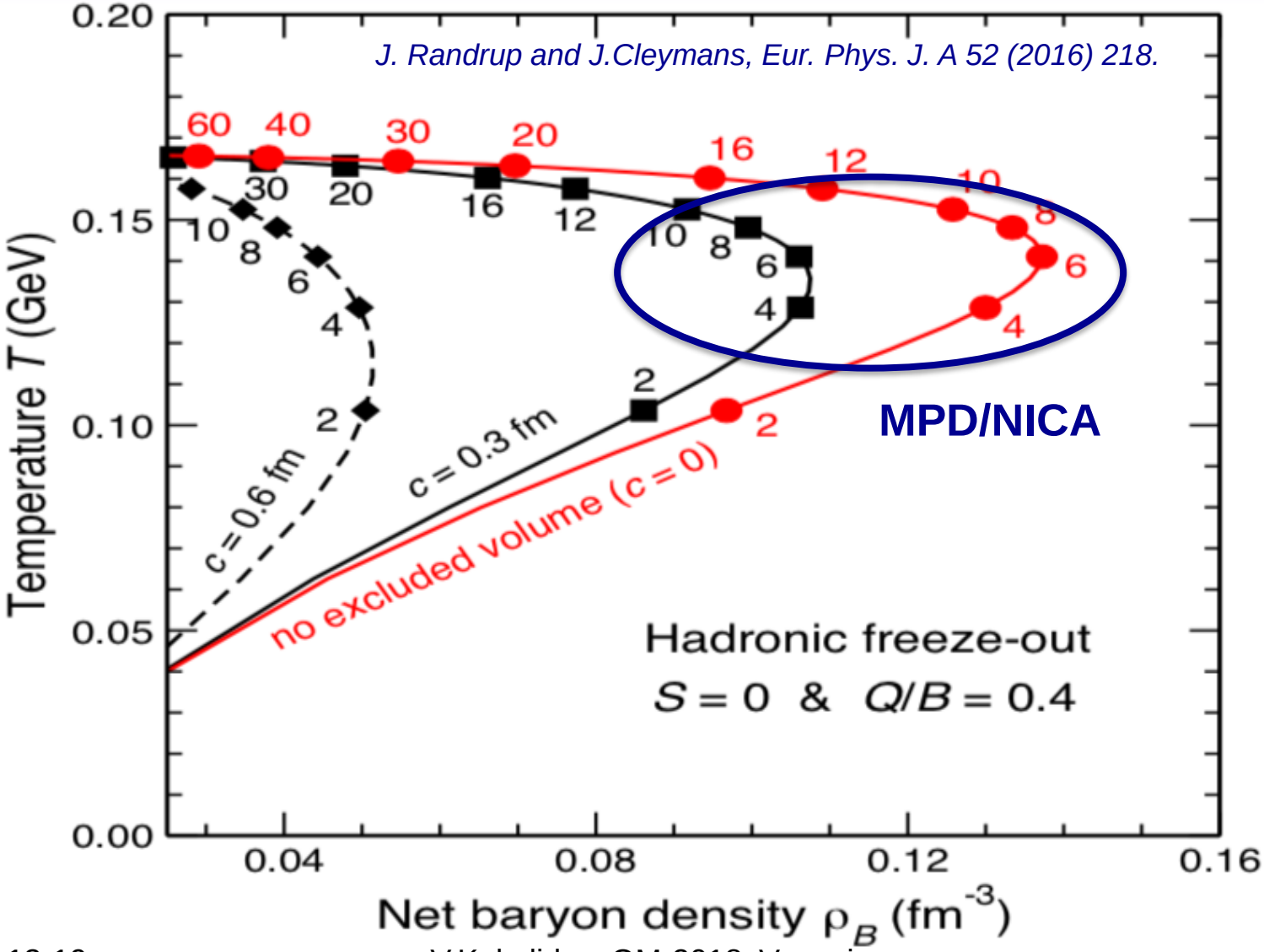
Comprehensive study of:

- ***bulk properties, EOS***
  - particle yields & spectra, ratios, femtoscopy, flow
- ***in-medium modification of hadron properties***
  - onset of low-mass dilepton enhancement
- ***deconfinement (chiral) phase transition***
  - strangeness production
  - Chiral Magnetic (Vortical) effect, Λ polarization
- ***search for QCD Critical Point***
  - event-by-event fluctuations & correlations
- ***Y-N interactions in dense nuclear matter***
  - hypernuclei

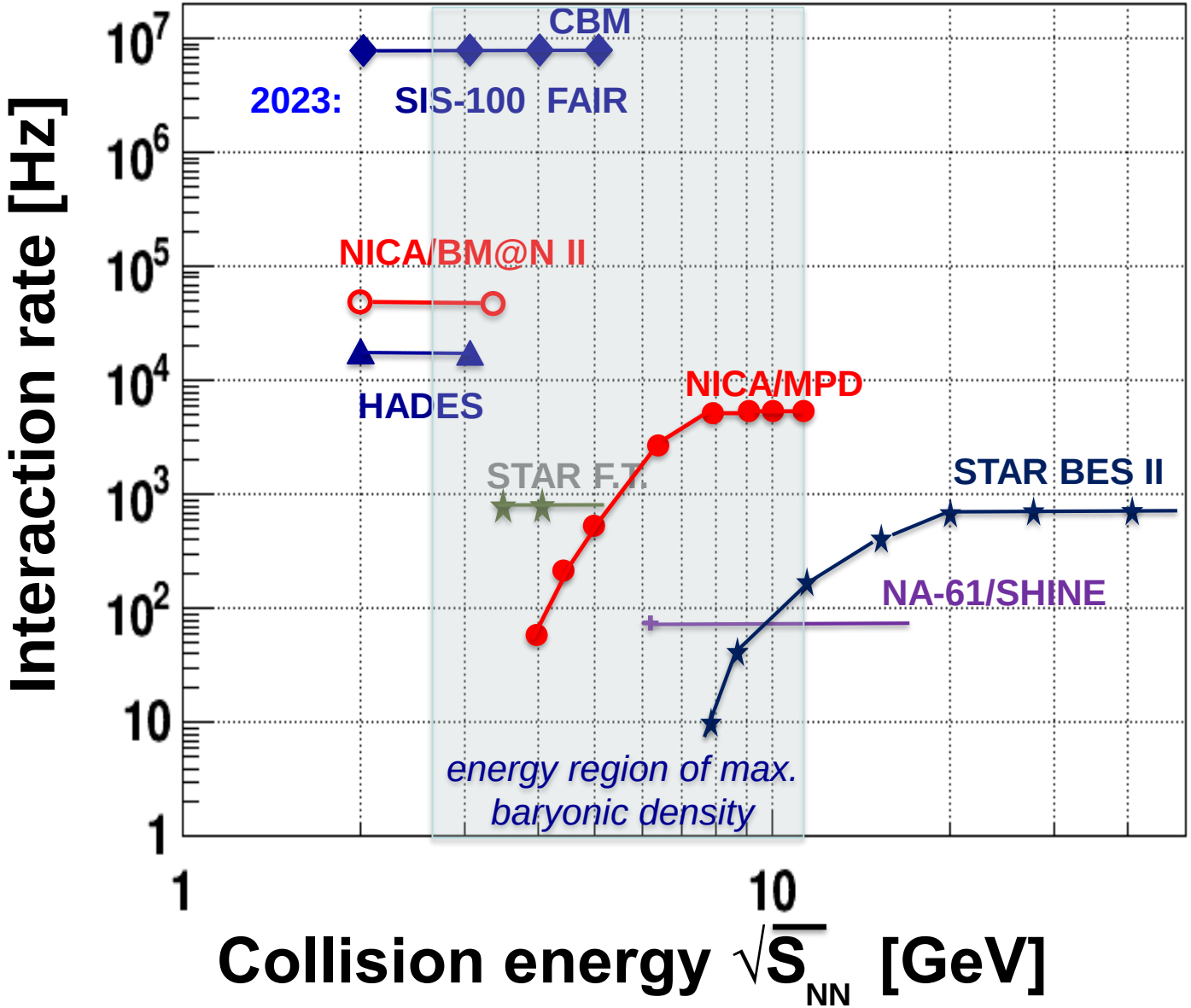
in the region of max net baryon density

Exploration of the QCD Phase Diagram

Exploring high-density baryonic matter: maximum freeze-out density



Present and future HI experiments

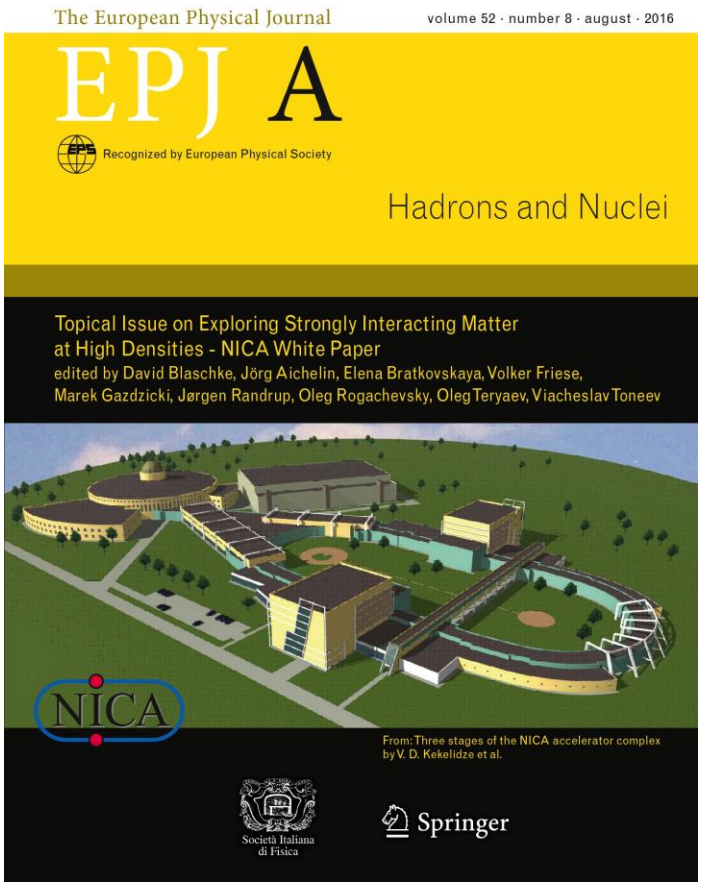


QCD matter at the NICA energies:

- *maximum in the net baryon density –* ***density frontier****;*
- *maximum in* K^+/π^+ *ratio;*
- *maximum in* Λ/π *ratio;*
- *maximum yield if hypernuclei*
- *transition from a Baryon dominated system*
  to a Meson dominated one;
- *maximum of the* Λ *polarization;*
- *1-st order transition & mixed phase creation;*
- *Critical EndPoint ?*

NICA White Paper

*Physics targets for the exploration of first order phase transitions in the region of the QCD phase diagram accessible to NICA & FAIR and possible observable effects of a "mixed phase indicated in the release of the "NICA White Paper" as a Topical Issue of the **EPJ A** (July 2016).*

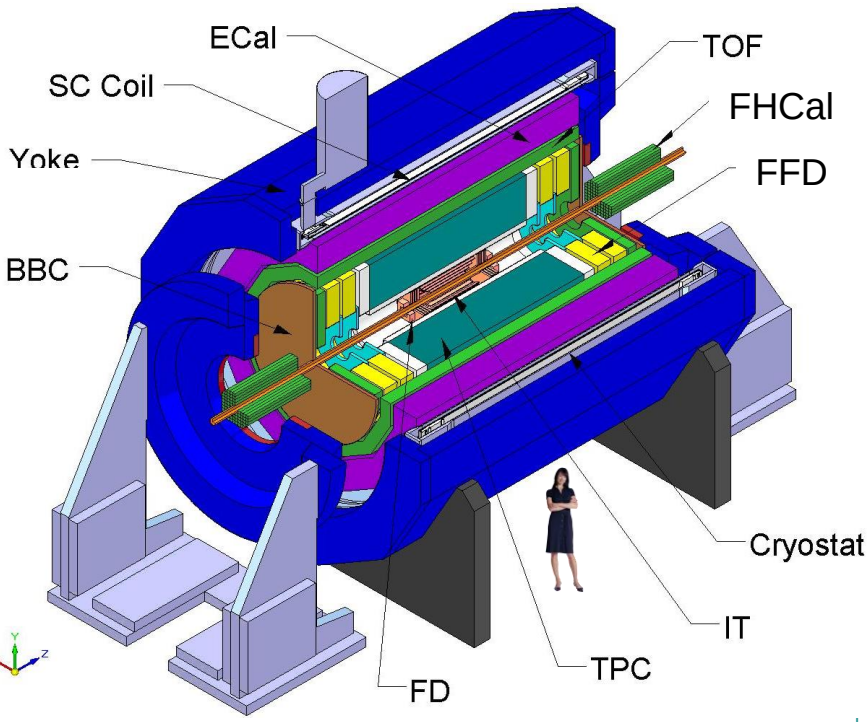


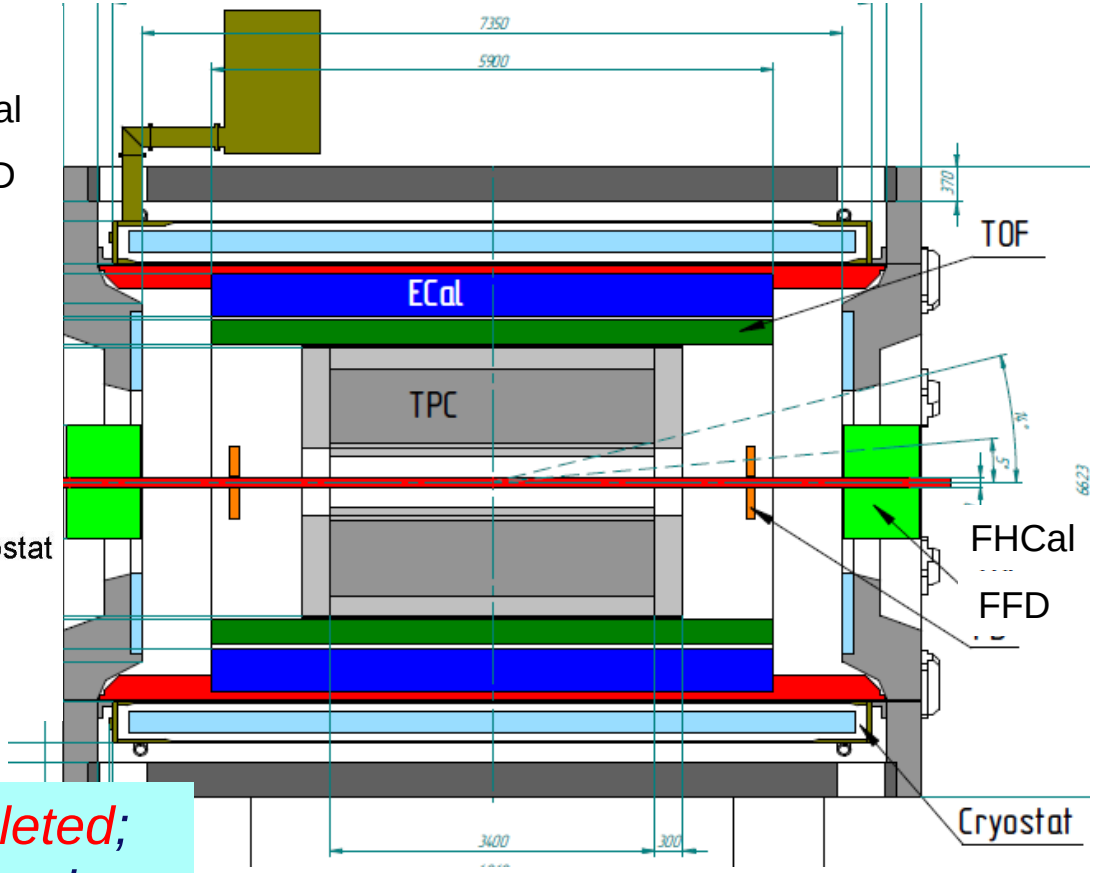
111 *contributions,*
188 *authors*
from **24** *countries*

MPD detector for Heavy-Ion Collisions @ NICA

tracking: *up to |h|<1.8* (**TPC**)
PID: *had., e, γ* (**TOF**, **TPC**, **ECAL**)
Reaction: *centrality & plane determination* (**FHCal)**

Stage 1 (2020):
TPC, TOF, ECAL, ZDC, FFD





Status: *technical design – completed; production / preparation for production*

MPD detector for Heavy-Ion Collisions @ NICA

tracking: *up to |h|<1.8* (**TPC**)
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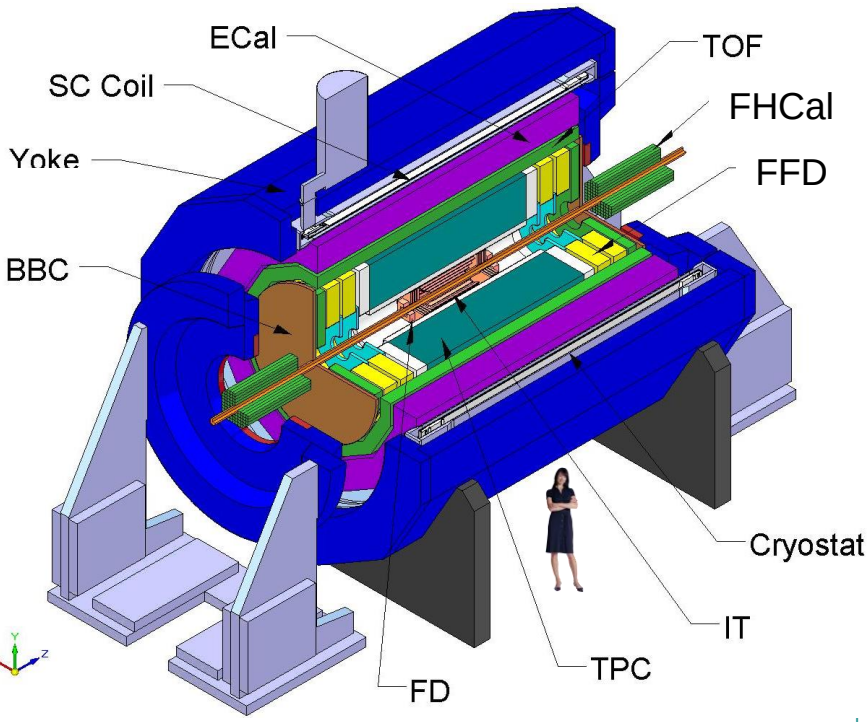
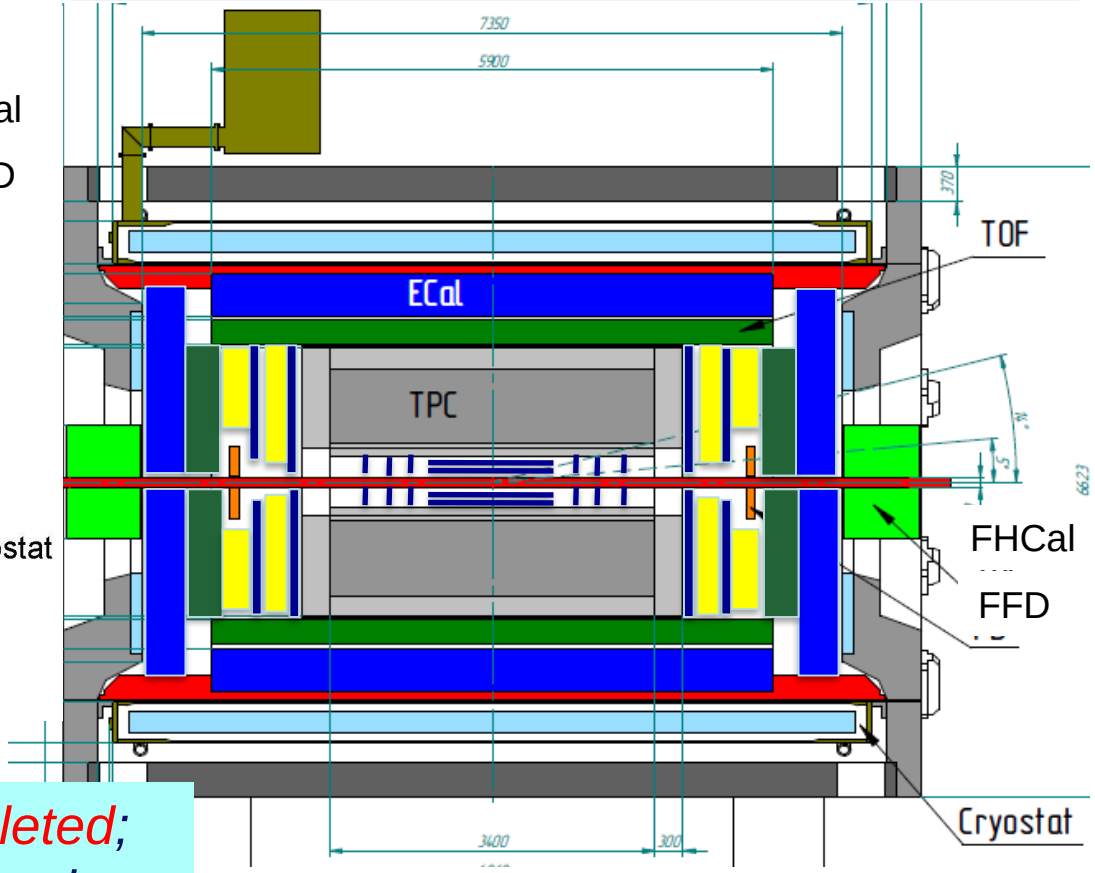
Reaction: *centrality & plane determination* (**FHCal**)

Stage 1 (2020):
TPC, TOF, ECAL, ZDC, FFD

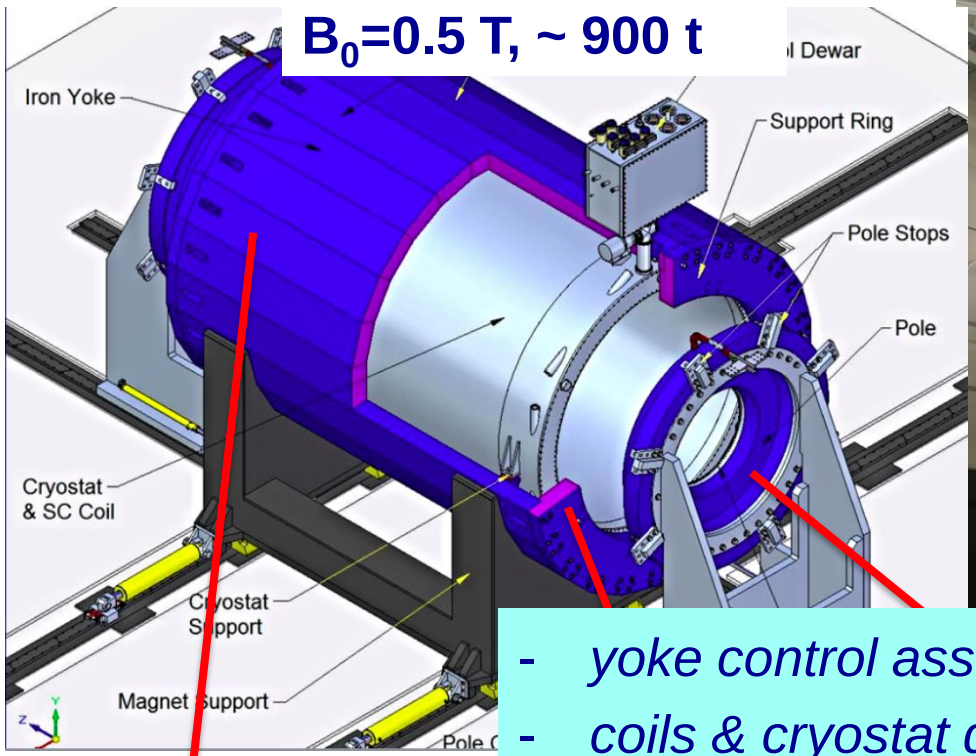
Stage 2 (2023):
ITS + EndCap (tracker, TOF, ECAL)





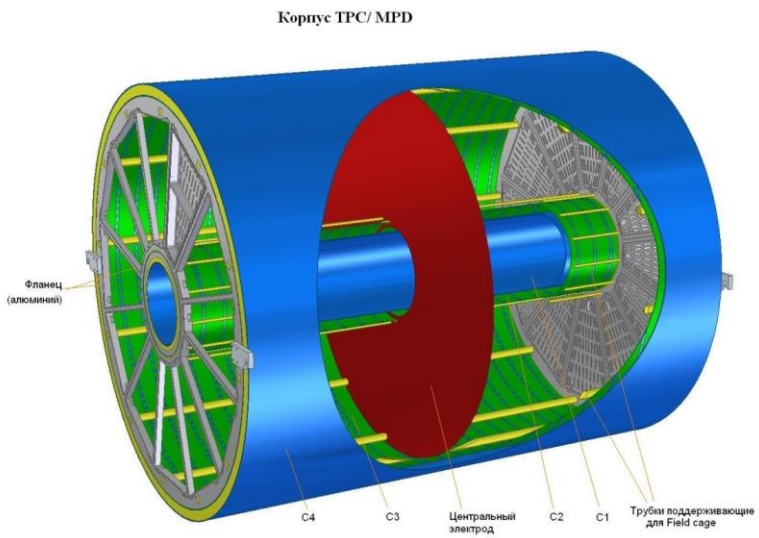
Status: *technical design – completed; production / preparation for production*

Magnet production: *at ASG (Genova) & Vitkovice HM*

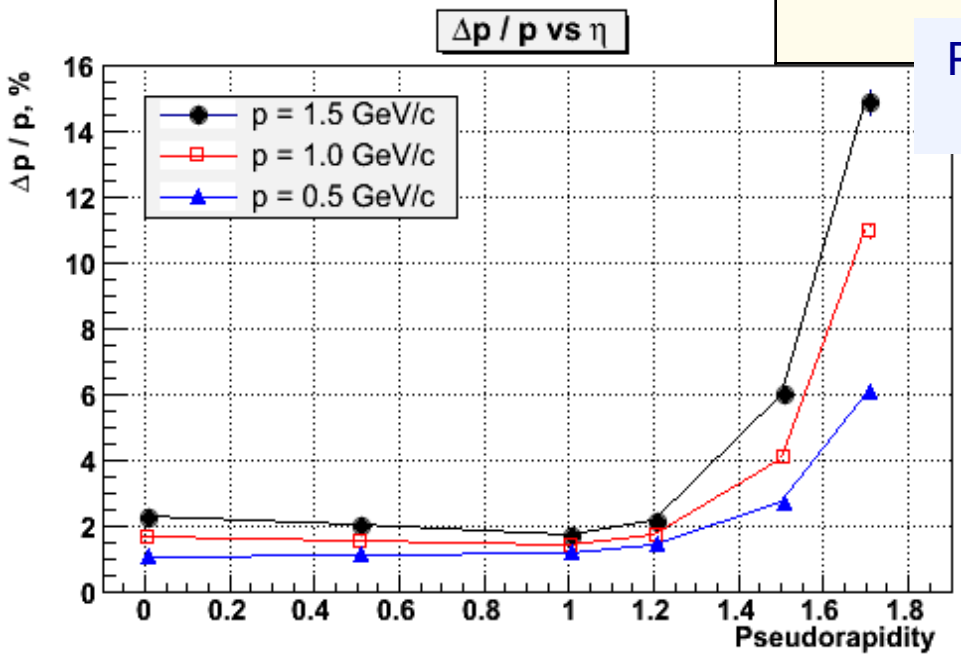


- *yoke control assembly at HM Vitkovice* - ***June 2018***
- *coils & cryostat delivery to Dubna* - ***May 2019***

Time Projection Chamber (TPC) – basic tracker

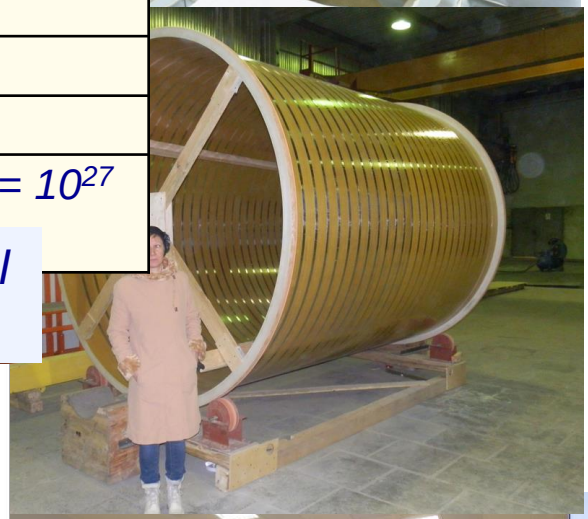


length	*340 см*
out Radii	*140 см*
in Radii	*27 см*
gas	*90% Ar+10% CH_4*
drift velocity	*5.45 см / mcs;*
velocity time	*< 30 mcs;*
N R-O Chamb.	*12 + 12*
N pads / chan.	*95232*
max event rate	*< 7 kGz (L= 10^{27}*

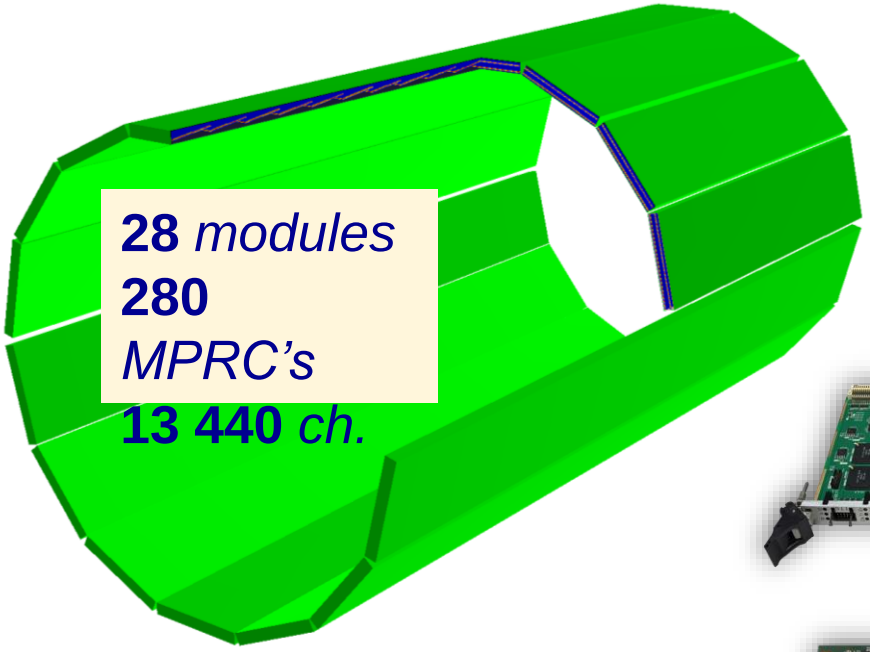


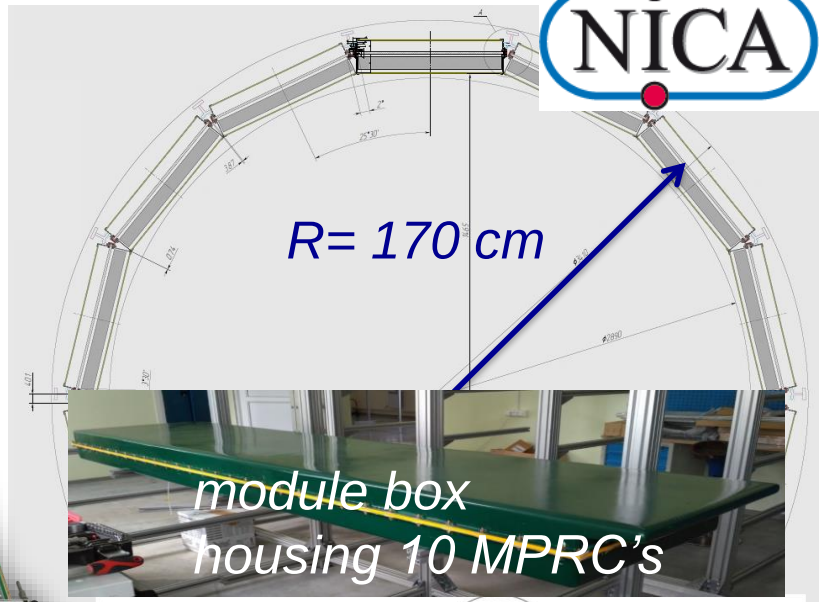
FEC64SAM - *dual SAMPA card*

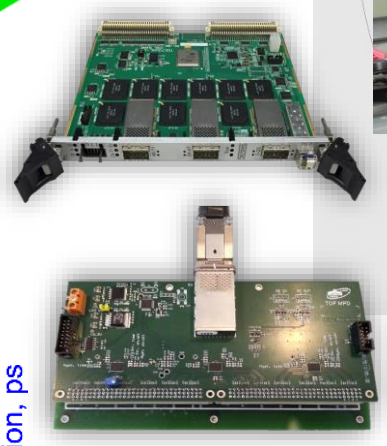
TPC/MPD Front-end card

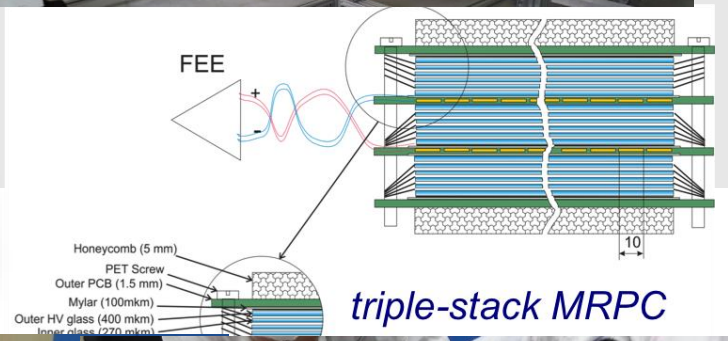


Time of Flight (TOF) system

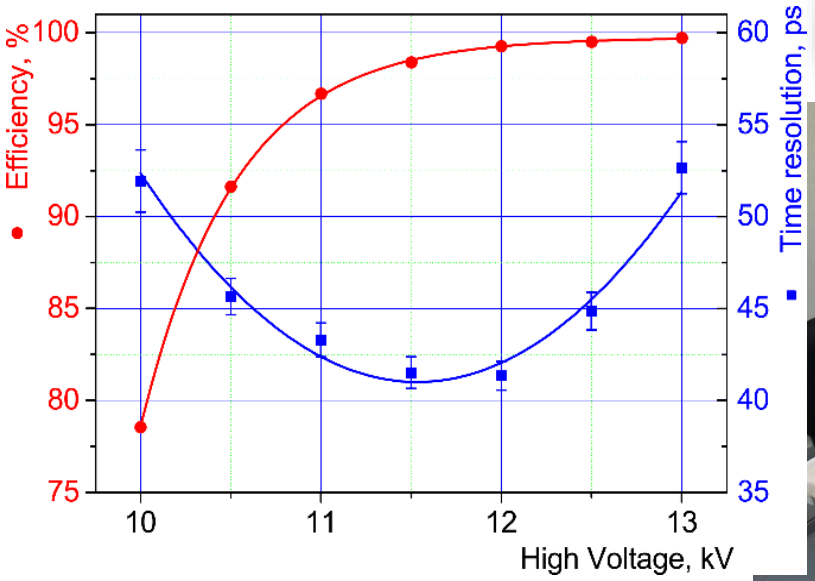


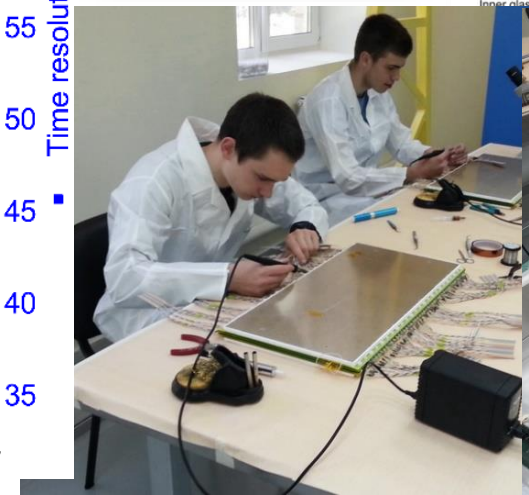


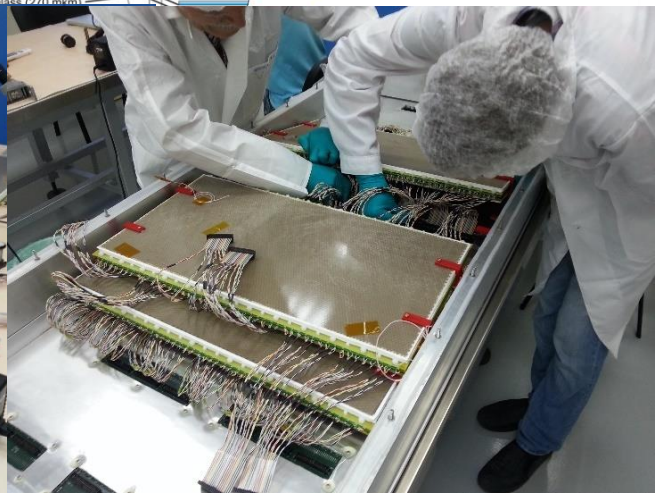




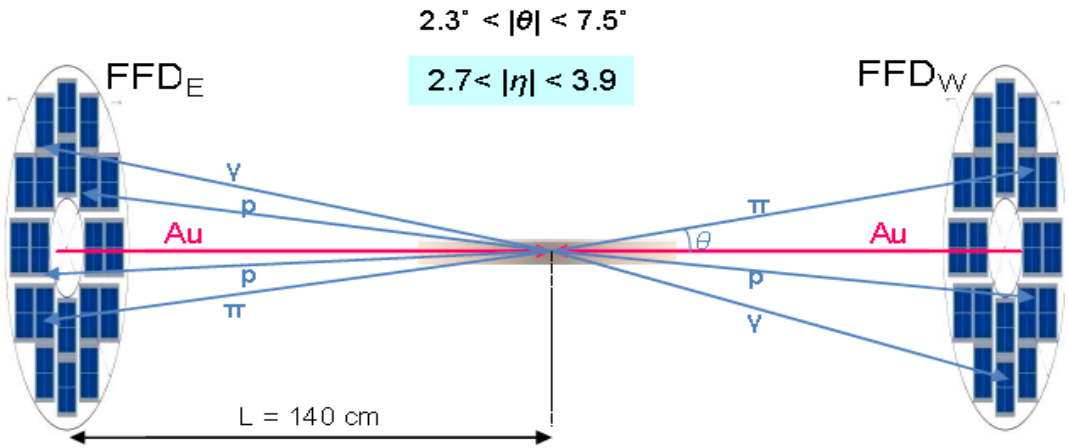
efficiency and time resolution



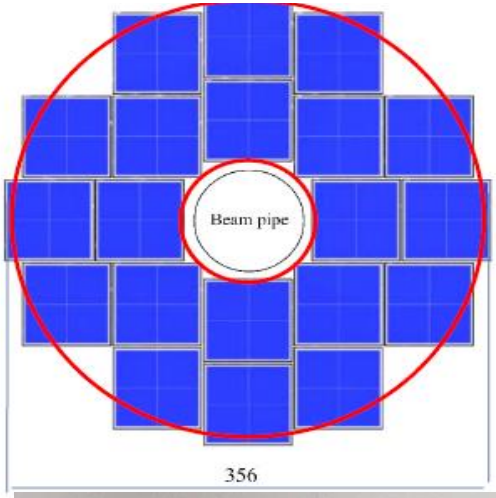




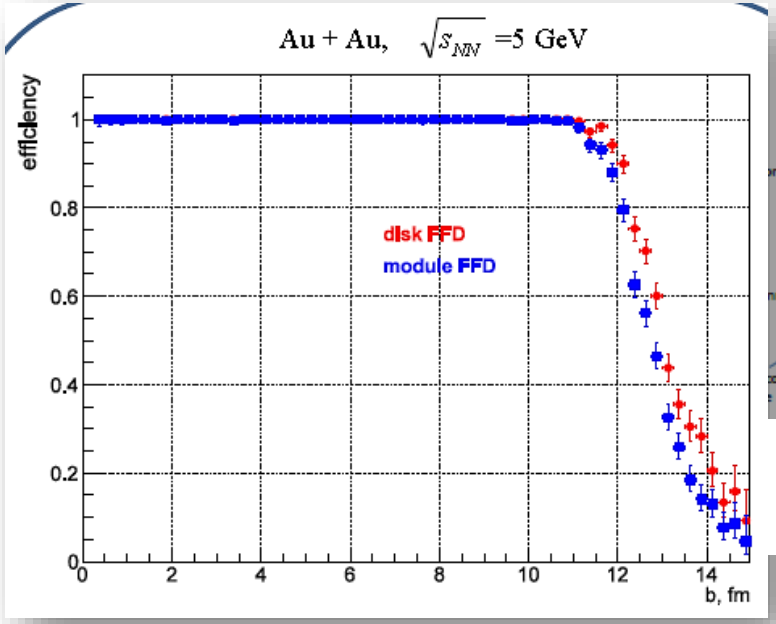
Fast Forward Detector – (FFD)

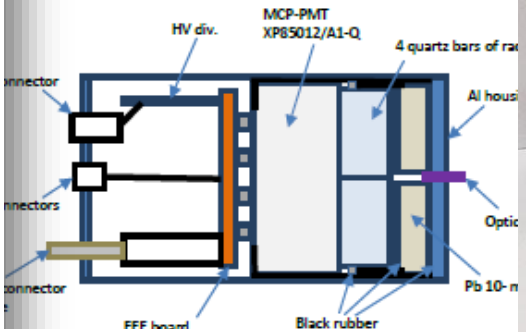


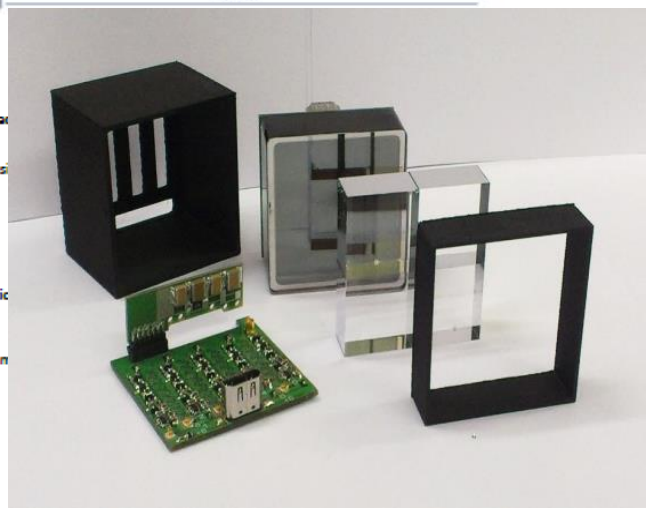
array of 20 modules
Planacon MCP-PMTs
80 +20 channels



time resolution < 50 ps

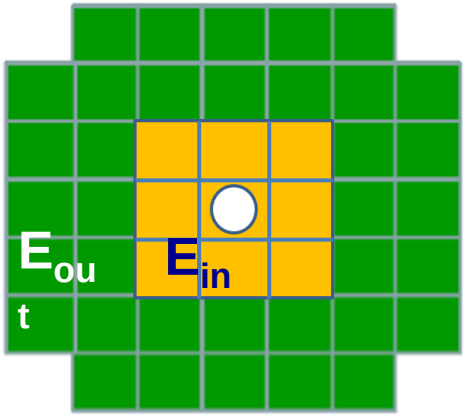


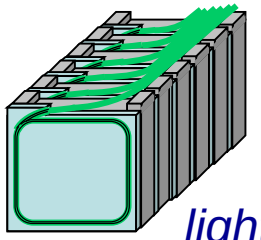




15 mm quartz radiator
10 mm lead converter

FHCAL: determination of reaction plane and centrality





light collection
WLS-fibers & SiPM

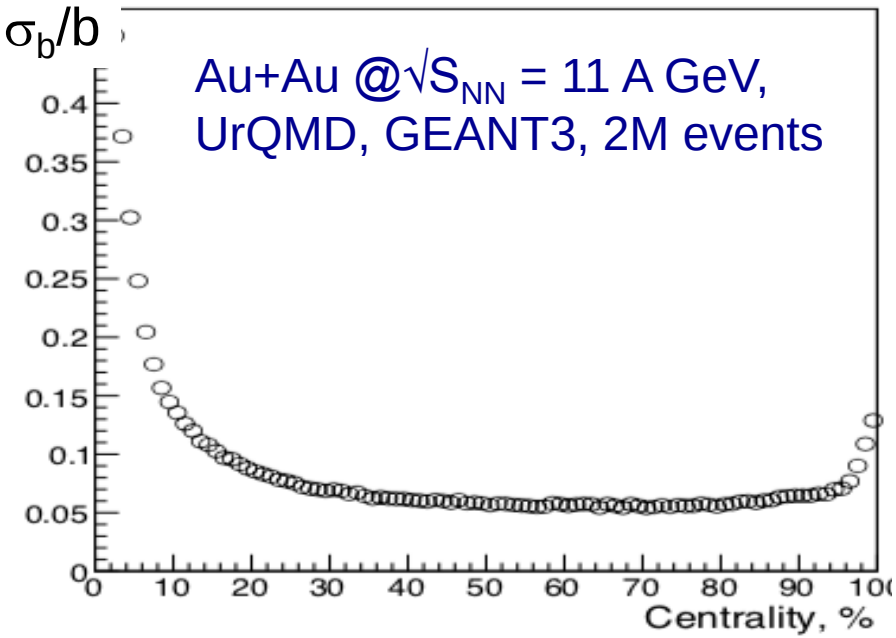
2 x **45** modules (15 x 15 cm^2 each)
located left and right at ~3.2 m from the **IP**)

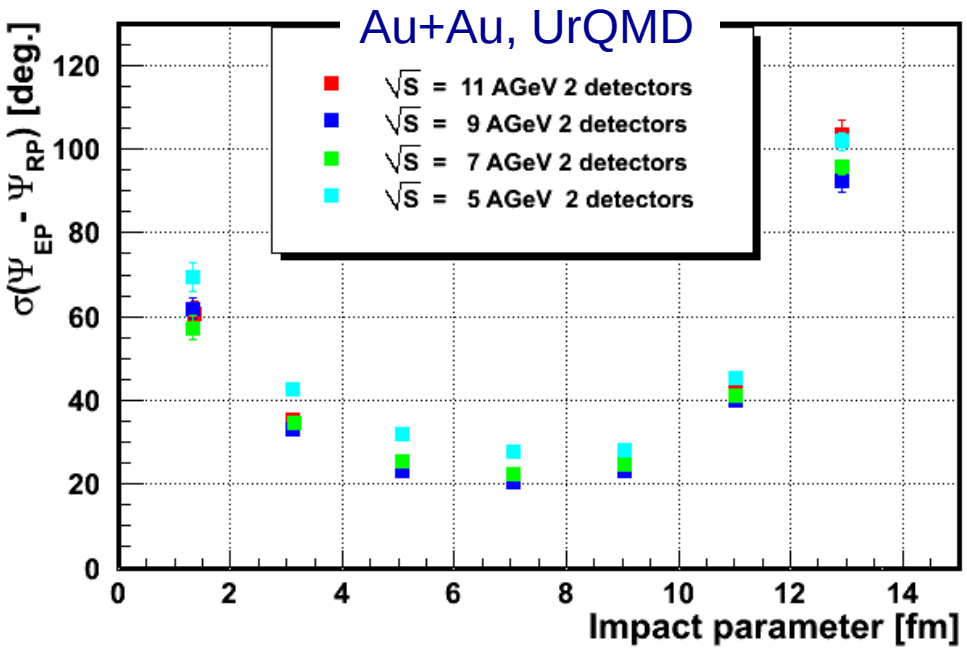
acceptance: 2.2<|η|< 4.8

$\sigma(E)/(E) = 53\%/\sqrt{E(GeV)} + 10\%$

transverse granularity allows to measure:

- *the reaction plane with accuracy* **~ 20^0-30^0**
- *the centrality with accuracy below* **10%.**

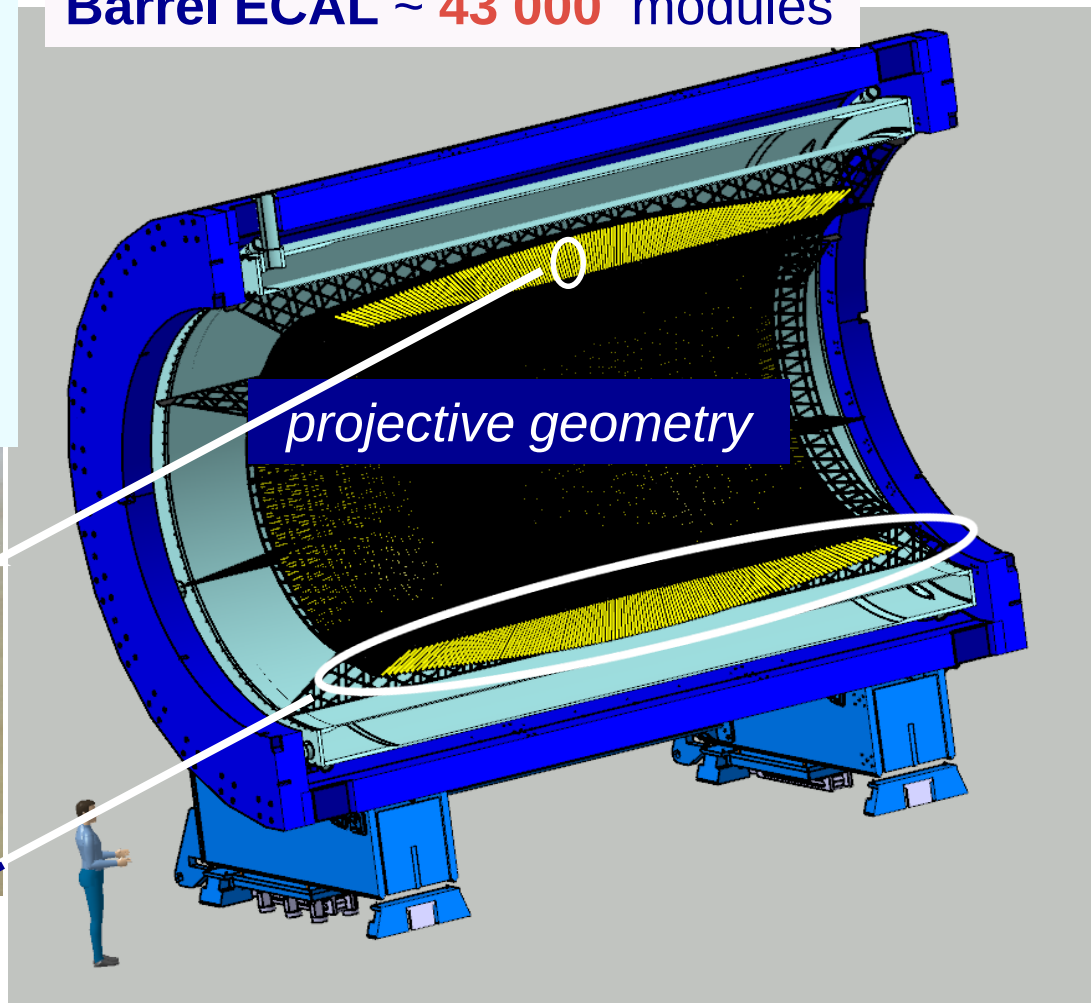


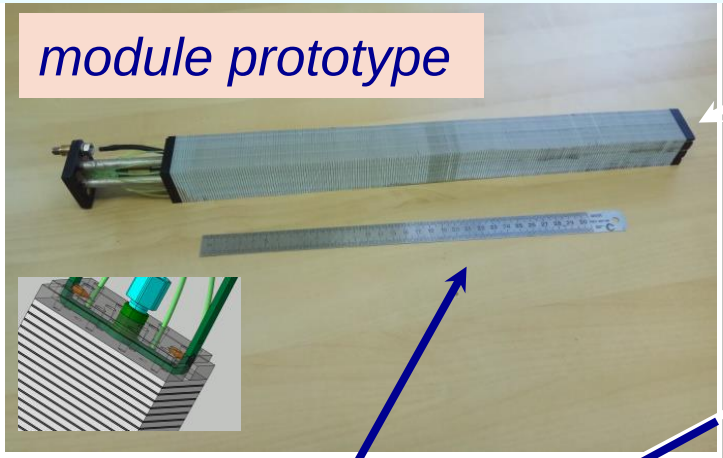


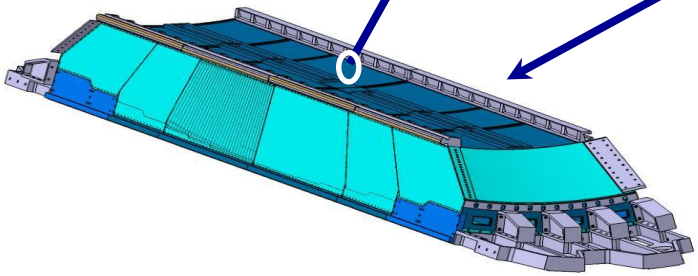
Electromagnetic calorimeter: ECAL

- *Pb+Sc "Shashlyk"*
- *read-out: WLS fibers + MAPD*
- *L ~35 cm (~ 14 X_0)*
- *Segmentation (4x4 cm^2),*
- *σ(E) better than 5% @ 1 GeV;*
- *time resolution ~500 ps*

Barrel ECAL ~ 43 000 modules







block of modules

MPD I stage

feasibility study

Stage 1: 2021-2023

energy and system size scan from 4 to 11 GeV in steps of 1-2 GeV

limitation by the accelerator:

- *lower luminosity*
- *extra reduction by 40% because of a larger beam diamond*

Detector limitation

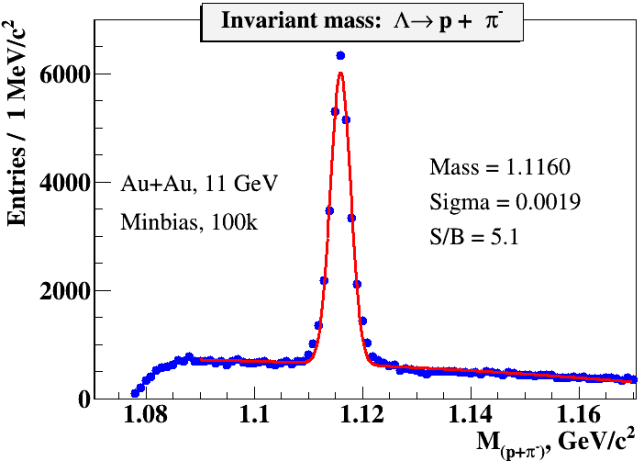
- ***TPC** tracking: $|\eta|<1.8$ (N points>10)*
- ***TOF** coverage: $|\eta|<1.2$*
- ***PID**: combined $|\eta|<1.2$, $0.1<pT<4$ GeV/c,*

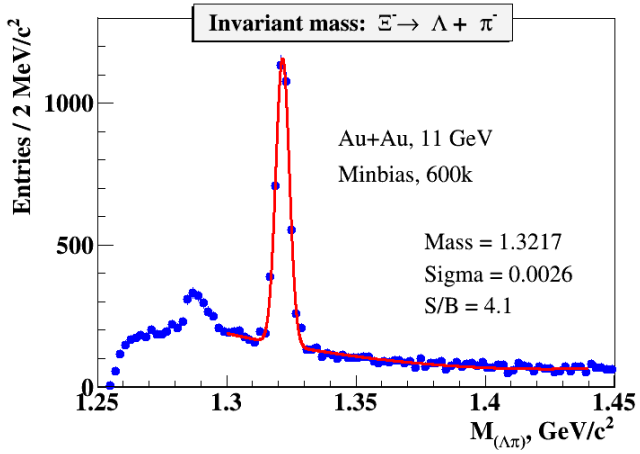
  limited in $1.2 < |\eta| < 1.8$ (only dE/dx)
- ***ECAL** coverage : $|\eta|<1.2$*
- ***FHCAL** coverage: $2.2<|\eta|<4.8$*
- ***FFD** inside the TPC inner pipe*

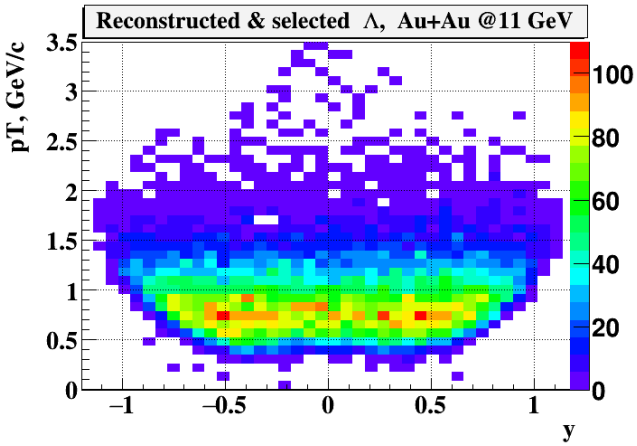
Strange and multi-strange baryons

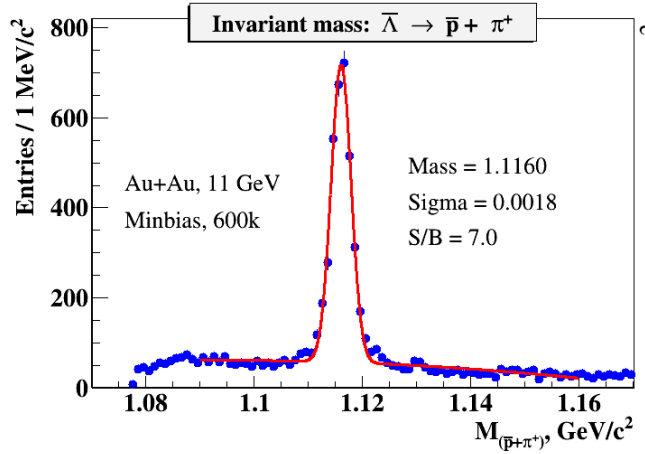
Stage'1 (TPC+TOF): Au+Au @ 11 GeV, UrQMD

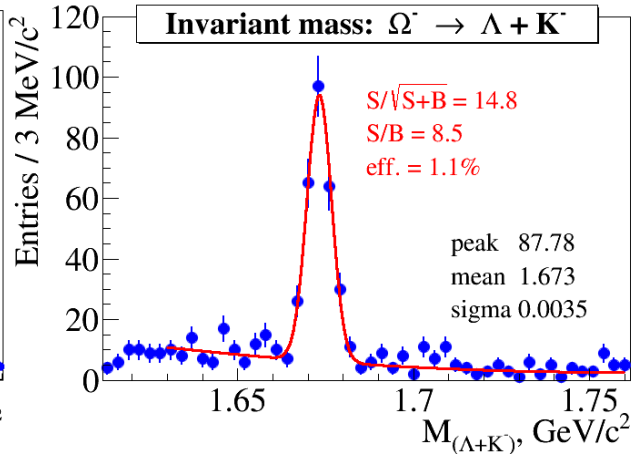
large phase-space

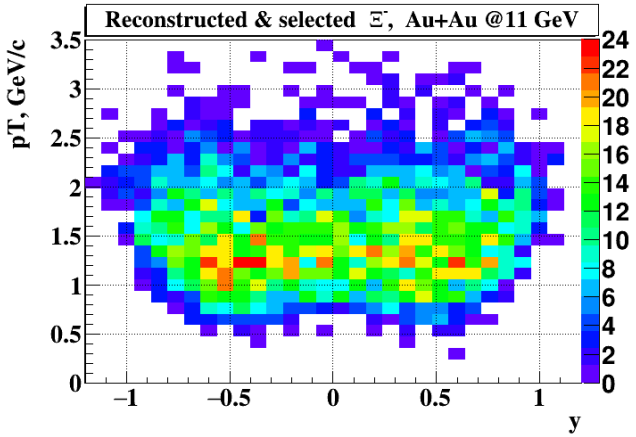








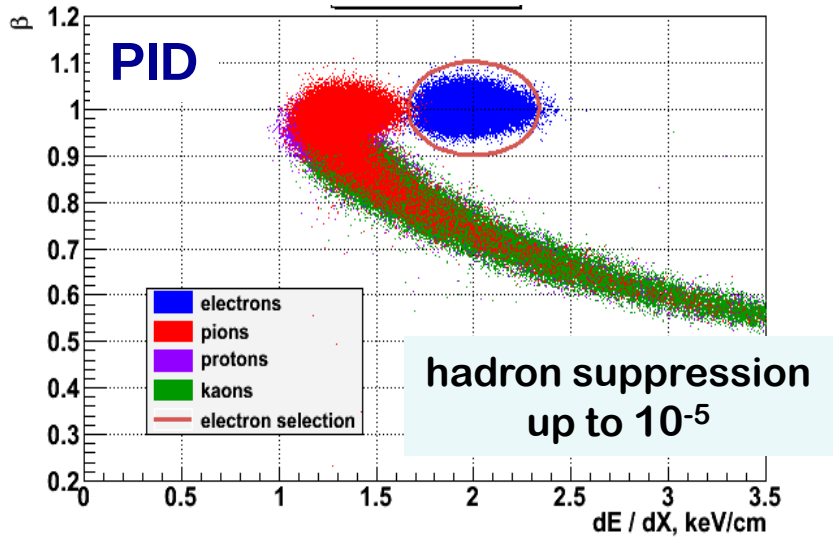


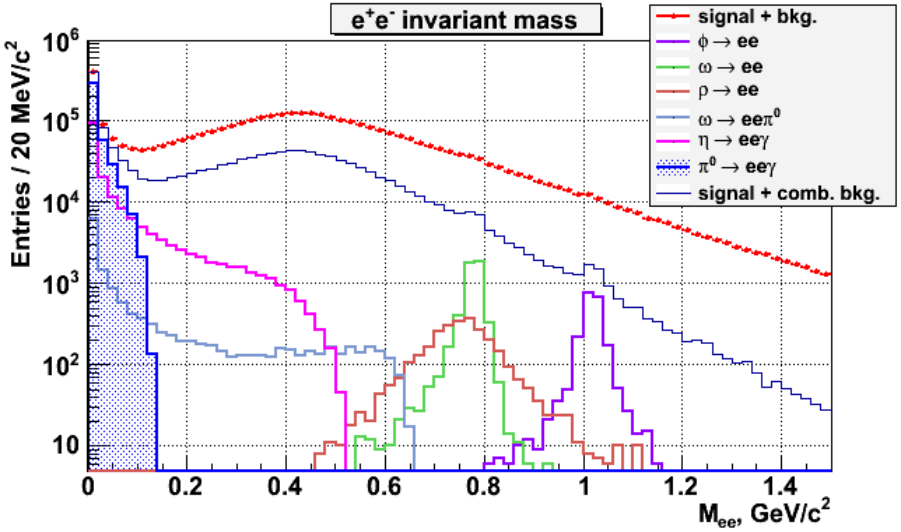


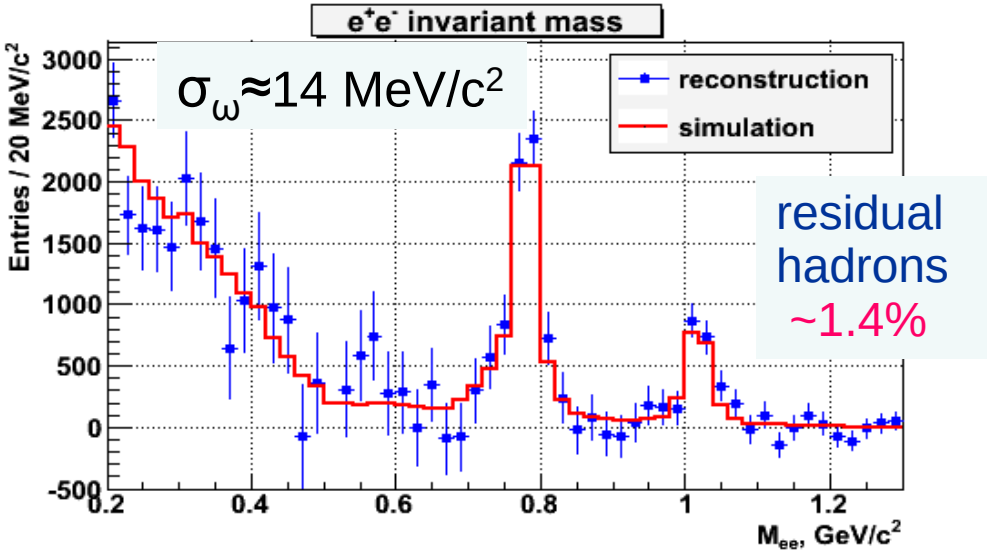
particle	Λ	anti-Λ	Ξ⁻	anti-Ξ⁺	Ω⁻	anti–Ω⁺
yield in 10 weeks	$3 \cdot 10^8$	$3.5 \cdot 10^6$	$1.5 \cdot 10^6$	$8.0 \cdot 10^4$	$7 \cdot 10^4$	$1.5 \cdot 10^4$

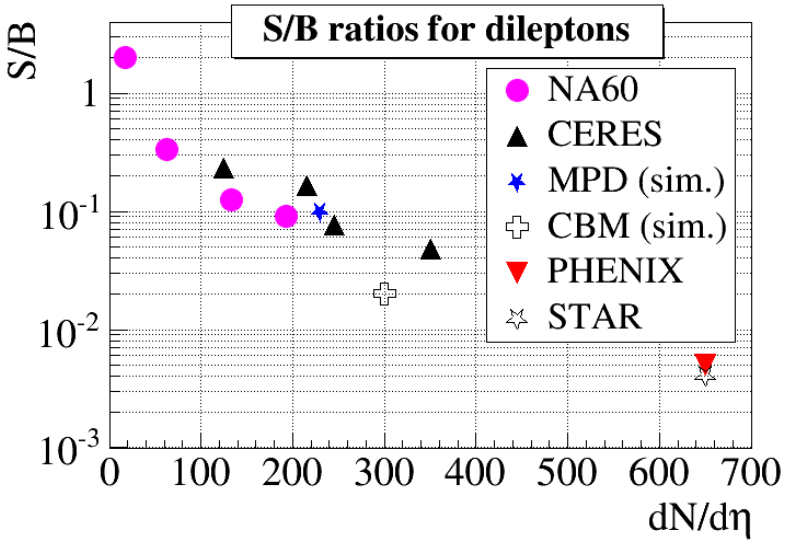
Prospects for study of dileptons

- **Event generator:** *UrQMD+Pluto (for the cocktail) central Au+Au @ 8 GeV*
- **PID**: *dE/dx (from TPC) + TOF (s ~100 ps) + ECAL*









Flow performance

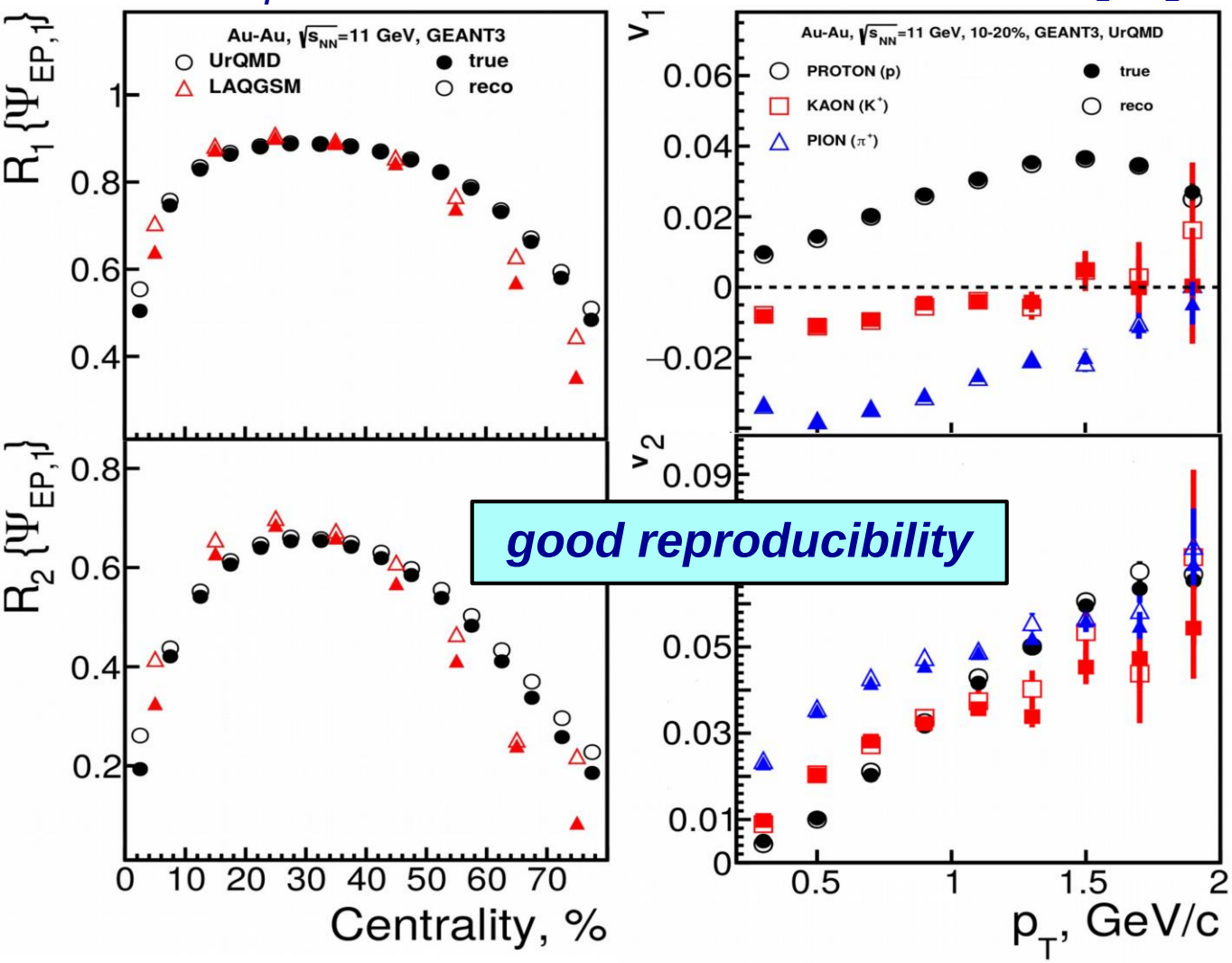
P. Parfenov, I. Selyuzhenkov, A. Taranenko, A. Mudrokh

Au+Au@11 A GeV; GEANT3; UrQMD (LAQGSM), 4M events

$v_n = \{\cos[n(\phi - \Psi_{EP,1})]\} / R_n(\Psi_{EP,1})$ - *azimuthal flow coefficients*

event plane resolution

flow harmonics (v_1 / v_2)



good reproducibility

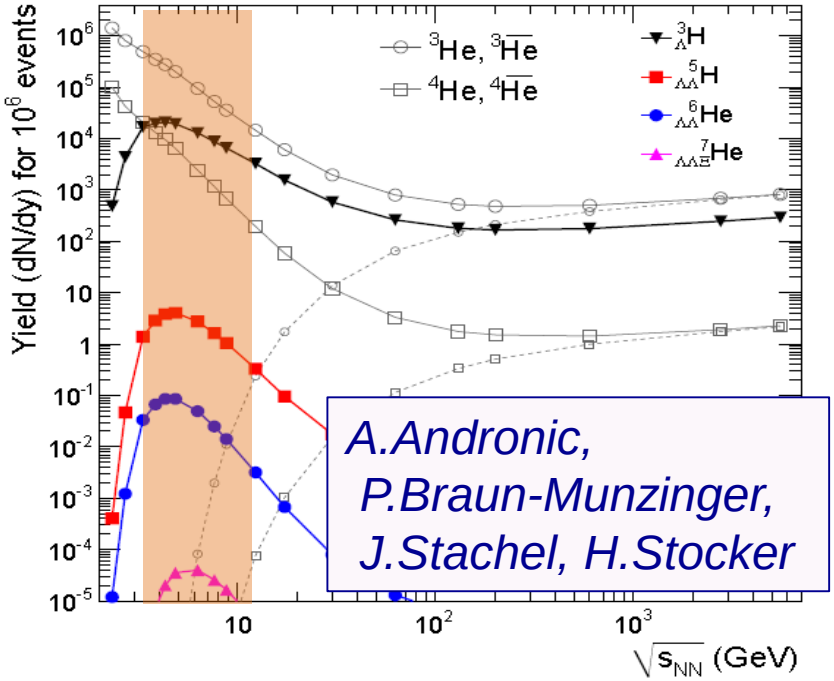
$R_n(\Psi_{EP,1})$ – *resolution correction factor*

ϕ – *azimuthal angle of produced particle*

$\Psi_{EP,1}$ – *event plane angle*

event plane: **FHCal**
centrality: **TPC**
PID: **TOF+TPC**

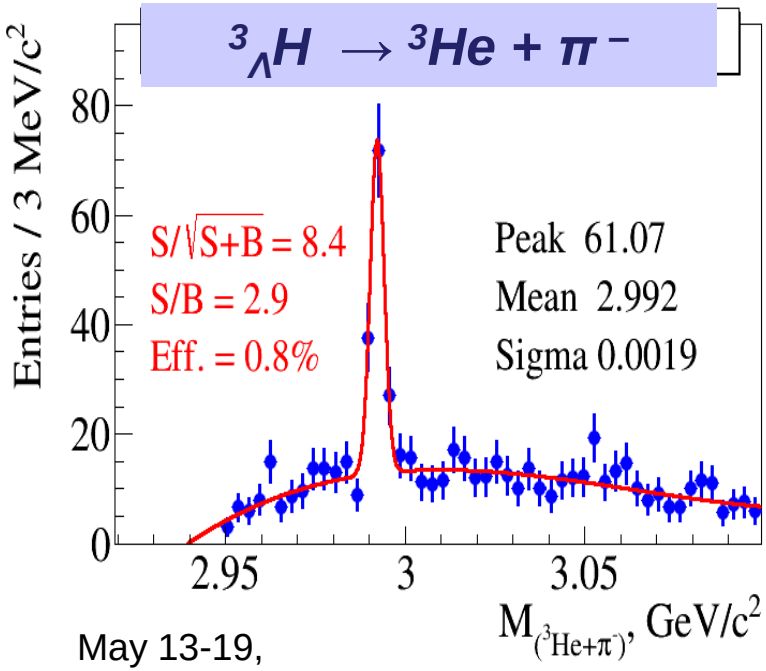
Hyper nuclei

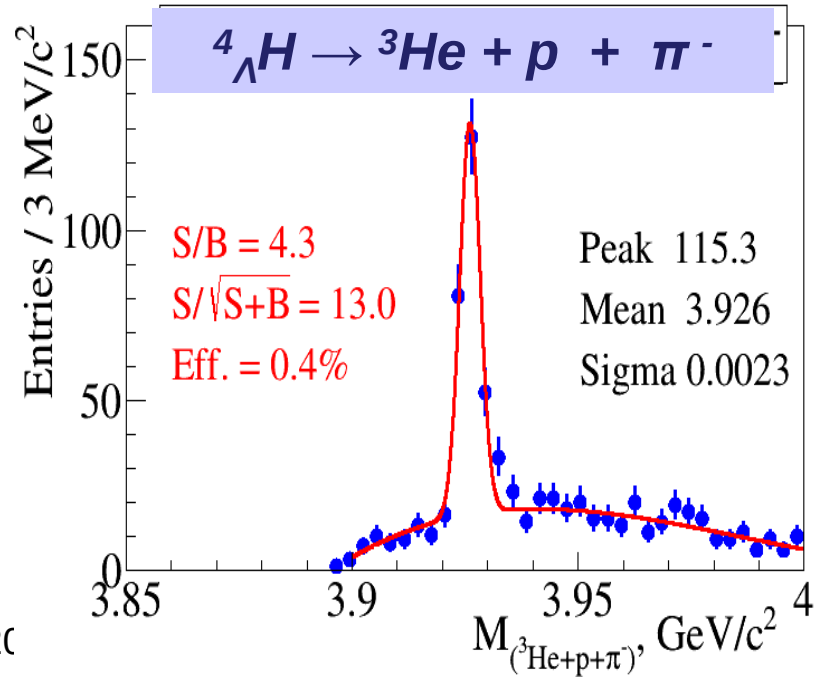


A.Andronic, P.Braun-Munzinger, J.Stachel, H.Stocker

Stage 2: *central **Au+Au** @ **5** AGeV; DCM-QGSM*

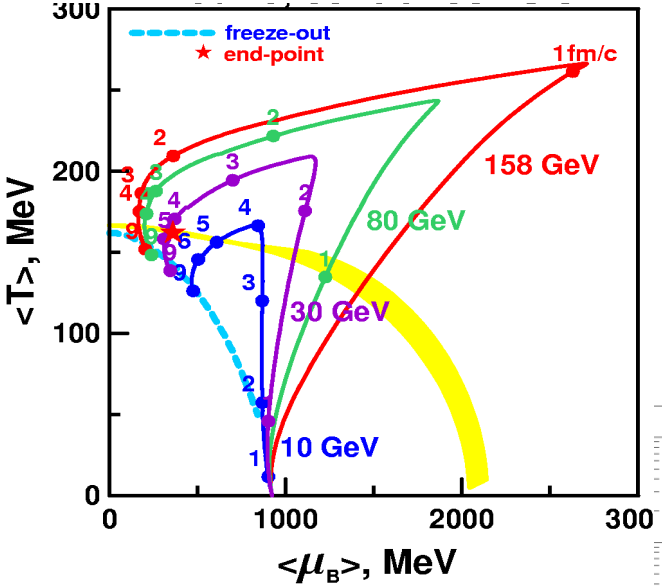
hyper nucleus	yield in 10 weeks
$^3_\Lambda$He	$9 \cdot 10^5$
$^4_\Lambda$He	$1 \cdot 10^5$





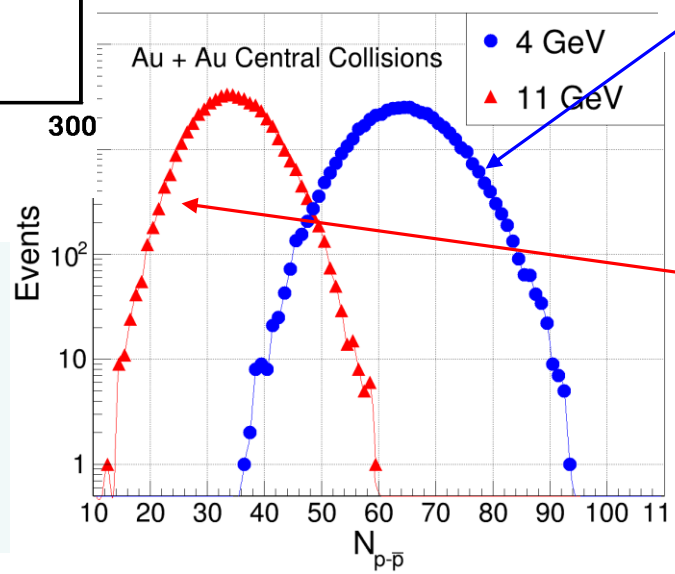
Prospects to search for CEP

trajectories calculated by a 3-fluid hydrodynamics (Toneev & Ivanov)

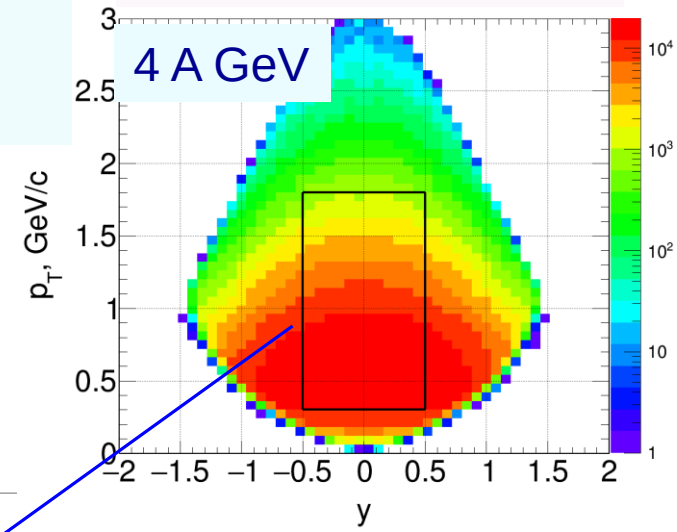


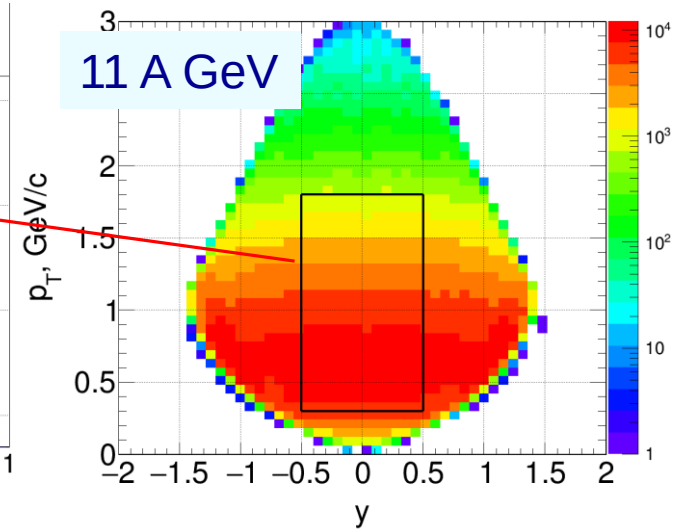
abnormal fluctuations are expected for trajectory in the vicinity of the CEP

Au+Au, central;
|y|<0.5, p_T<1.8 GeV/c



Au+Au; net-protons





MPD provides a uniform midrapidity phase-space coverage necessary to search for the CEP via EvE fluctuations

kick-off meeting on formation of the MPD and BM@N Collaborations

carried out in Dubna on 11-13 April, 2018

https://indico.jinr.ru/conferenceDisplay.py?ovw=True&confId=385

Concluding remarks

- **NICA complex has a potential for competitive research**
  in the field of baryon rich matter
- **The construction of both accelerator complex & MPD**
  is progressing close to the schedule
- **Welcome to join the MPD collaboration**

Thank you!