



Лаборатория Высоких Энергий им. В.И.Векслера и А.М.Балдина

- долгосрочная научная программа
Международное совещание посвященное
Памяти В.И.Векслера,
10-12 октября 2007, Дубна

- *Пролог*
- *Программа исследований*
- *Базовая установка: от Нуклотрона к НИКЕ*
- *Физика на Нуклотрона*
- *Физика на внешних ускорителях*
- *Инновации*
- *Заключение*

Пролог



Знаменательные события этого года:

- **100-й** летний юбилей
академика **В.И.Векслера**
- **50-я** годовщина запуска
синхрофазотрона





Пролог



1957г. запуск синхрофазотрона – крупнейшего в мире ускорителя фактически дал старт ускорительной физике высоких энергий, обеспечив на определенном отрезке истории лидирующую роль ОИЯИ в этих исследованиях

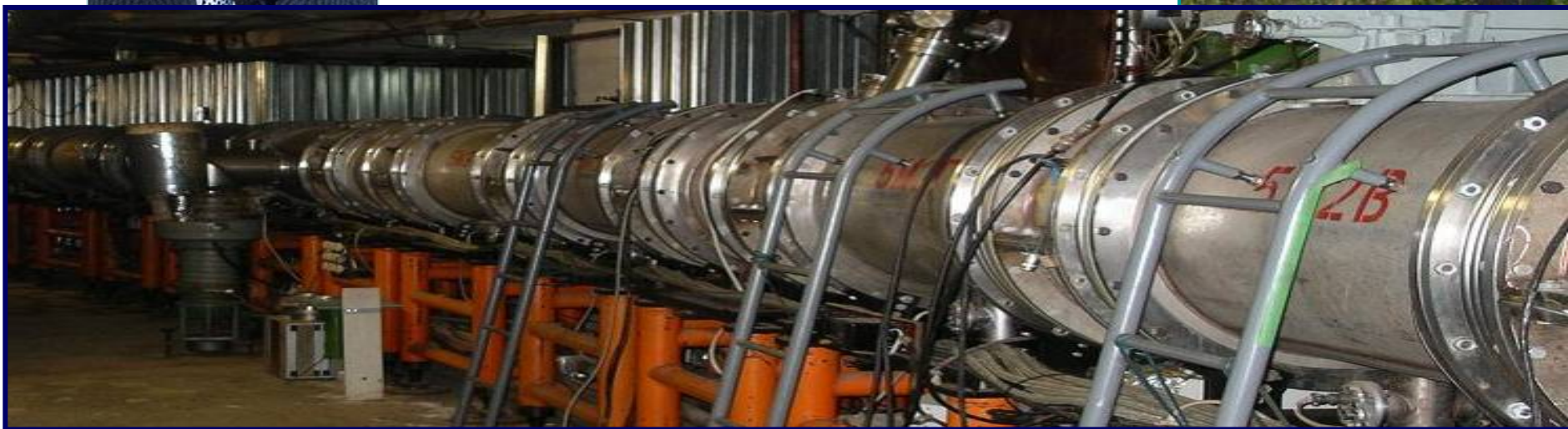
Пролог

Очередным прорывом в области ускорителей было создание в ОИЯИ по инициативе академика А.М.Балдина



НУКЛОТРОНА – первого сверхпроводящего ускорителя релятивистских ионов

построен в ОИЯИ за пять лет (1987-92 гг.) и запущен в 1993 г.





Программа Исследований



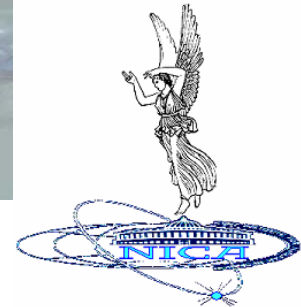
Научная программа Лаборатории оптимизирована в рамках «**Дорожной карты**» ОИЯИ

Основные области исследований:

- **Физика релятивистских тяжелых ионов**
*изучение фазовых состояний
сильновзаимодействующей материи
поиск фазовых переходов и критической точки*
- **Поляризационные явления малонуклонных систем**
*исследования спин-зависимых процессов
поиск новых явлений*
- **Физика ароматов**
*изучение правила ОЦИ
поиск многокварковых состояний (пенакварки)
экзотические ядра (гипер ядра)*

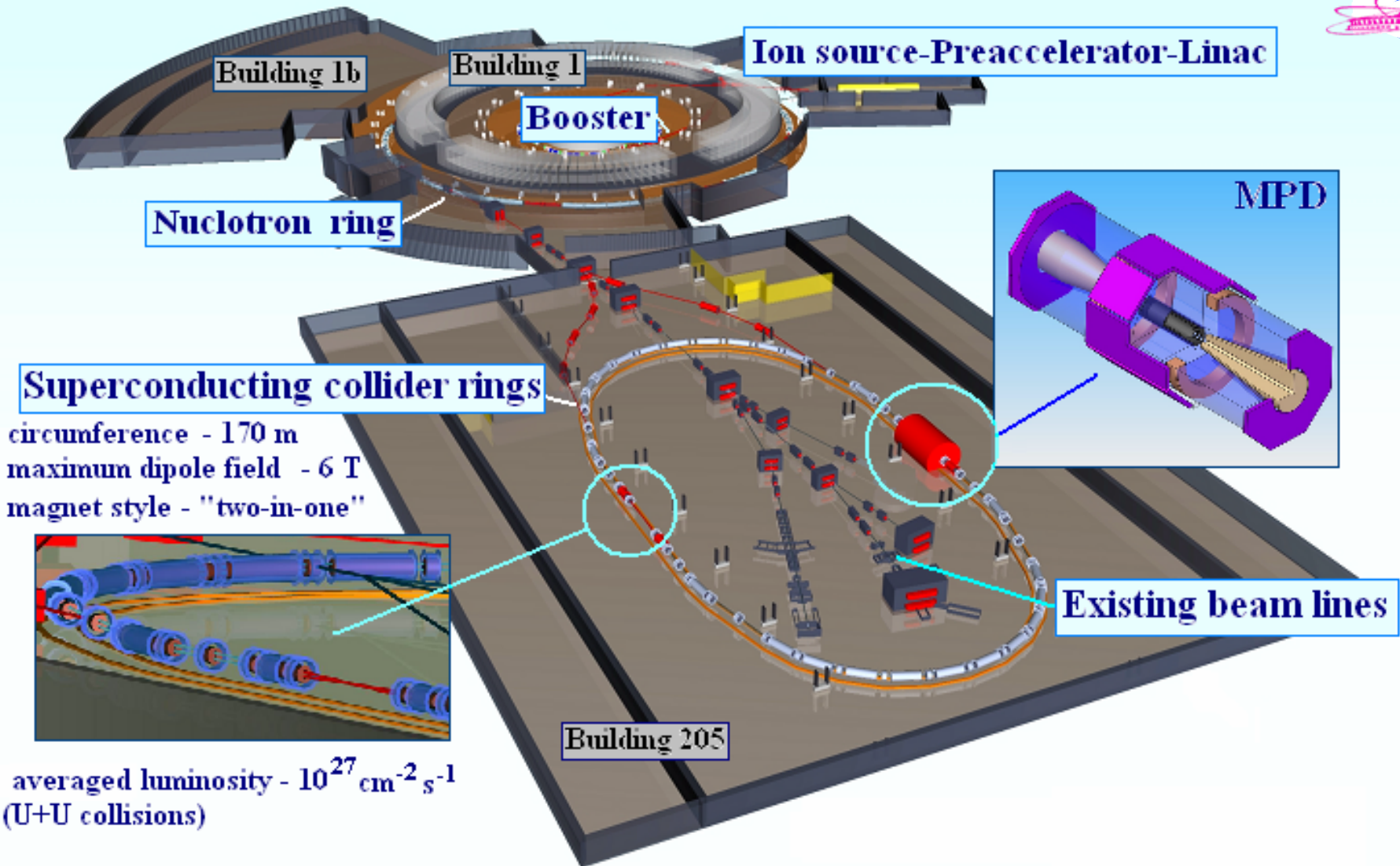


Программа Исследований



- **NICA / MPD** проект нацелен на исследование горячей и плотной сильно-взаимодействующей материи и поиску проявлений фазовых переходов и критической точки в столкновениях тяжелых ионов
- **NICA / MPD** – лидирующий проект ЛВЭ как по научной программе, так и по развитию базовой установки в **2008-2015**
- ожидается, что этот **флагманский** проект обеспечит:
 - проведение передовых исследований по физике тяжелых ионов
 - привлечение молодежи
 - и образование широкой международной кооперации
 - развитие новых технологий (в т.ч. нано-..)
 - привлечение и освоение значительных ресурсов

Nuclotron-based Ion Collider Facility & MultiPurpose Detector





Collider **NICA** characteristics



Ring circumference, m	251.2
Ion kinetic energy, E [GeV/u], min/max	1/3.5
Particle number per bunch, $N_{\text{ion/bunch}}$	$2.0 \cdot 10^9$
Bunch number, n_{bunch}	20
Horizontal emittance, ε [π mm mrad]	0.7
Momentum spread, $\Delta p/p$	0.001
IBS life time [sec]	≥ 100
Beta function at interaction points, β^*	0.5
RF voltage, U_{RF} [kV]	200
Laslett tune shift, ΔQ	0.0044
Beam-beam parameter	0.009
Luminosity, L [$\text{cm}^{-2}\text{s}^{-1}$], peak/average	$2 / (1 \div 1.5) \cdot 10^{27}$



NICA project major stages



➤ **Stage I**
(2007-2009)

*upgrade of the **Nuclotron** facility
wide program of R&D
preparation of **Technical Design Report***

➤ **Stage II**
(2008-2012)

*design & construction
infrastructure development*

➤ **Stage III**
(2010-2012)

+ assembling

➤ **Stage IV**
(2013)

*commissioning
& putting in operation*



Nuclotron-M - the first stage of NICA



- New Injection complex includes:
 - developed source of highly charged ions (KRION) - in progress*
 - R&D on the RF system - in progress*
 - new Linac - the contract under negotiation*
- Improved vacuum system *- equipment partially ordered*
- Upgraded system for the main magnetic field cycle control *- first block at the commissioning stage*
- Modernization of the beam diagnostic system *- in progress*

Necessary R&D are planned at the forthcoming Nuclotron seances

- This stage should be completed by the **end of 2009** providing:
- *acceleration of heavy ions up to Au*
 - *with an intensity of extracted beams $\sim >10^9$ A/cycle*
 - *(& repetition rate 0.2-0.4 Hz)*
 - *at the energy of ~ 3.5 GeV/n (for Au)*
 - *developed infrastructure*



Experimental Tasks – the first stage



the following effects will be studied

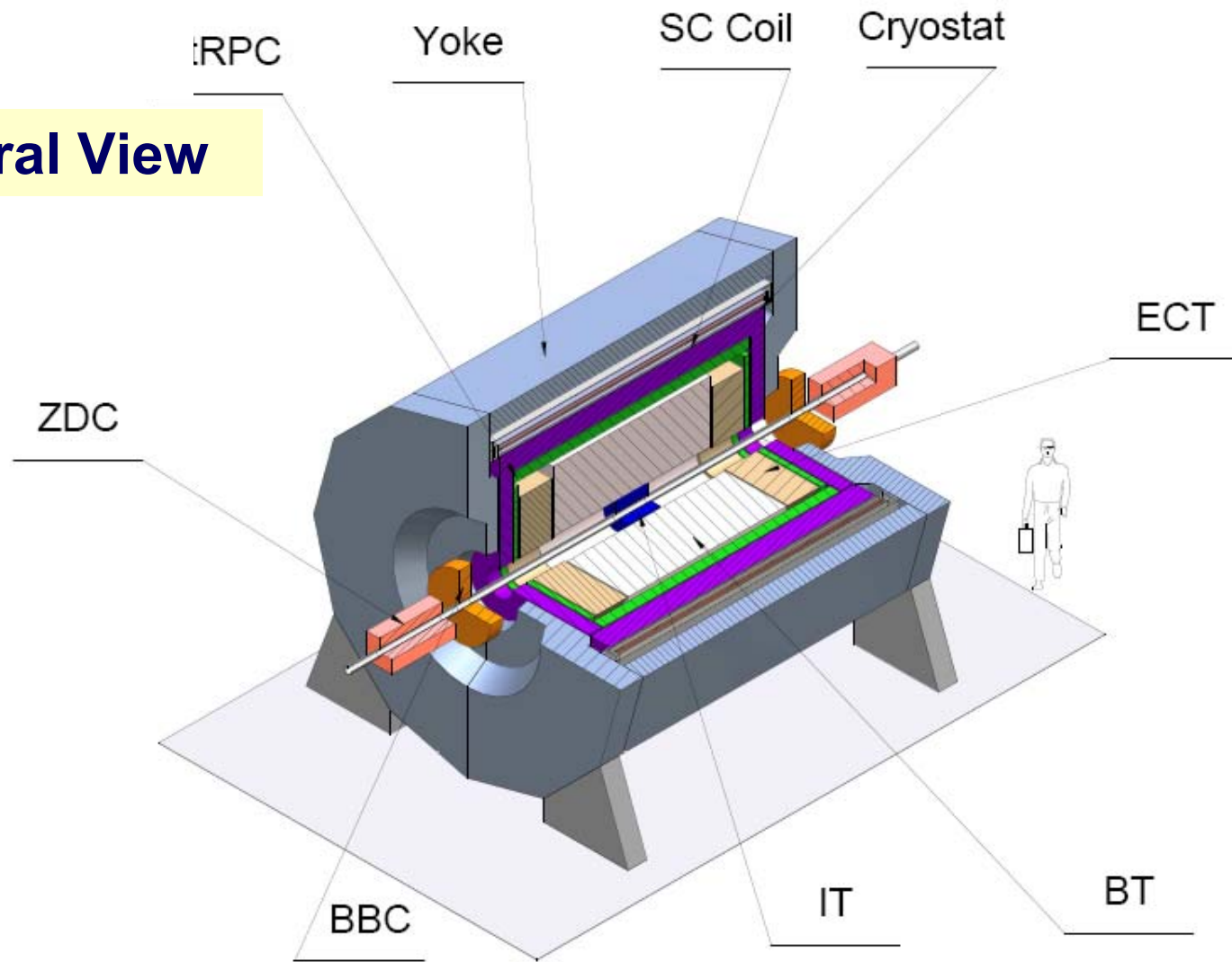
(on energy & centrality scanning):

- *Event-by-event fluctuation in hadron productions*
(multiplicity, P_t etc.)
- *HBT correlations indicating the space-time size of the systems involving π , K , p , Λ*
(possible changes close to the de-confinement point)
- *Directed & elliptic flows for various hadrons*
- *Multi-strange hyperon production:*
yield & spectra (the probes of nuclear media phases)

MPD – conceptual design



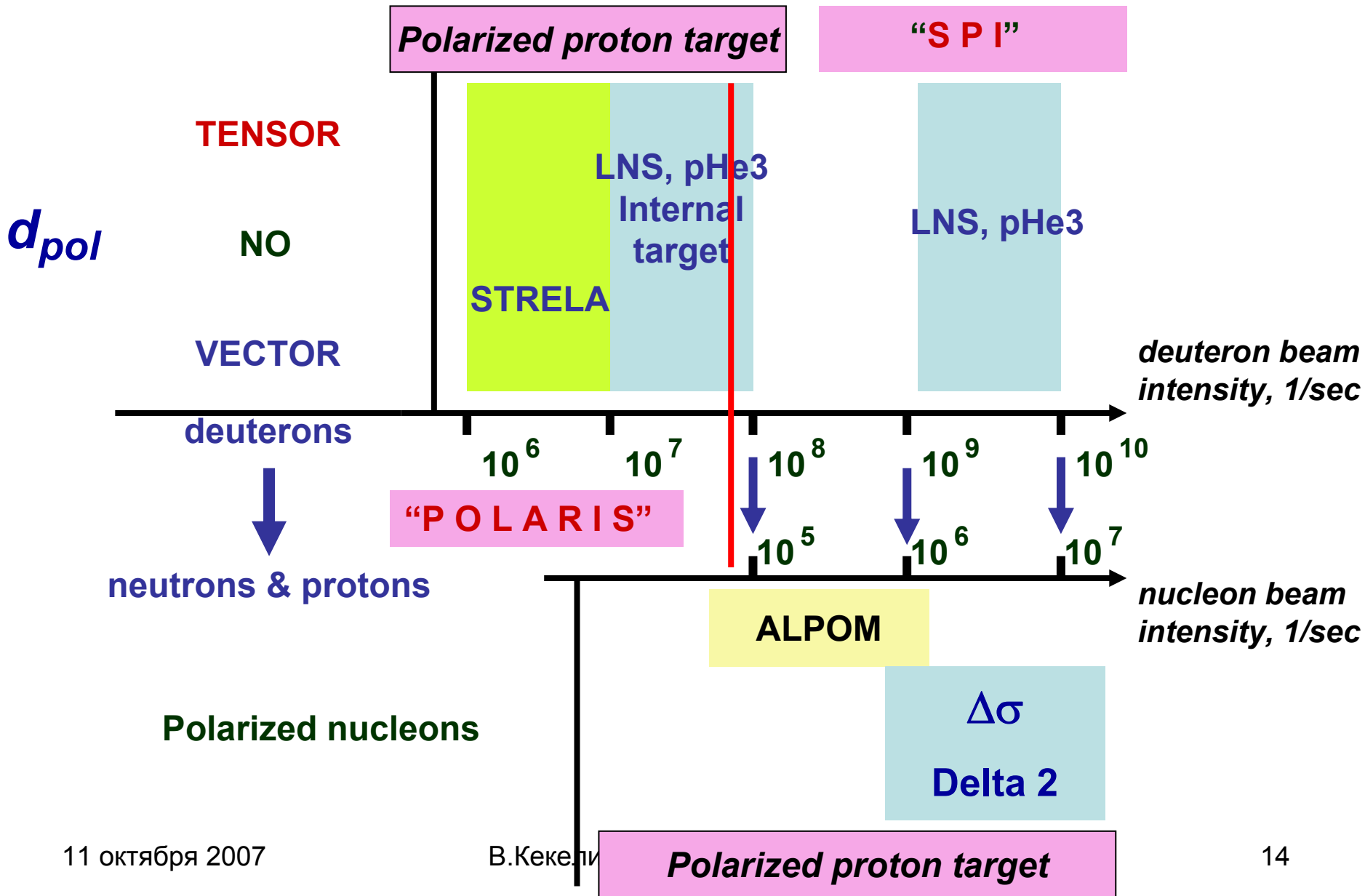
General View





Physics at Nuclotron

POLARIZATION PROGRAM





		2007		2008				2009				2010	
Nuclotron runs: period, # / hours		Oct.-Nov., 37 / 600		Feb.-Mar., 38 / 600		Oct.-Nov., 39 / 600		Feb.-Mar., 40 / 600		Oct.-Nov., 41 / 600		Feb.-Mar., 42 / 600	
beams		d, ${}^6\text{Li}$		d, ${}^6\text{Li}$		p, $A \leq 130$		d \uparrow , p, $A \sim 4$ GeV/n		p, $A \leq 200$		d \uparrow , p, A	
Accel. R&D	Nuclotron-M	x		x		x		x		x		x	
	«CIPIOS» → SPD	put in operation										ready	
Flavor	NIS+GIBS		x		x		x		x		x		x
Polarization	TPD		x										
	Internal target: LNS				o				x				x
	Extracted beams: STRELA, $\Delta\sigma$, $\Delta 2$, ALPOM ($T \geq 4.5$, GeV/n)		o		o				x				x
	MPPT	preparation (transverse polarization)										ready	
RNP	FAZA		x		x		x		x		x		x
	Physics & R&D for NICA: Marusya, η -nucl., Becquerel		x		x		x		x		x		x
Applied & innovation works			x		x		x		x		x		x

Well focused tasks of Nuclotron-M program, 100-300 h. Pre-requisit for NICA & physics.

Physics – ready to start

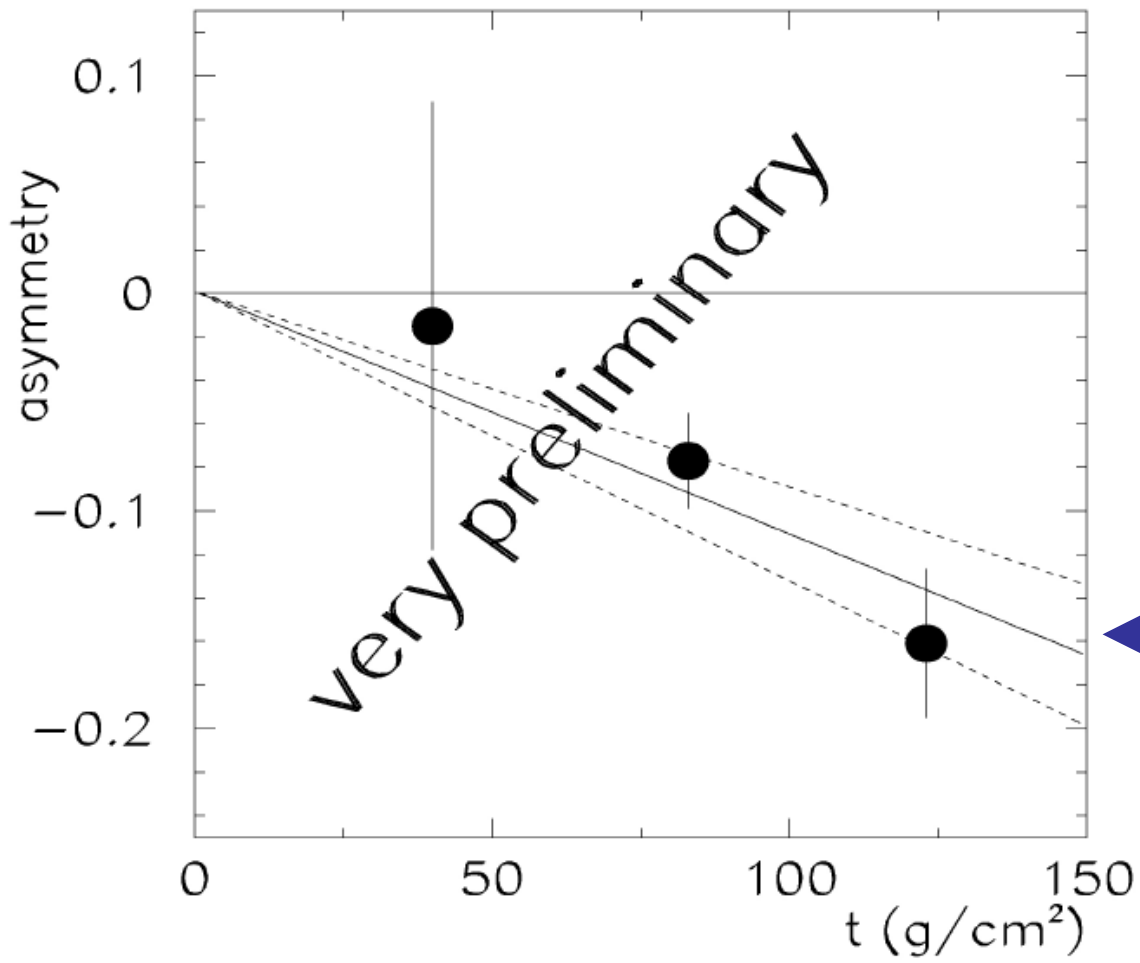
Work with POLARIS (conditional): requires successful Nuclotron-M stages (high intensity, energy)



TPD experiment

L.Zolin, L.Azhgirey

Search for the effect of induced tensor polarization of deuterons passing through the material (different “refraction” index for different spin states).

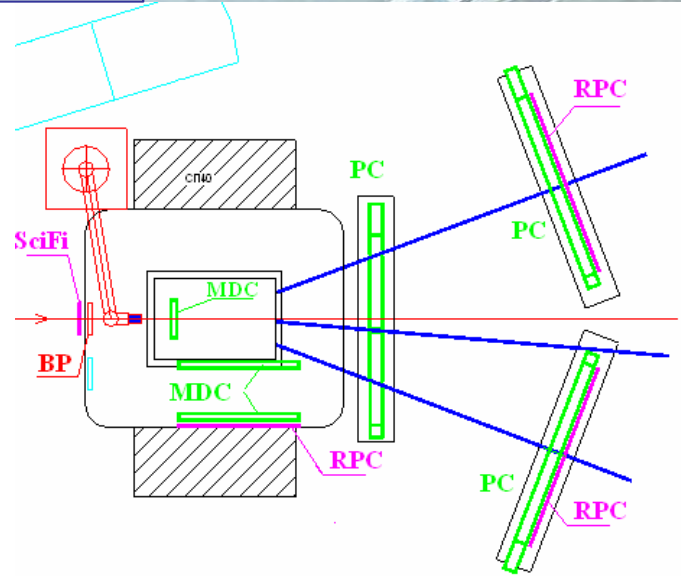


Unpolarized deuteron beam is passing through the matter & are analyzing in the polarimeter sensitive to the tensorial polarization.

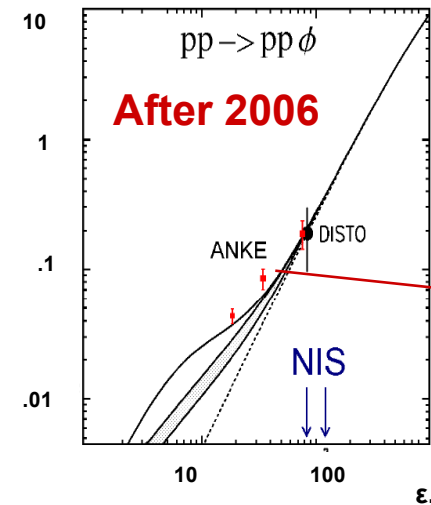
First measurement obtained in March '07 run at Nuclotron (to be confirmed)

1. Test of OZI rule in $pp \rightarrow pp + \phi/\omega$ and $np \rightarrow np + \phi/\omega$ near threshold

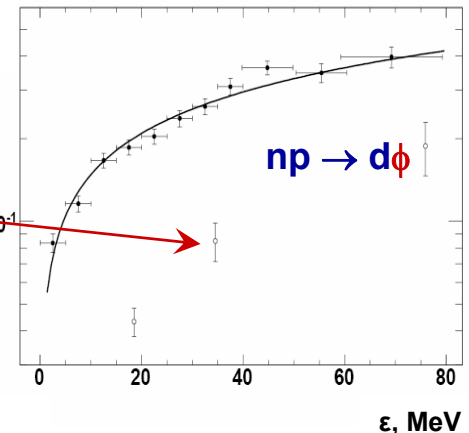
ANKE data: $R_{\phi/\omega} \approx 8 \times R_{OZI}$ (function of excess energy)



$\sigma, \mu\text{b}$



$\sigma, \mu\text{b}$

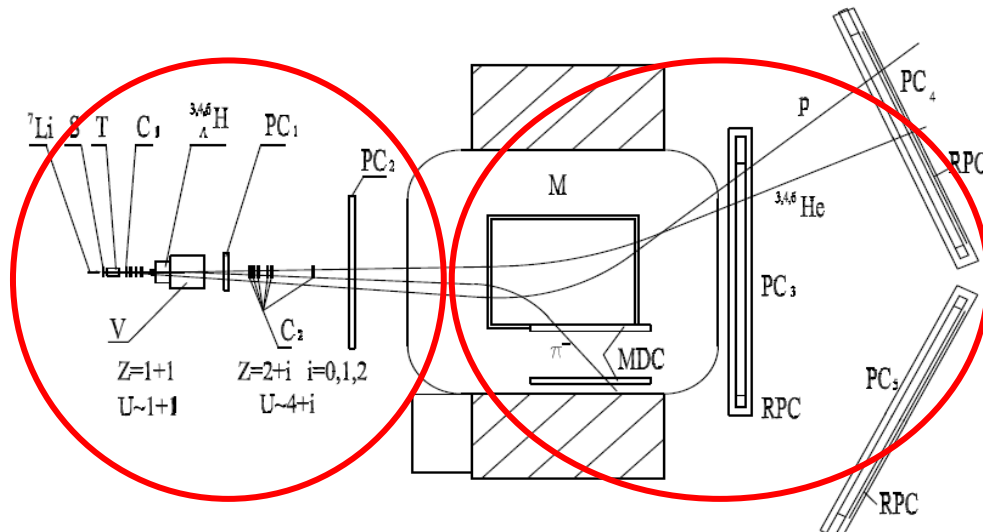


Q.: $R(\phi/\omega) \gg R(OZI)$ is a privilege of annihilation or not?

A.: It is not!

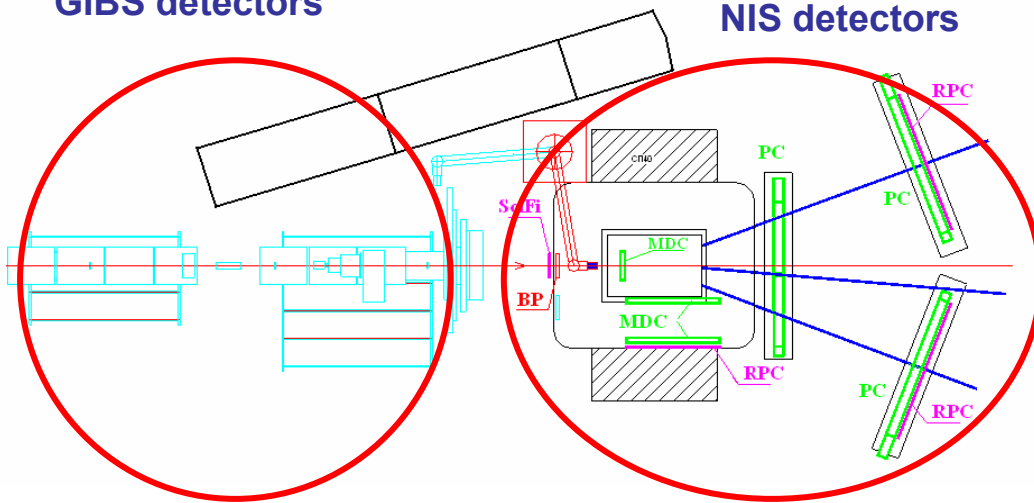
- **Exotic baryons:** New states, can be detected by the NIS spectrometer (at production level $\sigma \geq 0.05 \mu\text{b}$)
- **Intrinsic strangeness** and exotic baryons may be closely connected and related with the problem of the “*Spin crisis*”...

2. Search for Θ^+ production in pp near threshold (the problem is not solved)



GIBS detectors

NIS detectors

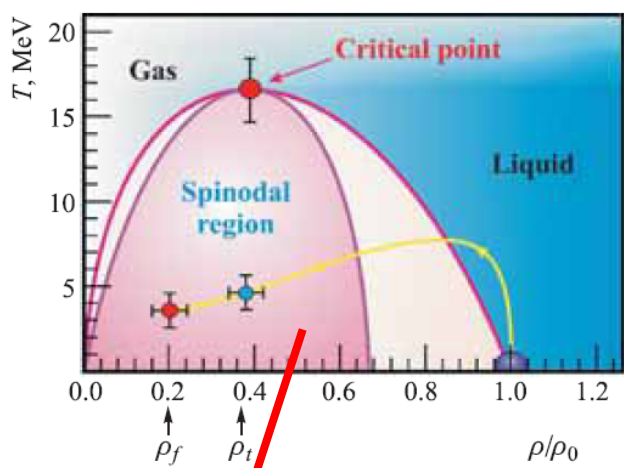


Physics of lightest hypernuclei

Goals:

- Search for unobserved ${}^6_{\Lambda}\text{H}$
(probing the drip-line for hypernuclei sector, low limit for cross section $\sim 0.02\mu\text{b}$)
- Measurement of lifetime for ${}^6_{\Lambda}\text{He}$
- Determination of matrix elements of *weak* ΛN interaction in study of non-mesonic decays of hypernuclei ${}^{10}_{\Lambda}\text{Be}$ and ${}^{10}_{\Lambda}\text{B}$
- Binding energy measurements for lightest hypernuclei

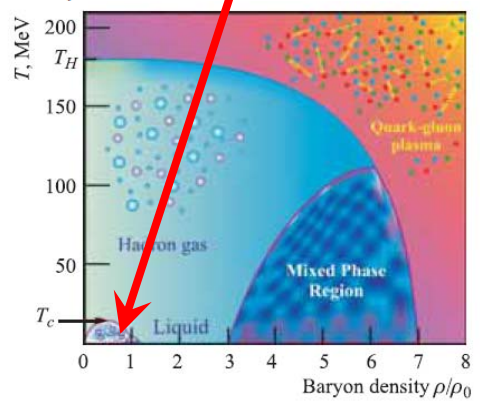
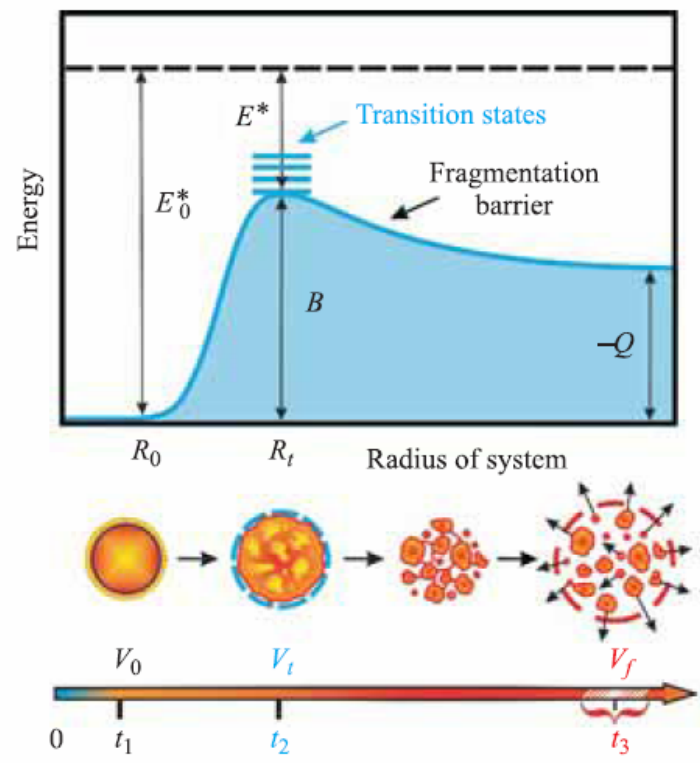
FAZA data for p+Au collisions.



Subject: phase transitions in hot nuclear matter
 (expansion and evolution from hot to cold)
The first goal: measurement of the mean emission time for thermal multifragmentation.

Line: zero rigidity of the nuclear matter

Fig. 1. The spinodal region for the nuclear system. Temperature and baryon density are shown on the axes. Data are obtained by FASA for p(8.1 GeV) + Au collision. The arrow line shows the way of the system from the starting point at $T = 0$ to the break-up at ρ_t , where prefragments are formed, and multiscission points at ρ_f



Assumed nuclear phase diagram.
 Baryon density is given in units of the normal one

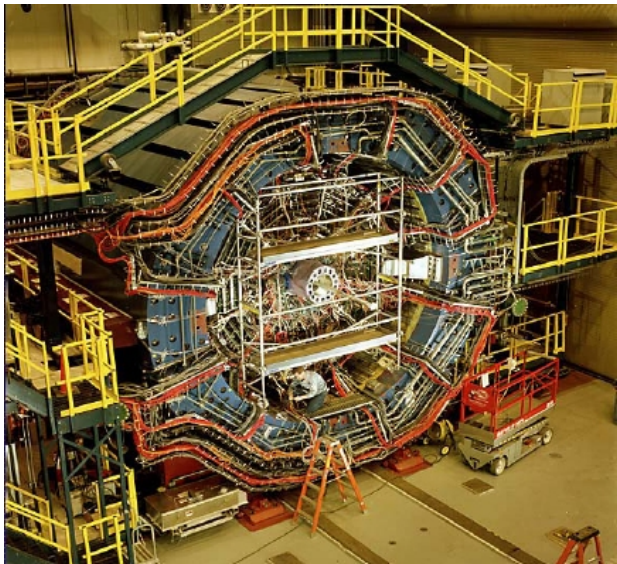


Physics at external accelerators



Project	Type of the agreement or signed document	Project status; current and future occupancy of LHE group				№ of participants (FTE)	Financial support from JINR and collaboration		
		R&D	Set-up construction	Data taking	Data analysis		2008	2009	2010
STAR	MoU →2009			+	+	28 (15,7)	95/2 2m.y.	102/2 2m.y.	120/2
NA49 (→NA61)	MoU finished Proposal	+	+ & simulation	+	+	9 (4,7)	30	30	35
CBM	Proposal	+	+ & simulation			20 (3,5)	75 INTAS BMBF	75 INTAS BMBF	90
ALICE ALICE/TRD	MoU →2010		+ & simulation +	+	+	31 (16,8)	60 INTAS	60	60
HADES	MoU →			+	+	8 (4,2)	35 INTAS BMBF	35 INTAS BMBF	35
PHENIX	MoU →	+	+	+	+	16 (5)	25	30	30

LHE groups have well defined responsibility in physics analysis & positions in physics program

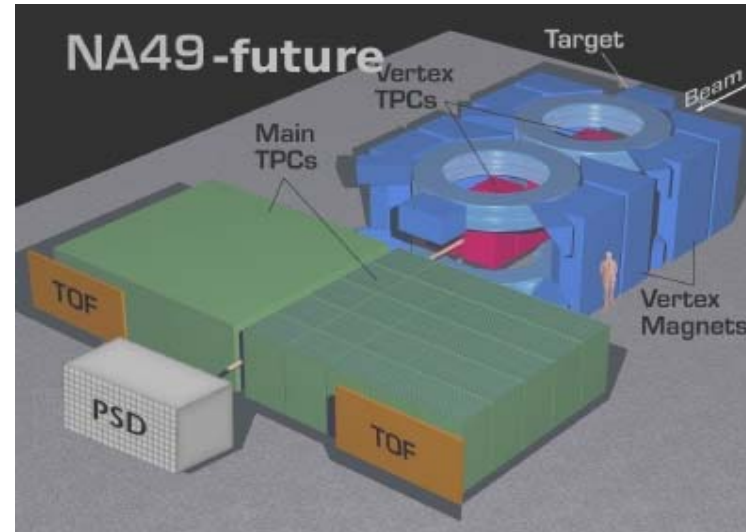
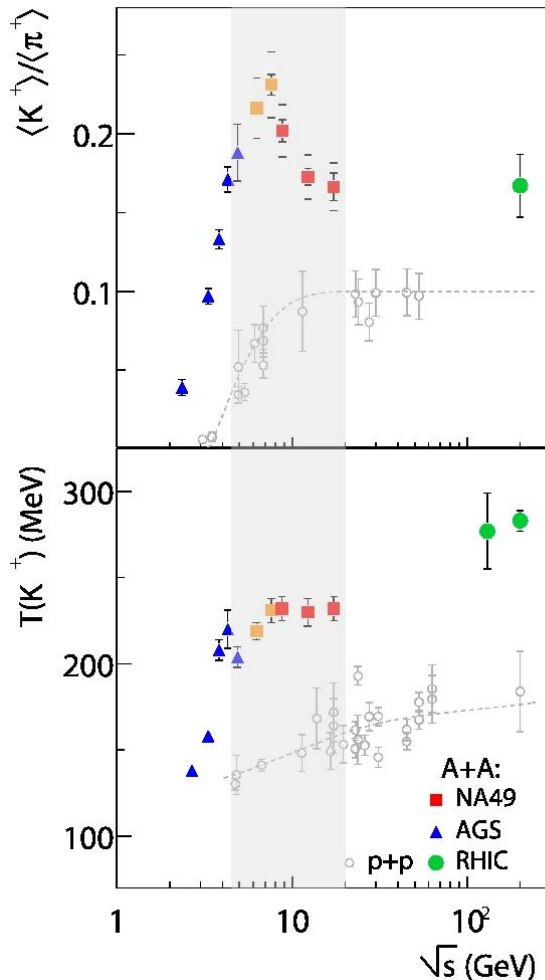


***The STAR
Collaboration:
12 countries,
49 Institutions,
~ 500 People***

RESEARCH PROGRAM FOR 2008-2010:

- **Definitive results on the saturation scale for the gluon distribution in relativistic heavy nuclei**
- **Decisive test of gluon saturation as the origin of particle suppression at forward pseudorapidity**
- **First significant measurements of the x dependence of gluon polarization in the proton, $\Delta G(x)$**
- **Definitive search for the existence and location of the QCD Critical Point**
- **First measurement of flavor dependence of sea quark anti-quark polarization in the proton**

Study of Hadron Production in Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS



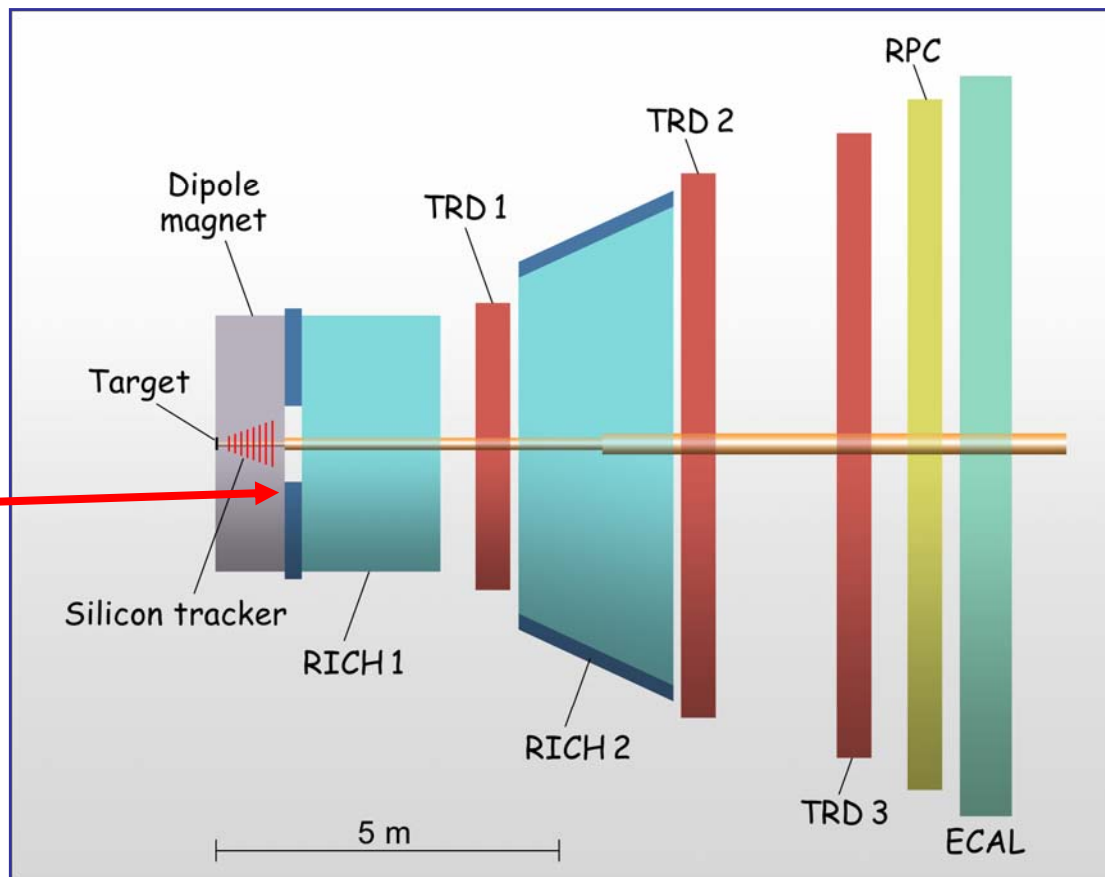
Search for the critical point of strongly interacting matter

Study the properties of the onset of deconfinement in nucleus-nucleus collisions

Measure hadron production at high transverse momenta in p+p and p+Pb collisions as reference for Pb+Pb results

LHE participation:

- **Transition Radiation Detector (TRD)**
- **Superconducting Dipole Magnet**
- **Simulation (tracking, magnetic field)**
- **Physics**
- **The NUCLOTRON will be used as a test bench for CBM detectors**





Innovations



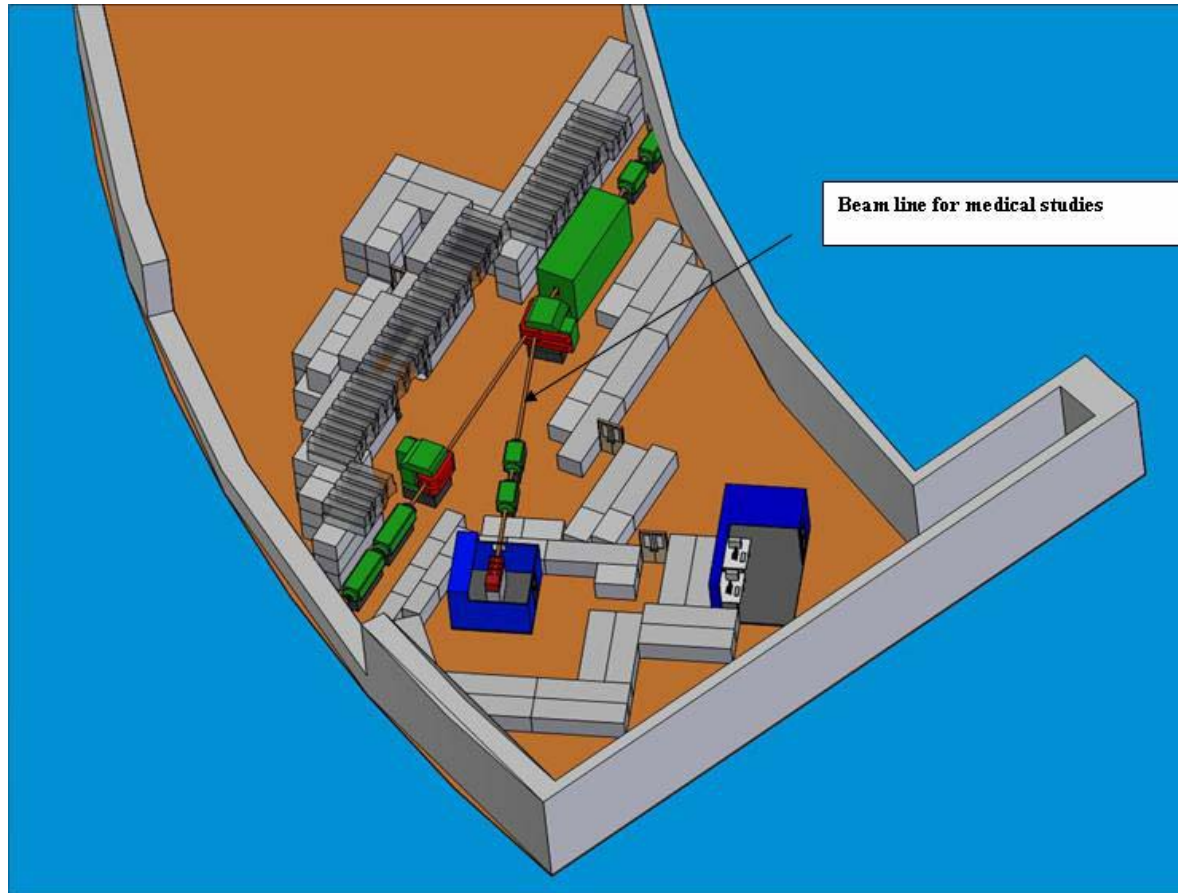
- **Development of radiotherapy methods with proton and heavy ion beams of the Nuclotron**
 - *Biomedical research on the proton and ion beam to develop new methods for oncology diseases therapy (V.M.Golovatyuk, E.A.Krasavin, J.Ruzicka)*
 - *Design a superconductive accelerator of heavy ions for medical therapy, design a beam transport system to the patient (**gantri**) with the superconductive magnet (N.N.Agapov)*

- **Study of transmutation of spent fuel from nuclear power plants (V.M.Golovatyuk, M.I.Krivopustov)**

- **Micro-pixel photodiodes (Z.Sadygov)**

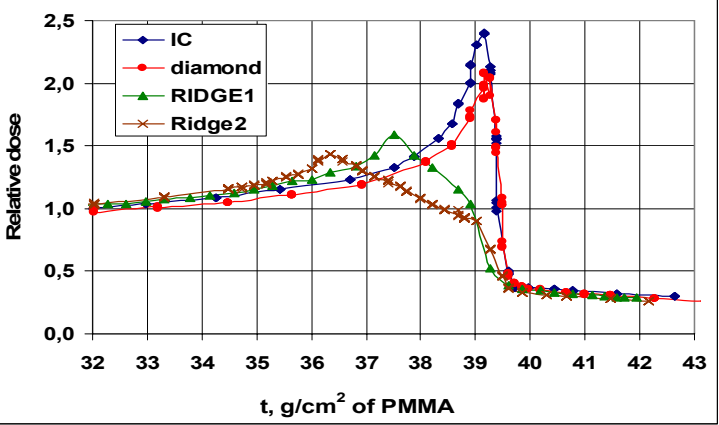
Medico-biological beam line

Depth-Dose distributions (Bragg peak) measured by wide aperture transmission ionization chamber & diamond detector & the modified depth dose distributions



Beam line for medical studies

Bragg peaks

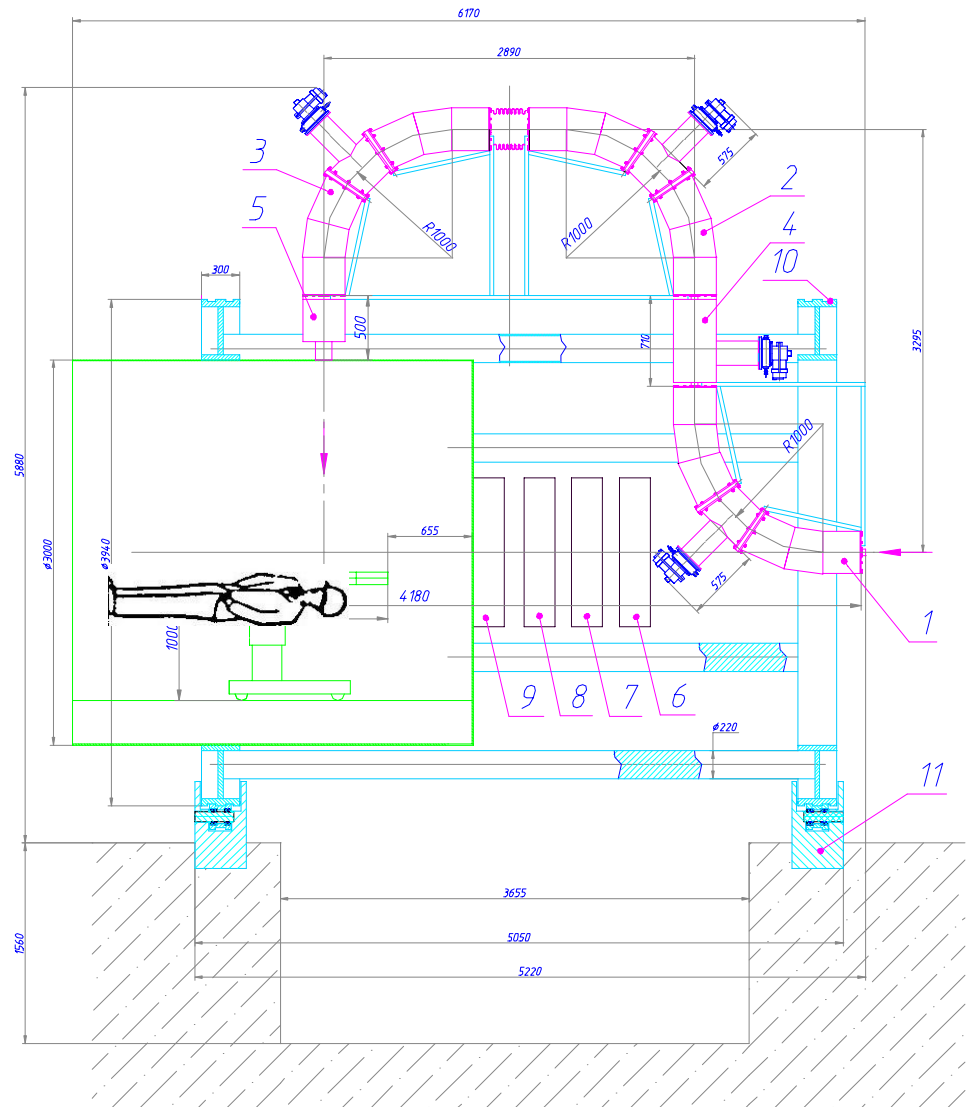


Slovakia & Romania representatives actively participate in the series of experiments with the Carbon beam at the Nuclotron.

GANTRY with superconducting magnets

- 1, 2, 3 - dipole magnets;
- 4 - focusing magnet;
- 5 - scanning magnet;
- 6 - sealing of helium tubes;
- 7 - sealing of vacuum tube;
- 8 - electric sliding connection;
- 9 - electric sliding connection of cold head valves;
- 10 - frame of GANTRY;
- 11 - support of frame wheels;
- 12 - screen.

Weight & size are 10 times less than the "warm" systems



Заключение

- *Реализация I этапа проекта NICA в 2007-2009 важнейшая задача - **критичная** для формирования стратегических планов Лаборатории*
- *Научная программа Нуклотрона определяется прежде всего:*
 - *задачами развития ускорительного комплекса*
 - *и конкурентоспособными экспериментами привлекательными для широкой кооперации*
- *Эксперименты на внешних ускорителях непосредственно связаны с домашними задачами*
- *Имеется определенный интерес к продолжению начатых инновационных проектов*



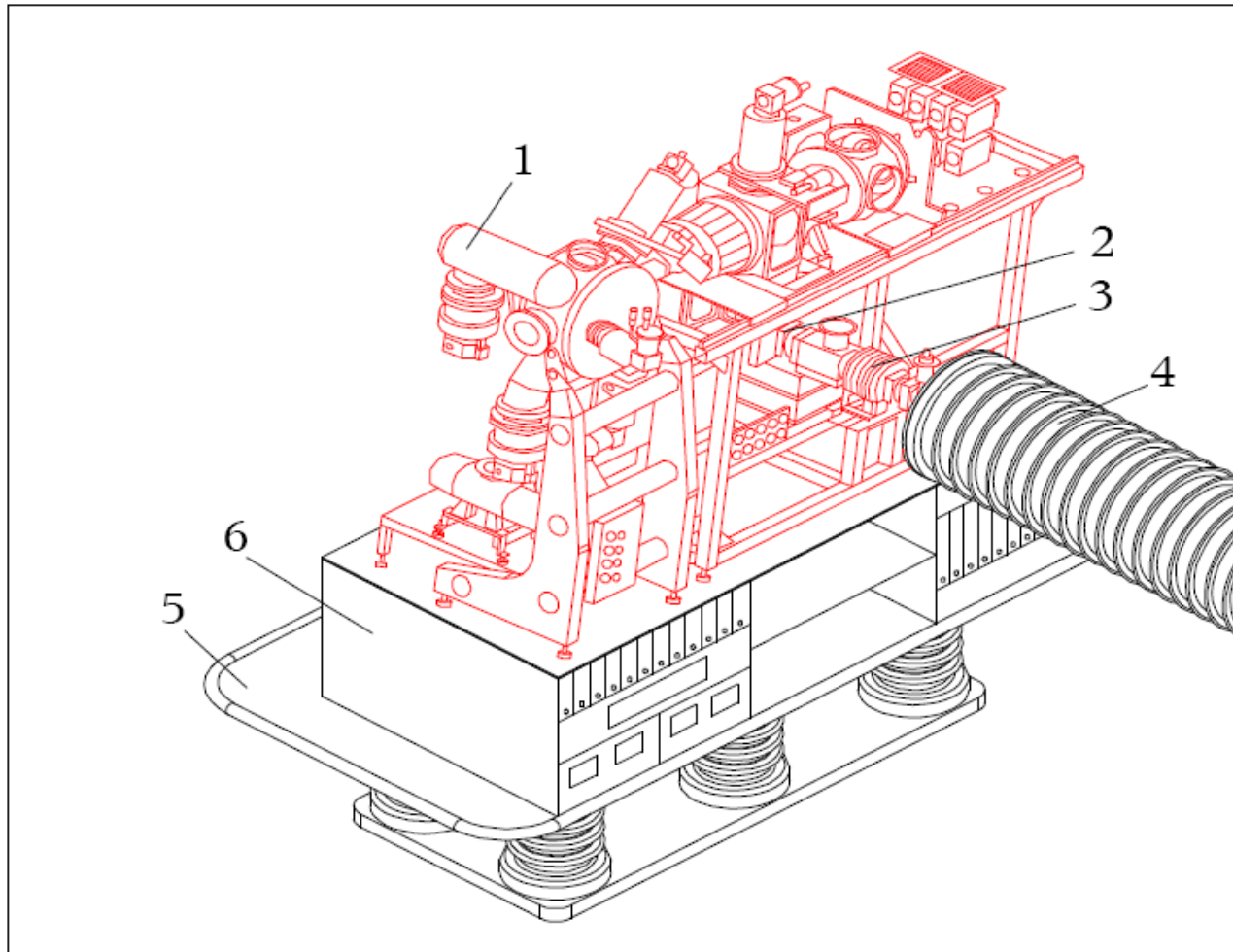
Remarkable events in **2007**:

- the **100-th anniversary** of academician V.I. Veksler
- the **50-th anniversary** of Synchrofasatron

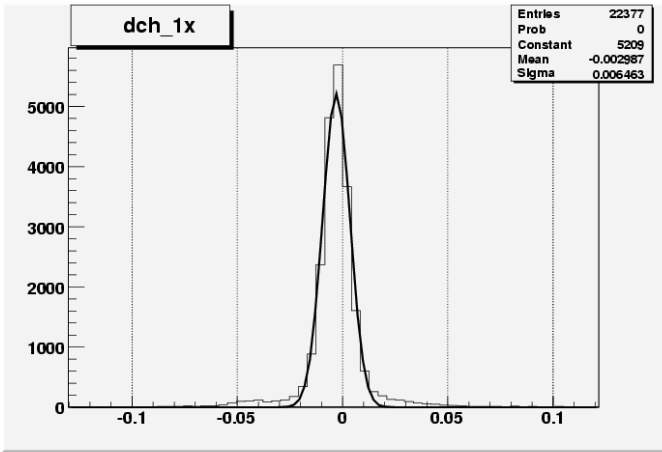


*Dedicated celebration events will take place **in October***

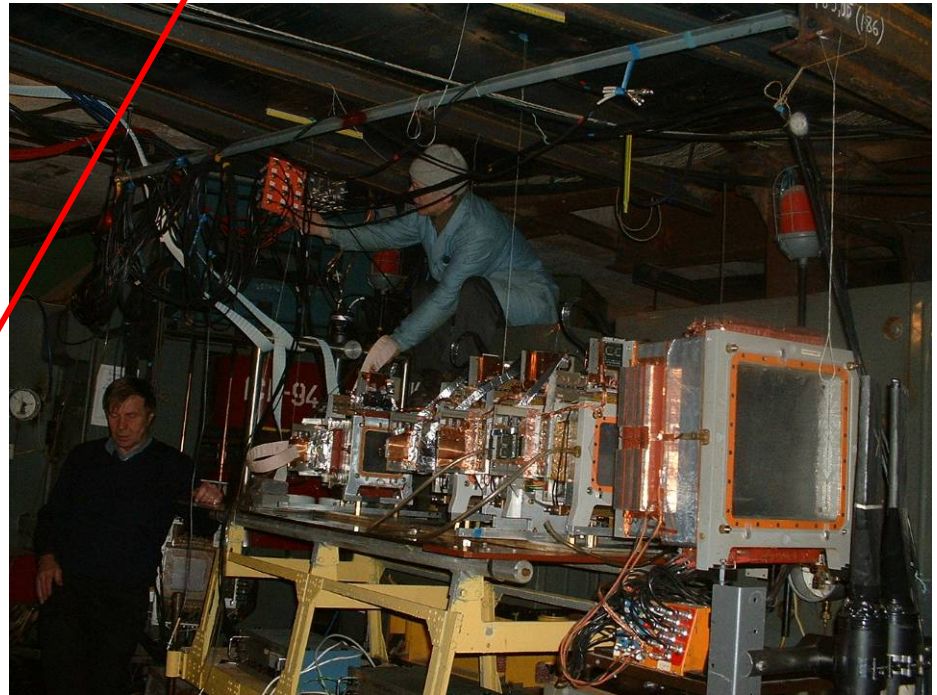
spare



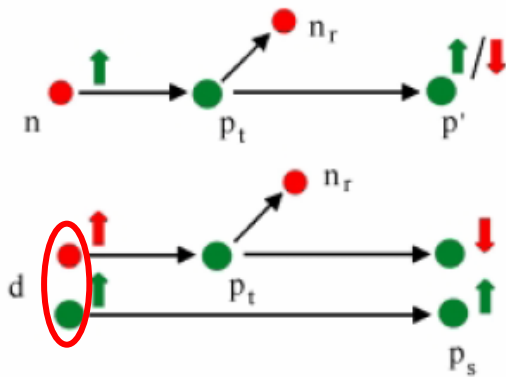
The key pre-requisit for polarization studies at JINR



Measurements of the cross section and T_{20} in $dp \rightarrow pp(^1S_0) + n$ charge exchange reaction



coordinate resolution ~ 100 μm (drift chambers)



$$\frac{d\sigma}{dt} (dp \rightarrow n(pp)_S (\theta_{\text{cm}} = 0^\circ)) = [1 - F_d] \left(\frac{d\sigma}{dt} \right)_{\text{spin-indep.}} + \left[1 - \frac{1}{3} F_d \right] \left(\frac{d\sigma}{dt} \right)_{\text{spin-dep.}}$$

at small $|t|$: $F_d \rightarrow 1$ and

11 октября 20

$$\frac{d\sigma}{dt} (dp \rightarrow n(pp)_S (\theta_{\text{cm}} = 0^\circ)) = \frac{2}{3} \left(\frac{d\sigma}{dt} (\rightarrow pn) \right)_{\text{spin-dep.}}$$

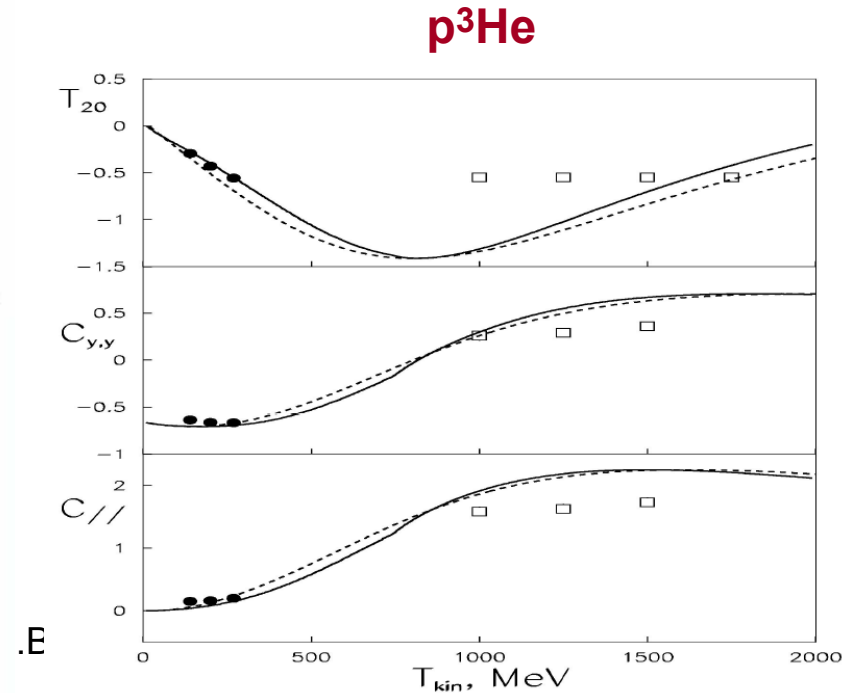
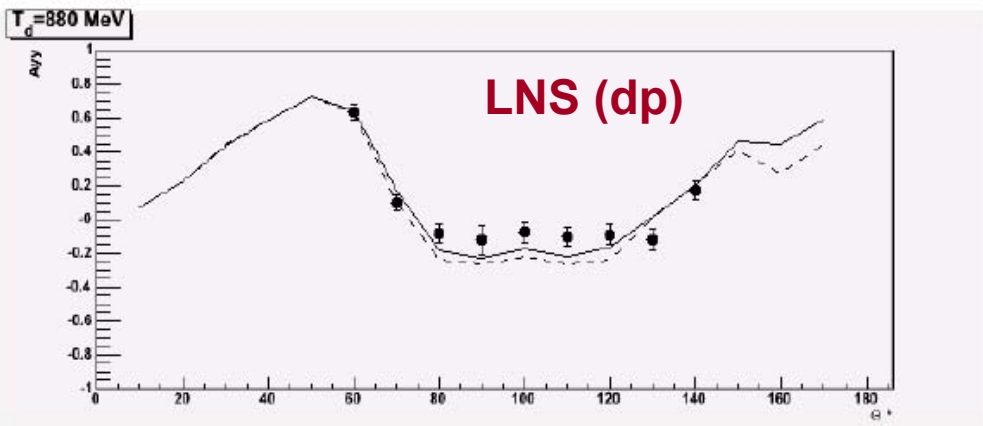
LNS+p³He

V.Ladygin

tot. FTE ~ 14, LHE ~ 13.1

The goals are: (1) to measure the analyzing powers in the dp-elastic and dp-breakup reactions, (2) to establish deuteron beam polarimetry at 270 MeV (**LNS**).

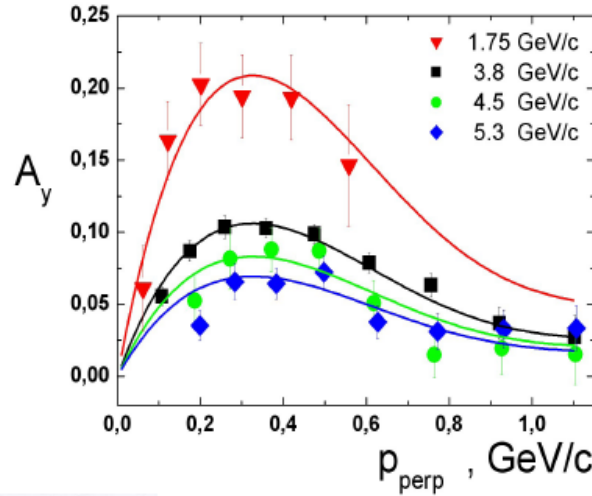
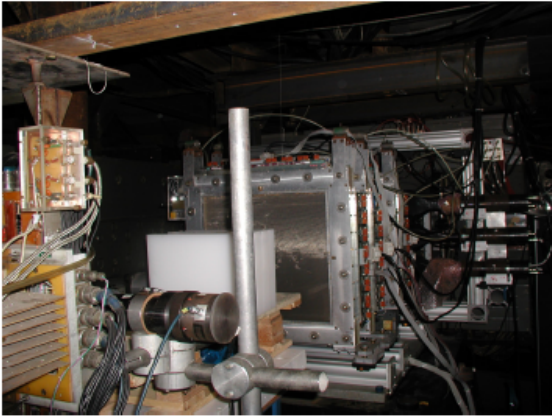
p³He: to measure the polarization observables in the d³He→pα in a GeV range in the region of the deuteron D-wave dominance; (2) the energy dependence of 3NF and high energy deuteron polarimetry.



ALPOM

I.Sitnik, M.Piskunov
tot. FTE ~1.8, LHE ~1.8

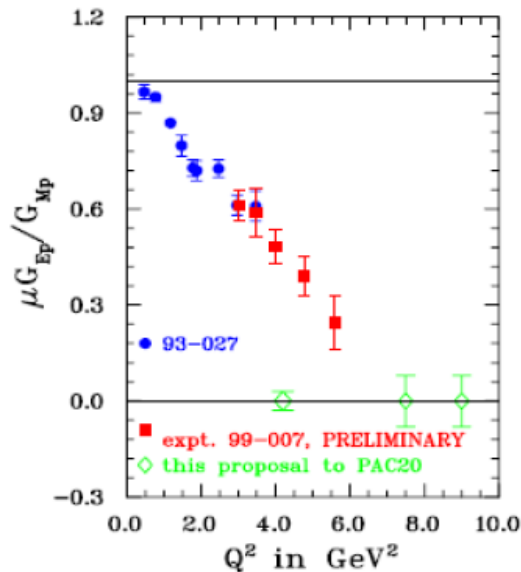
Calibration of polarimeter for JLAB $\mu_p G_{Ep}/G_{\mu p}$ experiment:
measurement of the analyzing power for $pCH_2 \rightarrow "p"X$ reaction at momenta ~ 7 GeV/c



Previous data



“The $\mu_p G_{Ep}/G_{\mu p}$ puzzle”



JLAB data from
expt. 93-027 & 99-007
and proposal 00-111
for $\mu_p G_{Ep}/G_{\mu p}$

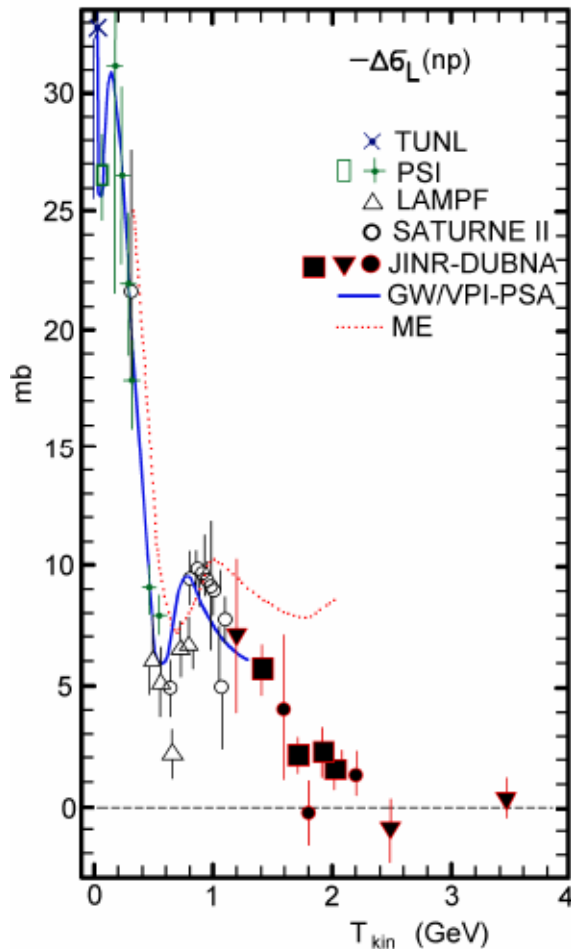
T

$\Delta\sigma$ -experiment

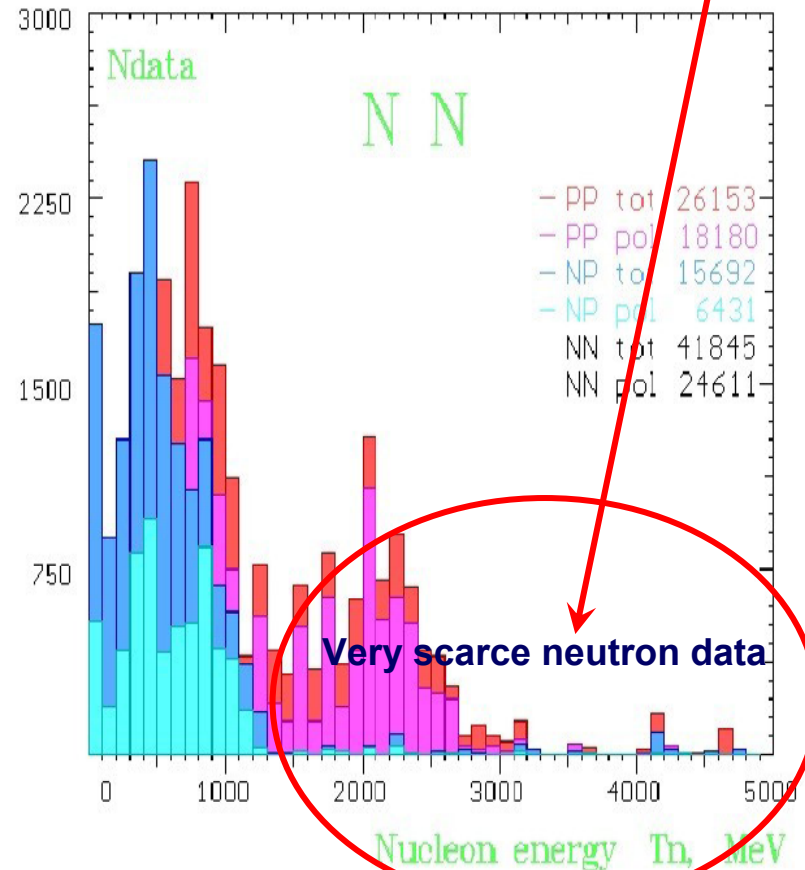
L.Strunov, V.Sharov
tot. FTE ~ 12.5, LHE ~ 9

Full determination of the np elastic scattering matrix element at zero degree in the few GeV energy region. Needs SPI and MPPT.

Nuclotron's region



The world NN data base



11 октября 2007

В.Кекелидзе,

V.I.Sharov et al, Czech. Journ. of Phys. 52 (2002),
Suppl. C, C287; also at SPIN-2002 Conf.

Введение



Дальнейшее развитие ф.в.э. в ОИЯИ было обусловлено наличием соответствующей ускорительной базы

Потеря лидирующих позиций синхрофазотрона обусловила реализацию части программы по ф.в.э. и р.я.ф. на внешних базовых установках для сохранения научного потенциала и культуры современного эксперимента:

- **У-70** в Серпухове (БИС, БИС-2, ЧАРМ, ЭКСЧАРМ, Гиперон,...)
- **SPS** и **LEP** CERN (NA4, SMC, DELPHI, NA48, NA49, COMPASS)
- **RHIC** BNL (STAR, PHENIX), **HERA** DESY (H1, HERMES),
- **Tevatron** FNAL (CDF и D0), **SIS** GSI (HADES) и др.
- широкомасштабное участие в программе **LHC** в CERN:
ATLAS, CMS, ALICE
- подготовка к участию в программе на **FAIR** GSI: CBM, PANDA



Resource request from polarization working group

Запрос ресурсов – пучок (USER1)
без учета работы в режиме USER2

№ п/п	Эксперимент	2007	2008	2009
1.	LNS	50	50+100*	100*
2.	PHE3-CUPID		200*	
3.	$\Delta\sigma$	360+120*	480*	480*
4.	DELTA-2	50	100+150*	500*
5.	ALPOM	48	100*	
6.	STRELA	100	200	100*
7.	TPD	60	50	
		668+120*	400+1030*	1180*

* - пучок поляризованных дейтронов

Запрос ресурсов – мат.&МНТС

№ п/п	Эксперимент	2007	2008	2009
1.	LNS	29(5)	13(5)	8(5)
2.	PHE3-CUPID	50(10)	20(10)	-
3.	$\Delta\sigma$	15(4)	12(4)	8(4)
4.	DELTA-2	80(4)	60(6)	44(4)
5.	ALPOM	3(3)	3(3)	-
6.	STRELA	20(4)	12(4)	6(4)
7.	TPD	-	-	-
		197(30)	120(32)	66(17)

“Investigation of secondary particle generation and neutron yields from extended targets in nuclear interactions.

Study of transmutation of spent fuel from nuclear power plants (GAMMA-2md).”

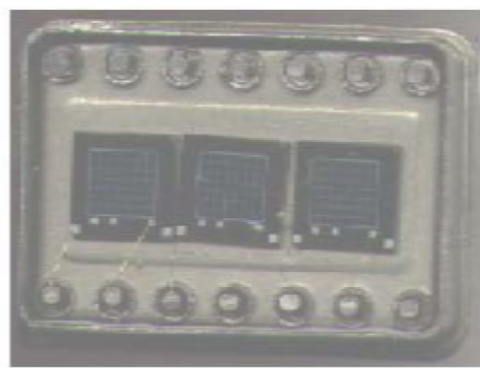
First experiment with graphite moderator - in the march 2007 Nuclotron run



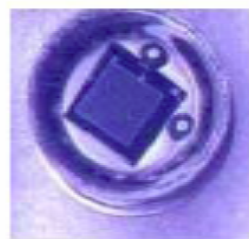
11 октября 200



Today available AMPD samples



64-element AMPD matrix for imaging.



4-element prototype for PET



Single element AMPD for muon beam monitor (for PSI)

