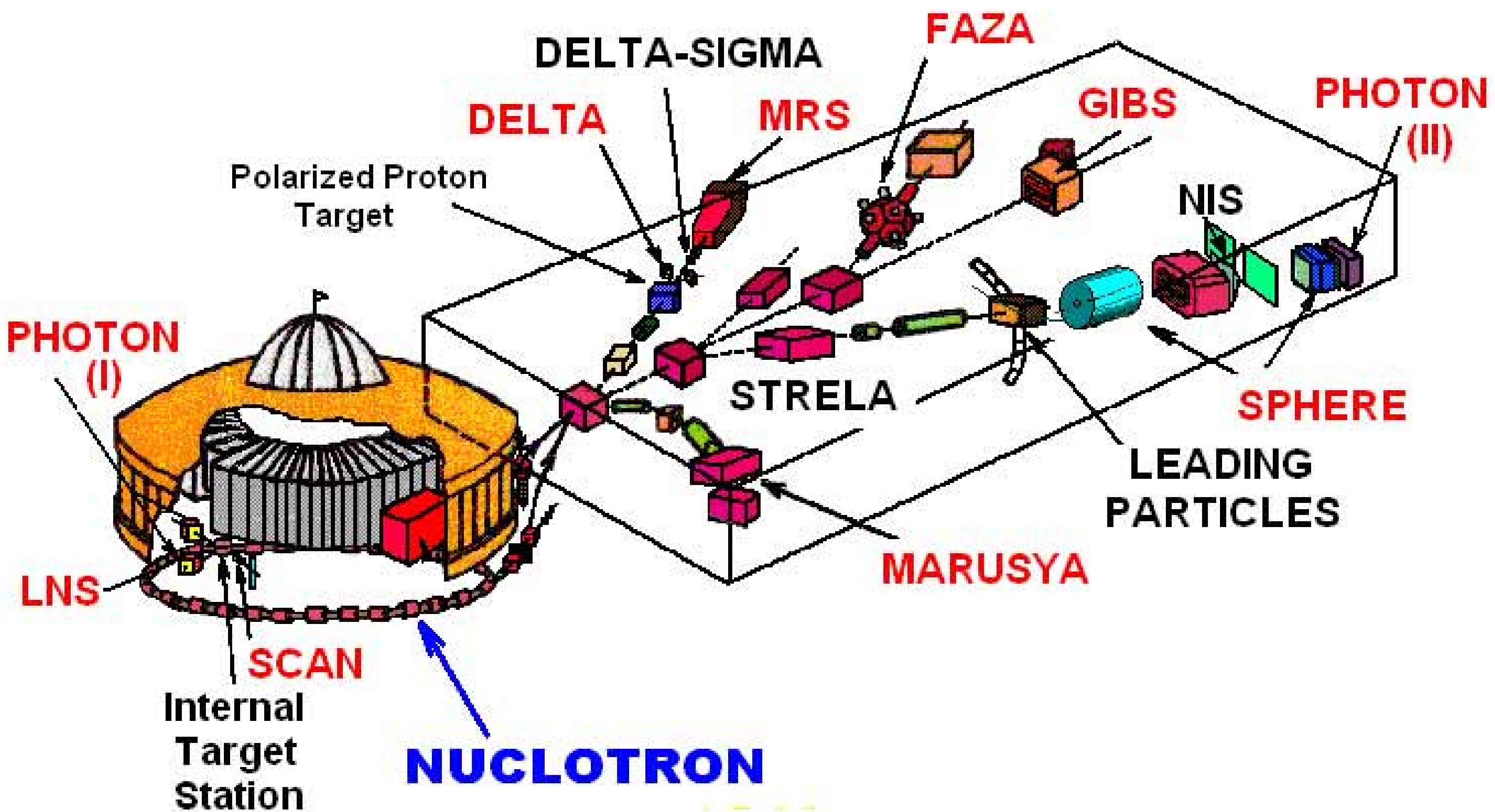
# The JINR Detector basis and perspectives of attracting of external detectors for the realization of the project of searching for the MIXED PHASE

***A.Malakhov***

**Round table discussion, Dubna, July 7-9, 2005**

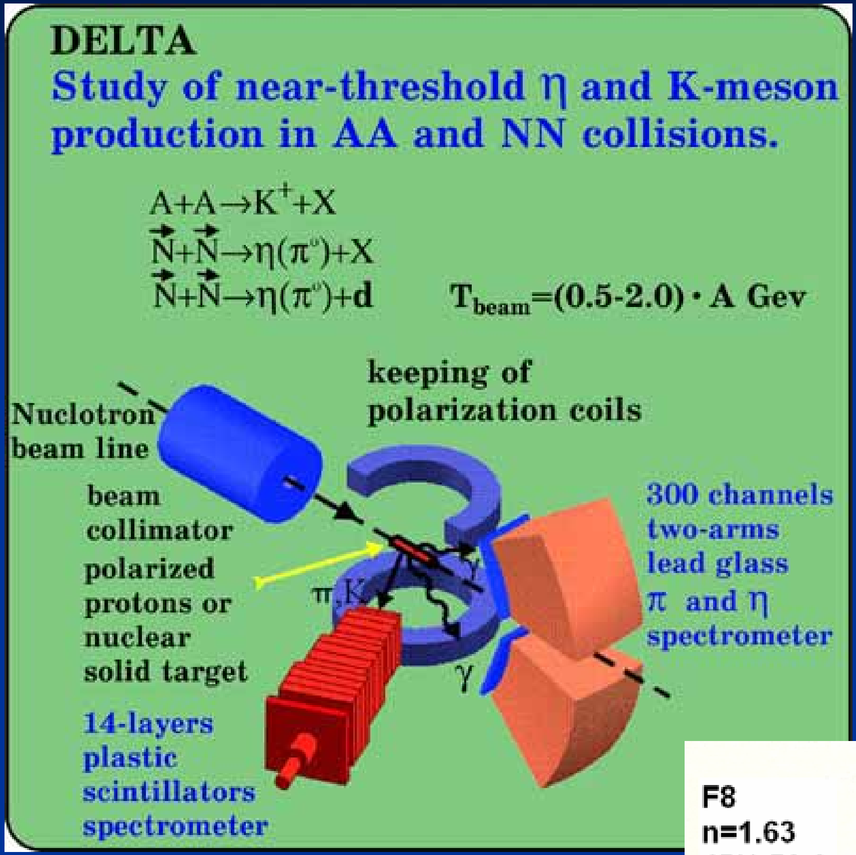
# JINR detectors

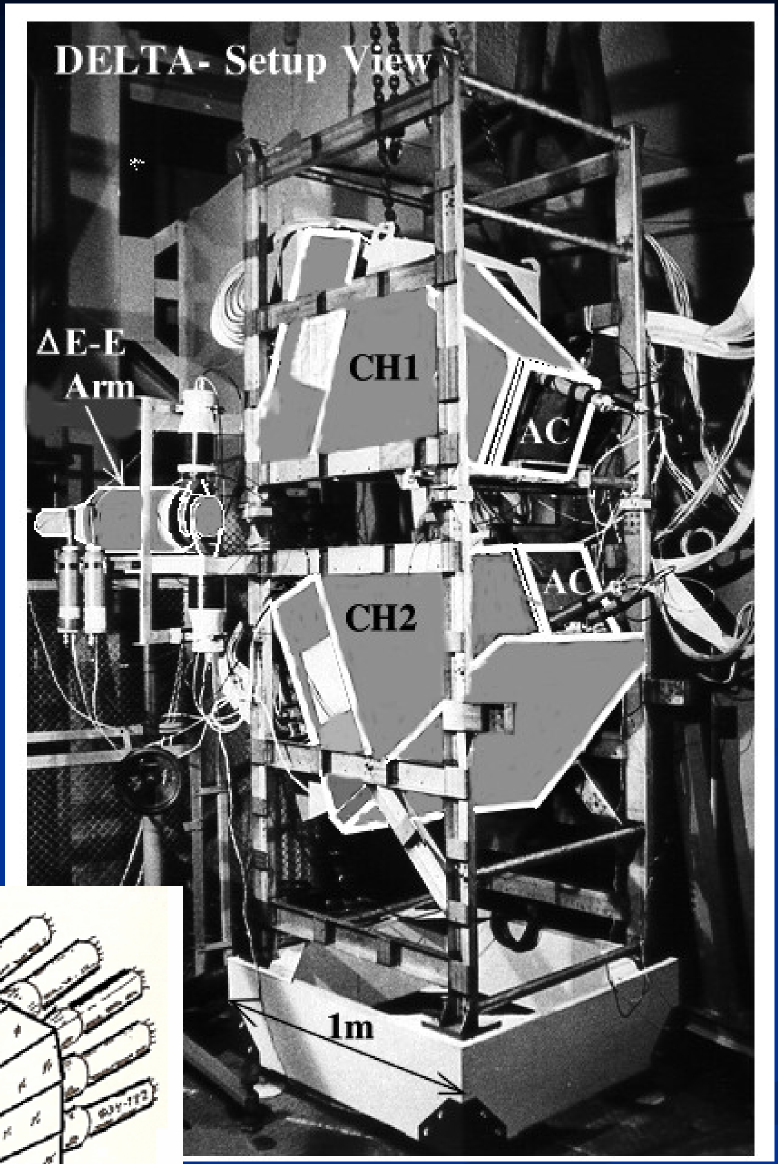


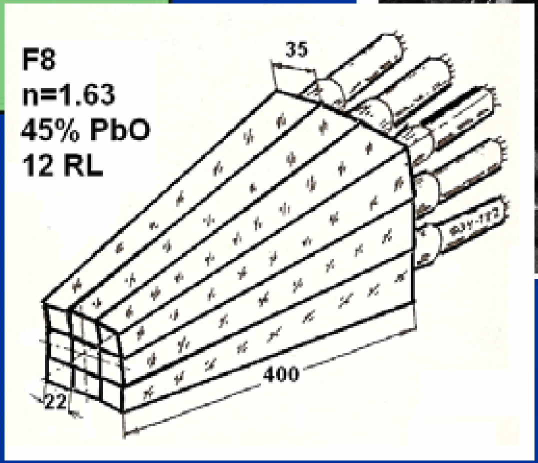
DELTA-SIGMA
FAZA
DELTA
MRS
GIBS
PHOTON (II)
Polarized Proton Target
NIS
PHOTON (I)
STRELA
SPHERE
LEADING PARTICLES
MARUSYA
LNS
SCAN
Internal Target Station
NUCLOTRON

1) Researching the hadron properties in hot and/or dense baryonic matter. A spectral change is all of the sigma-meson as the chiral partner of pions, which characterizes a degree of chiral symmetry violation and could play a role of a "signal" of its restoration. To derive, then to prove or disprove quantitative predictions is the aim of this investigation.

# DELTA

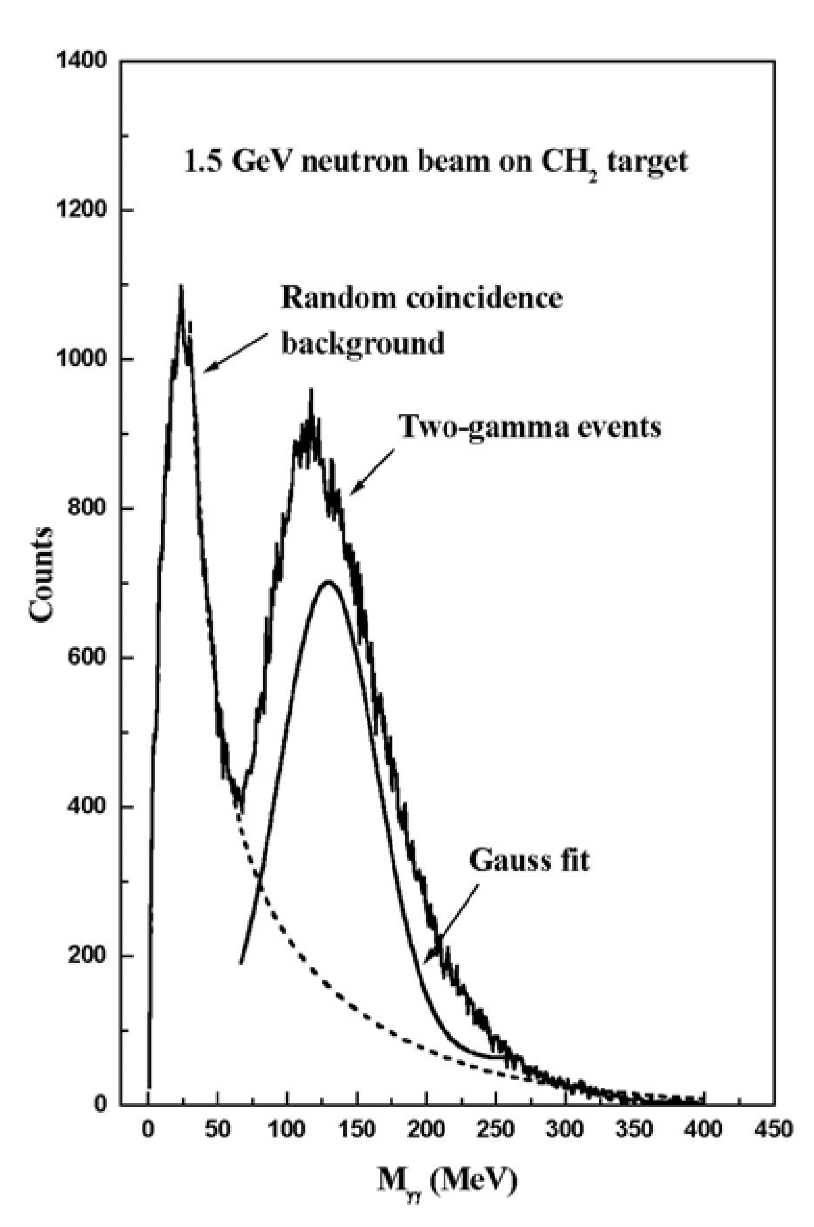



$\Delta E/E\ (\%) = 12/\sqrt{E}(\text{GeV})$

$\sigma(x,y) \approx 3$ mm


1.5 GeV neutron beam on $CH_2$ target
Random coincidence background
Two-gamma events
Gauss fit
Counts
$M_{\gamma\gamma}$ (MeV)
0
200
400
600
800
1000
1200
1400
0
50
100
150
200
250
300
350
400
450

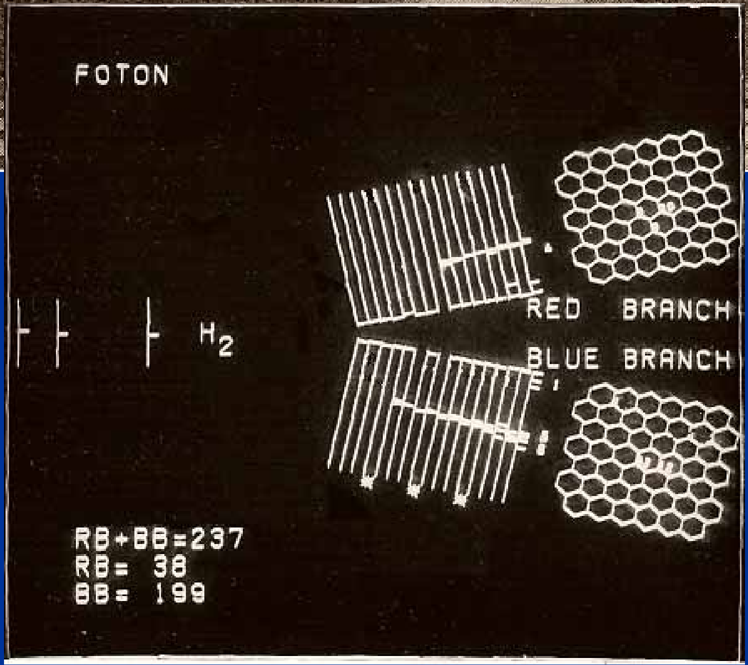
# DELTA

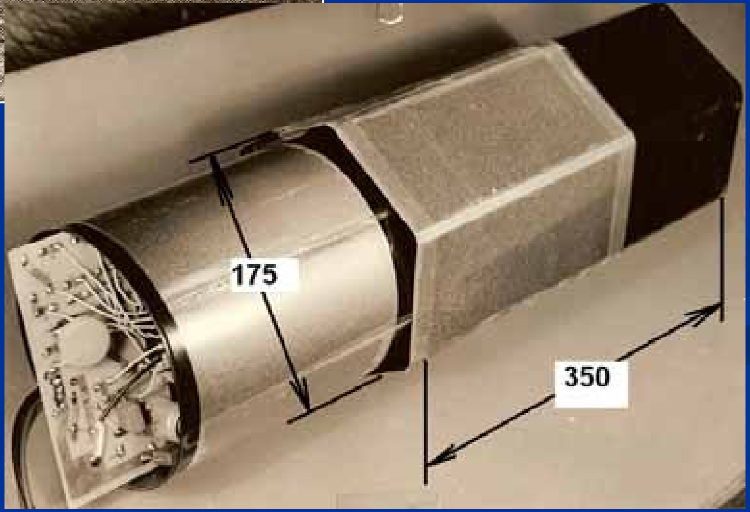
# 90-channel Cherenkov lead glass gamma-spectrometer

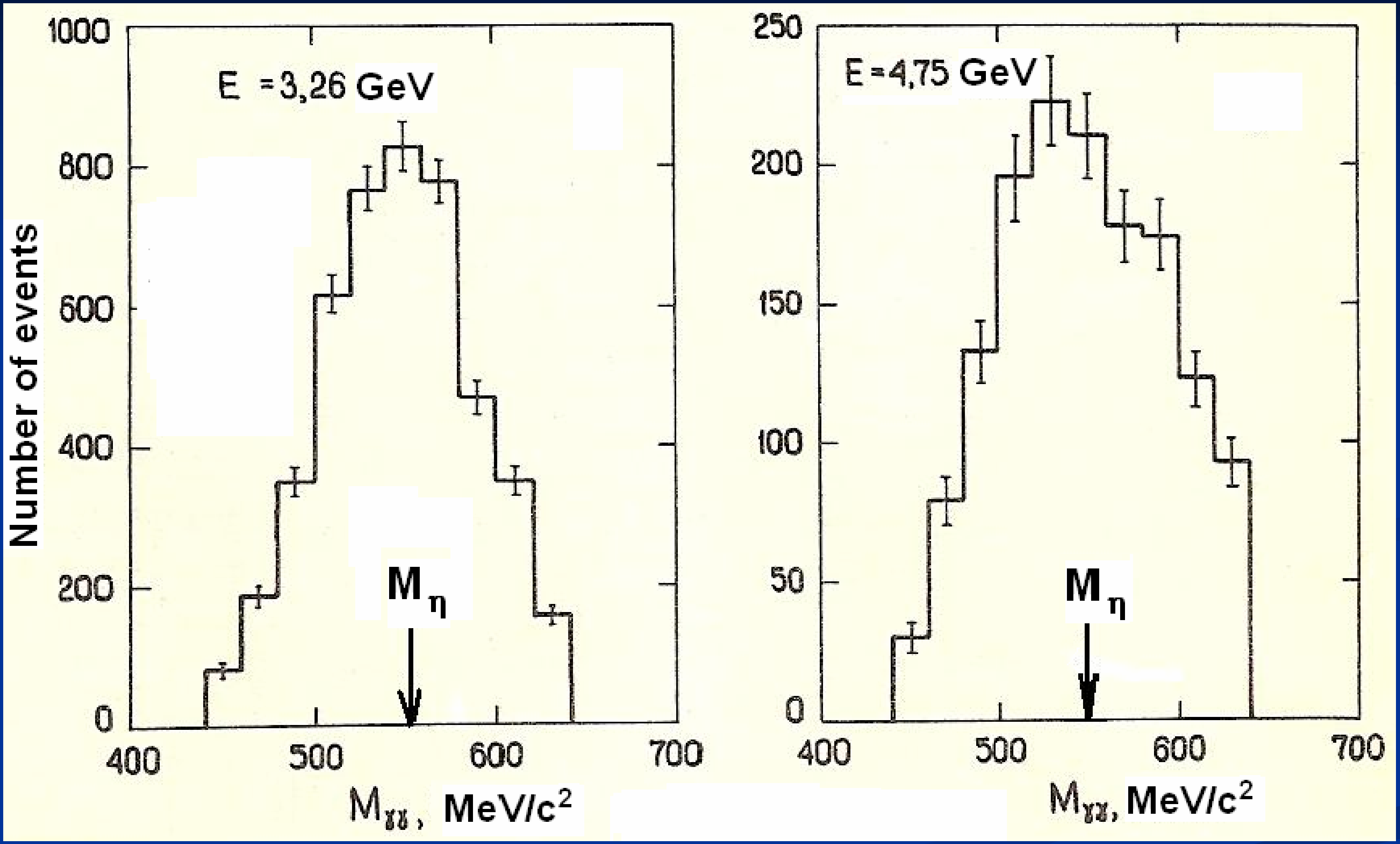
# PHOTON

$\Delta E/E\ (\%) = 9/\sqrt{E}(\mathrm{GeV})$

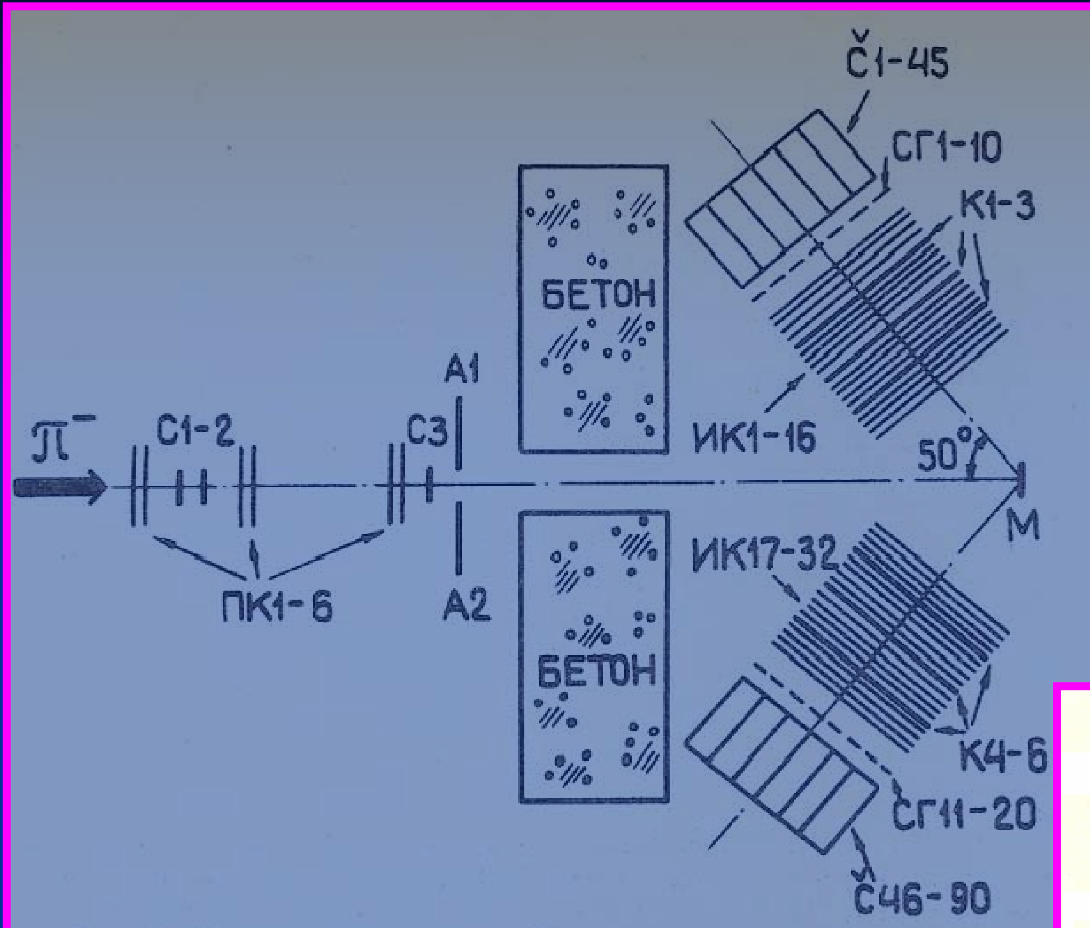
$\sigma(x,y) \approx 35$ mm

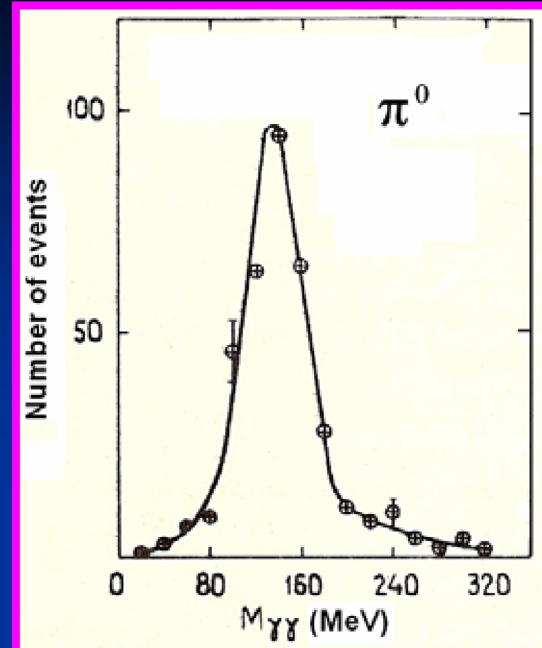


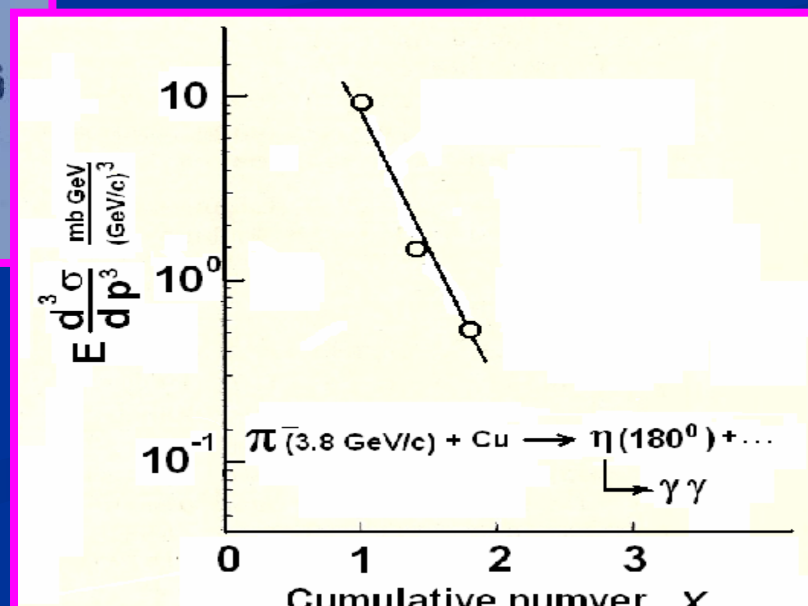





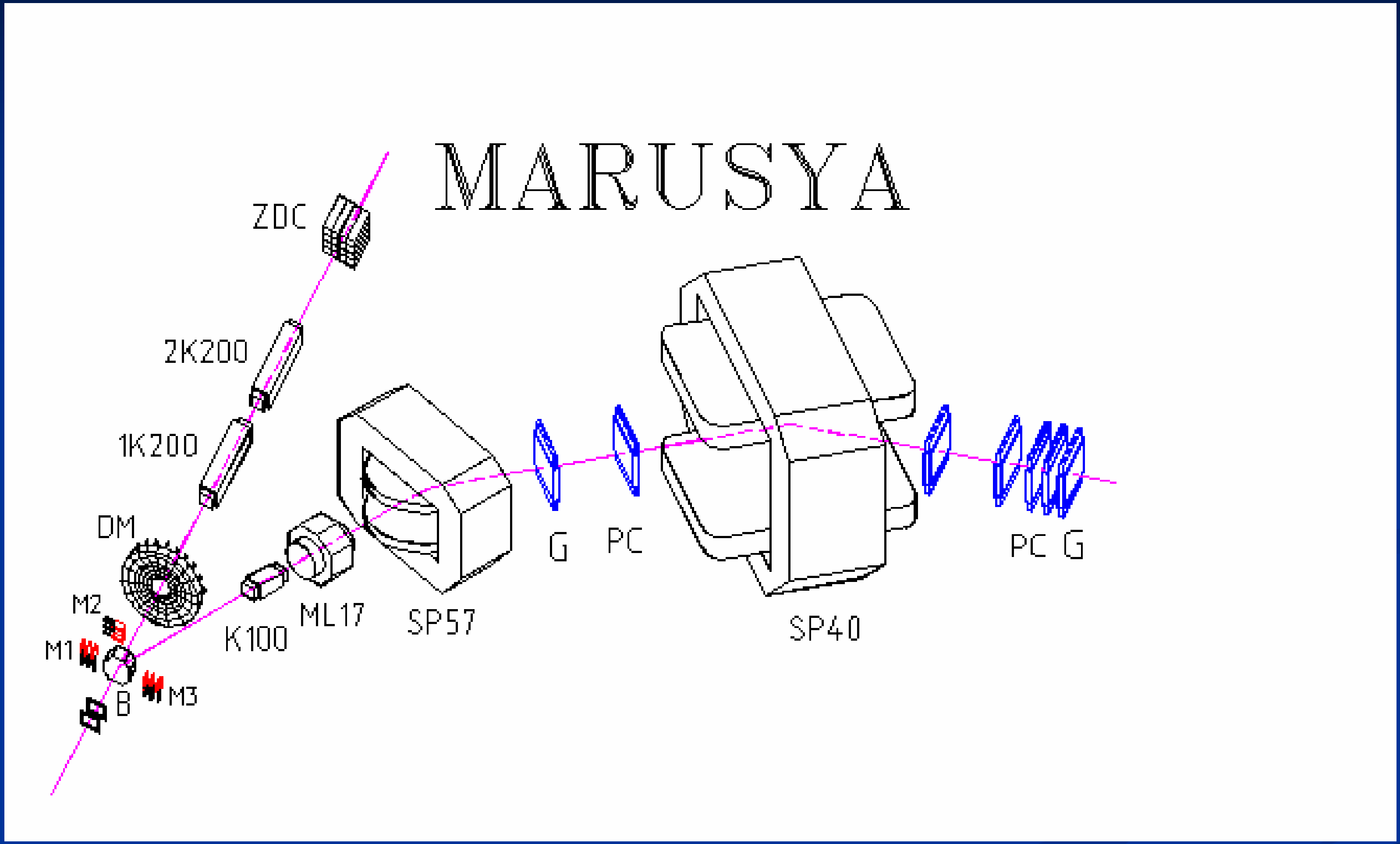

$$\pi + p \rightarrow \eta + n$$


Č1-45
СГ1-10
К1-3
БЕТОН
А1
π⁻
С1-2
С3
ИК1-16
50°
М
ПК1-6
А2
ИК17-32
БЕТОН
К4-6
СГ11-20
С46-90


π⁰
Number of events
100
50
0
80
160
240
320
Mγγ (MeV)


10
10⁰
10⁻¹
E d³σ/dp³ mb GeV/(GeV/c)³
π⁻(3.8 GeV/c) + Cu → η(180⁰) + ...
→ γγ
0
1
2
3
Cumulative numver , X

**2) Analyzing multiparticle hadron interactions, targeted to the development of new statistical treatment as well as codes for space-time evolution of heavy nuclei collisions at high energies. Particular attention should be paid to "signals“ of new phases formation during this evolution and to manifestation of baryon repulsion effects on hadron abundance.**

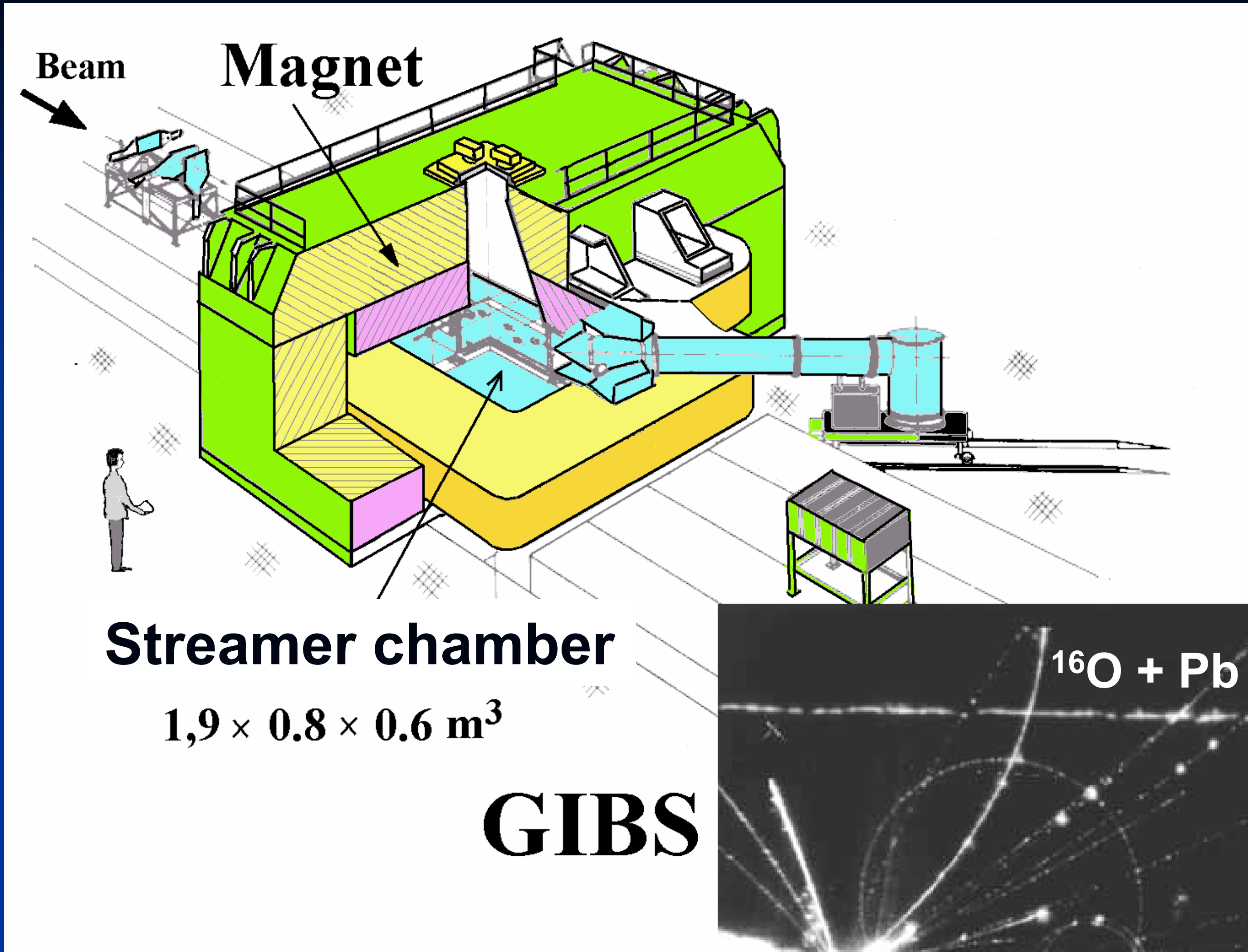

MARUSYA
ZDC
2K200
1K200
DM
M2
M1
B
M3
K100
ML17
SP57
G
PC
SP40
PC
G

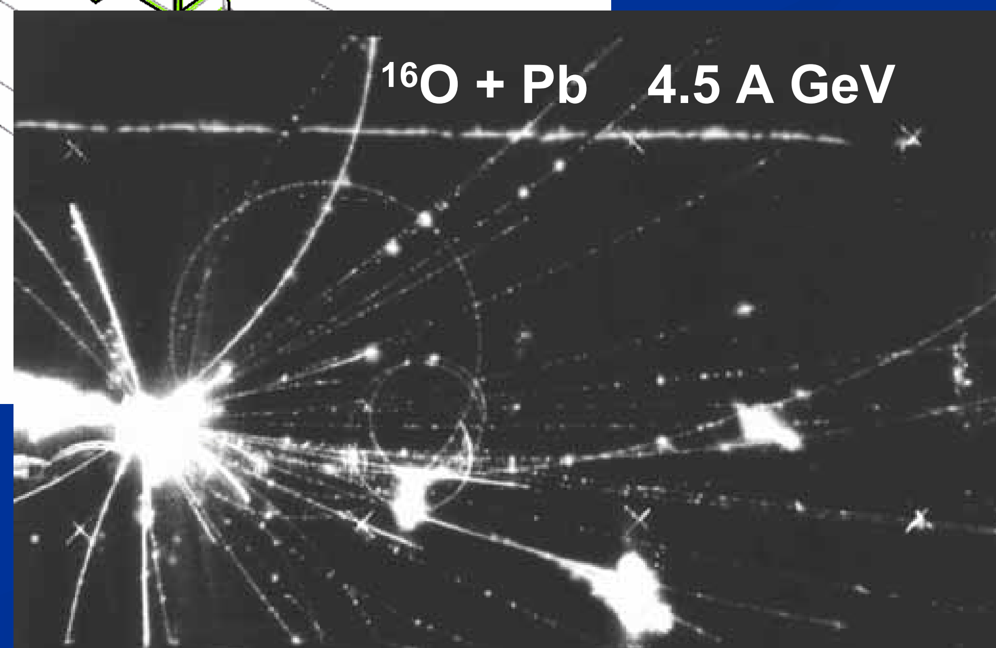
1. Measurements of the cross-section of the deuterons, kaons, pions, antiprotons and nuclear fragments production versus:

- types of beam nuclei and target nuclei (p-U);
- energy of beam nuclei (2-6 GeV/nucleon);
- momenta of detected particles (0.3 – 2.0 GeV/c);
- angle of particle production (20 - 90 deg.);
- direction of polarization of beam particles;

2. Under the conditions of item 1 simultaneous measurements of multiplicity and centrality at a Zero Degree Hadronic Calorimeter;
3. Detection of two particles belonging to one event in the aperture of a magnetic spectrometer with their identification and under conditions of item 2.

**3) Analyzing the energy and centrality dependences of the pion, baryon resonances and strange particle multiplicities, and the ratio of their yields, together with the transverse momentum, including $K^-$, $K^*$- and φ-meson spectra.**

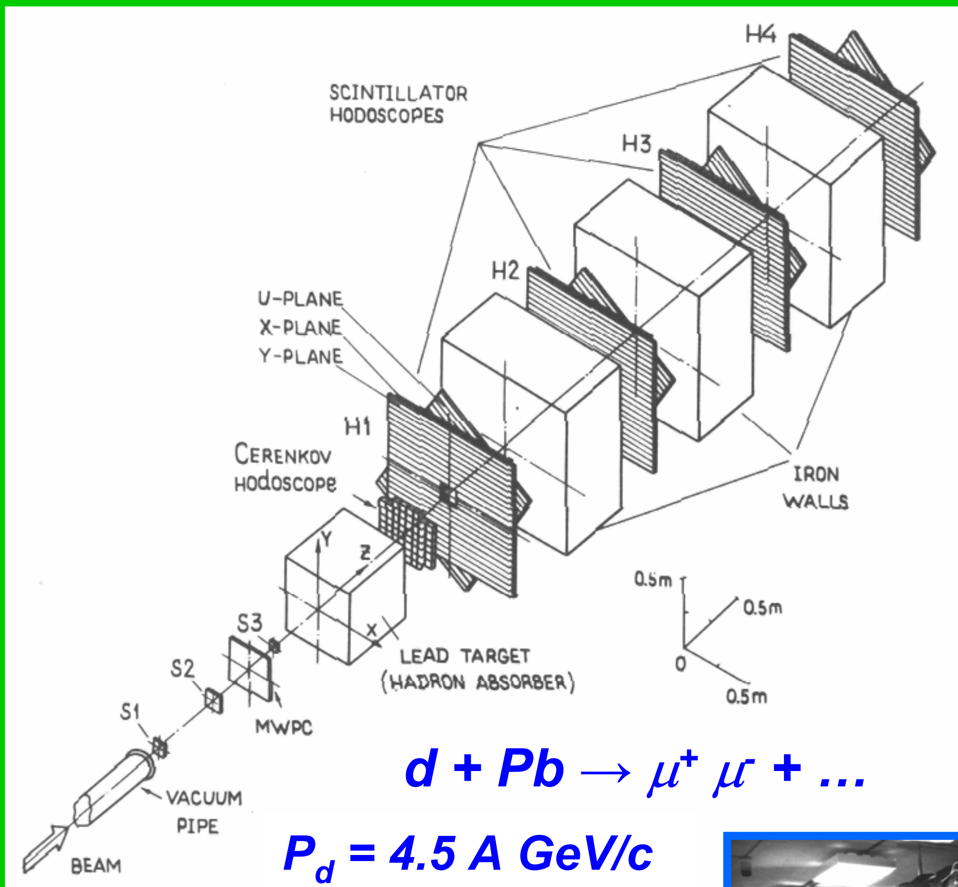



~ 50 tracks

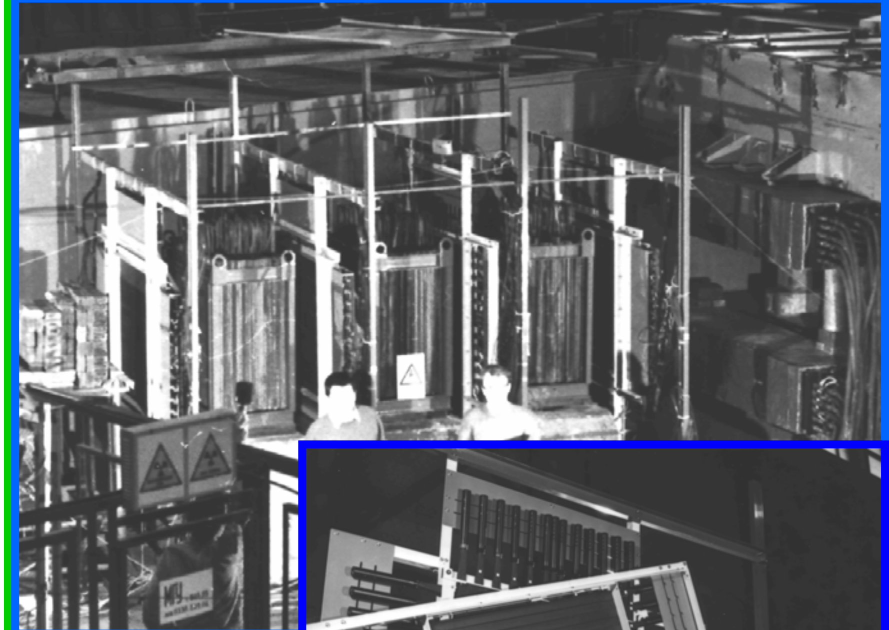
**4) Studying di-leptons and slow pion production (their enhancement comparing to hadron-hadron collisions is expected) (muon pairs).**

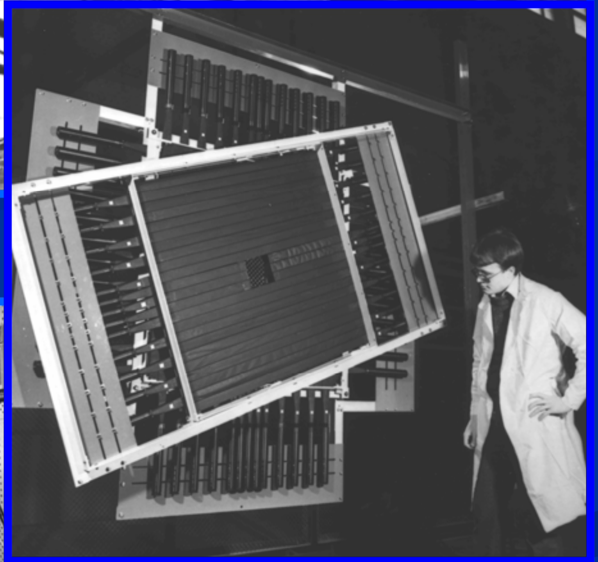
# SPHERE (Forward Detector)

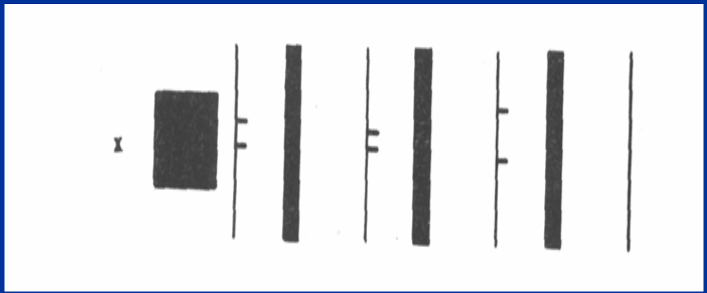


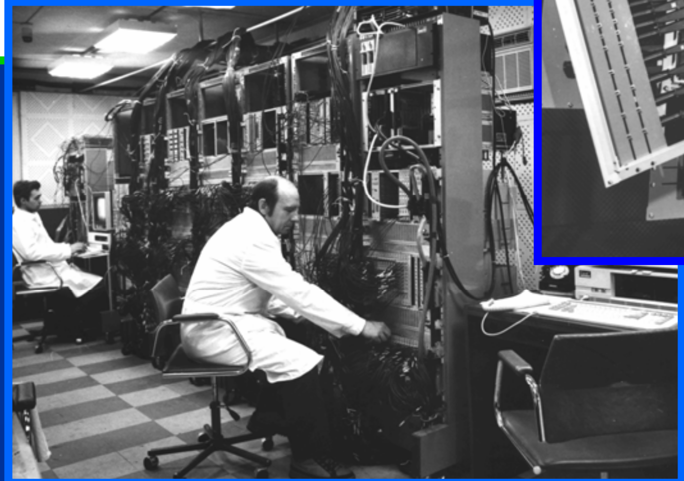

$d + Pb \rightarrow \mu^{+} \mu^{-} + \ldots$

$P_d = 4.5$ A GeV/c





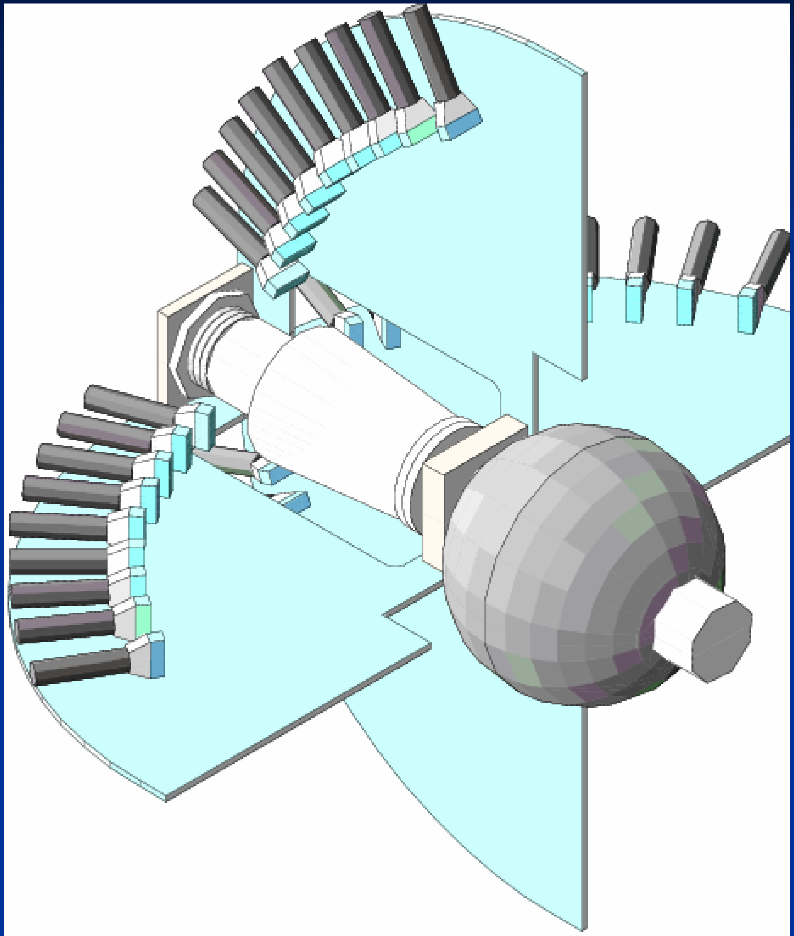


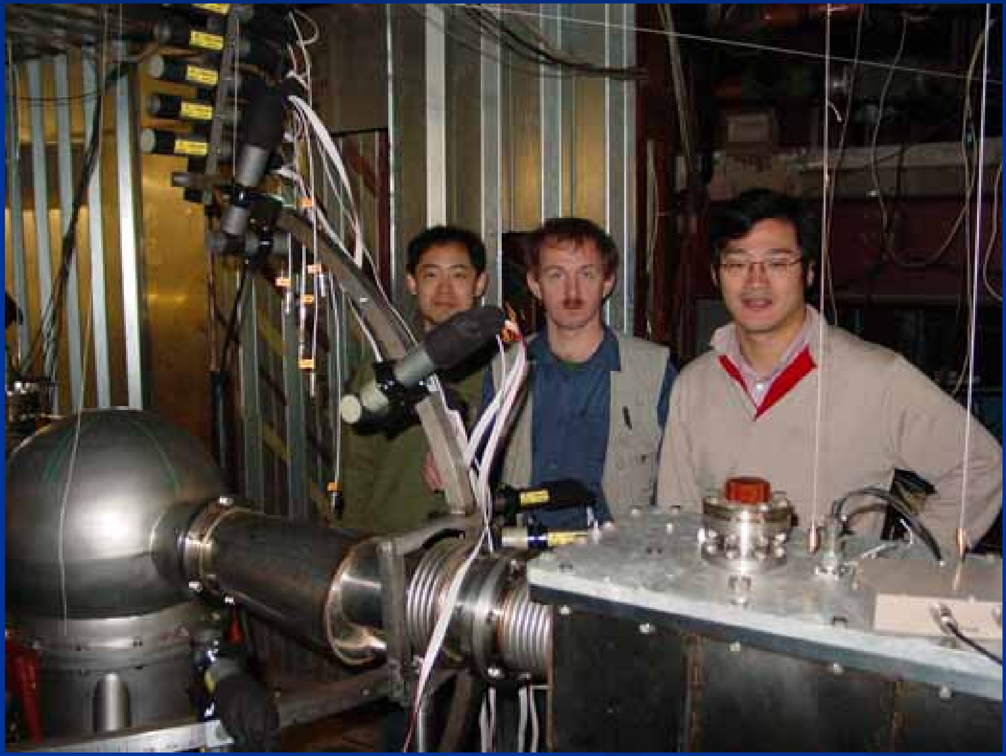
# NIS

# GIBS

**5) Studying the behaviour of angular correlations and radial, directed as well as elliptic flows (their different behaviour as compared to hadron-hadron interactions is expected).**

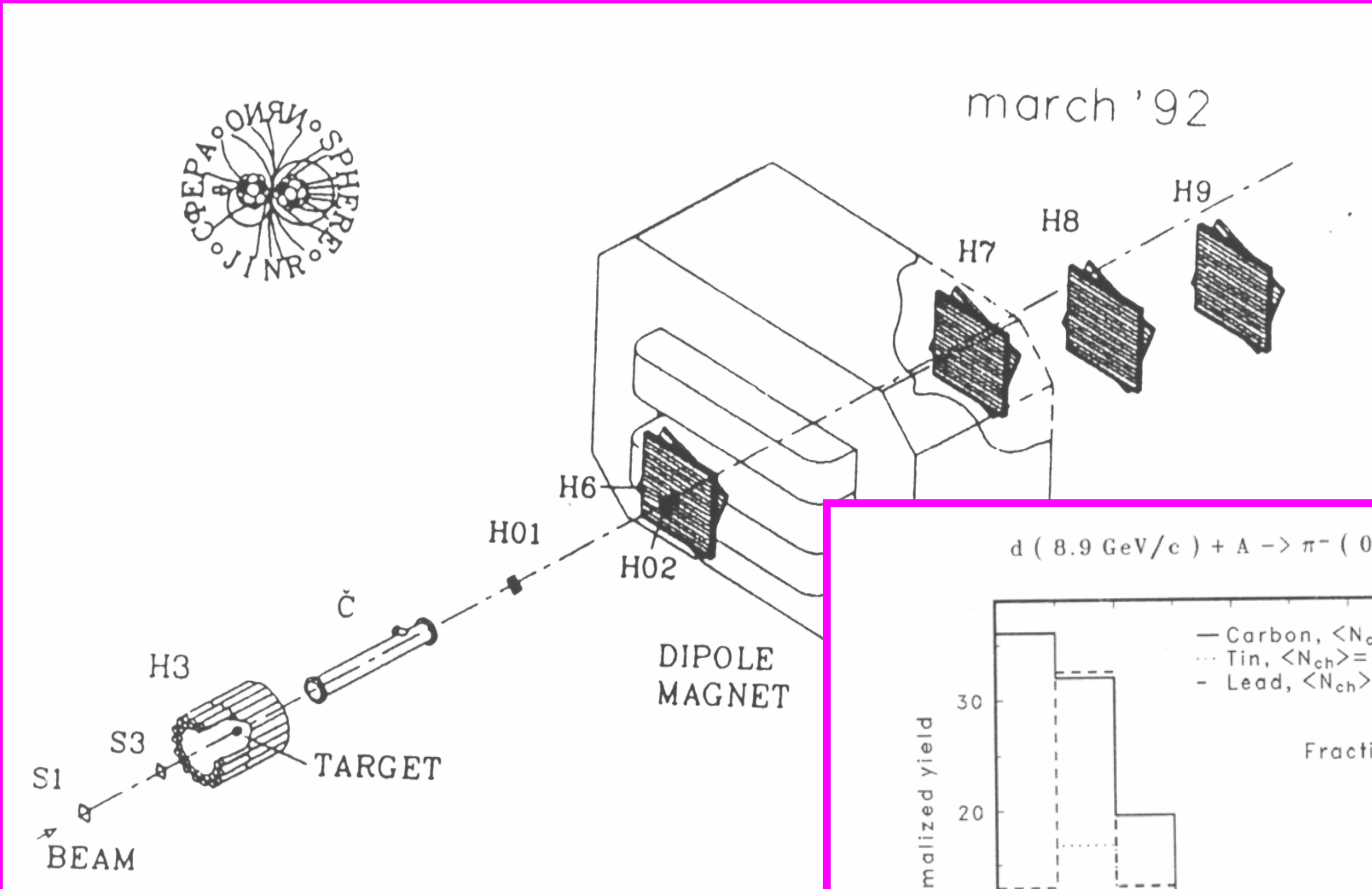


LNS



**6) Analyzing fluctuations of multiplicities, electric charge and transverse momenta for secondary particles (their energy dependences could give information on the phase transition range).**

# SPHERE



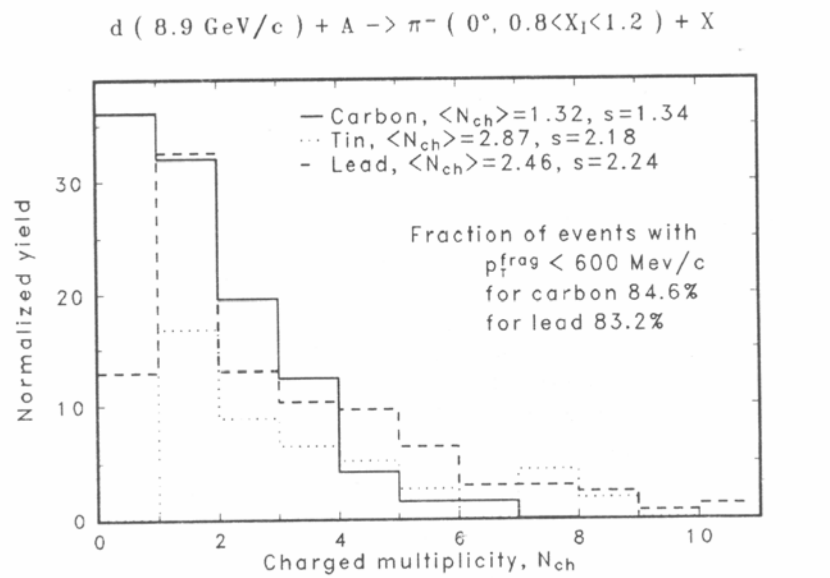
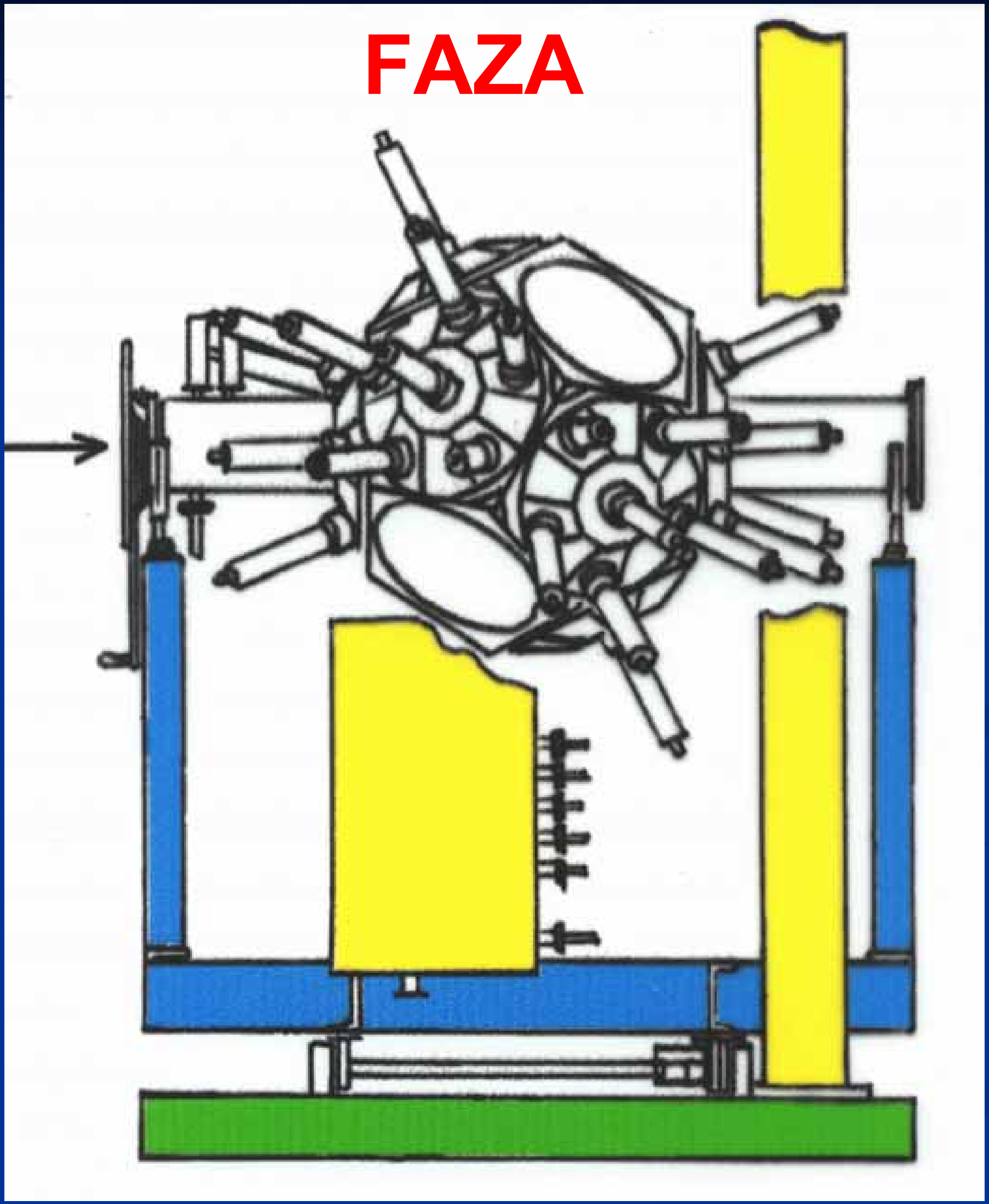




Fig.4. Charged multiplicity distributions for a deuteron fragmentation on carbon, tin and lead nuclei

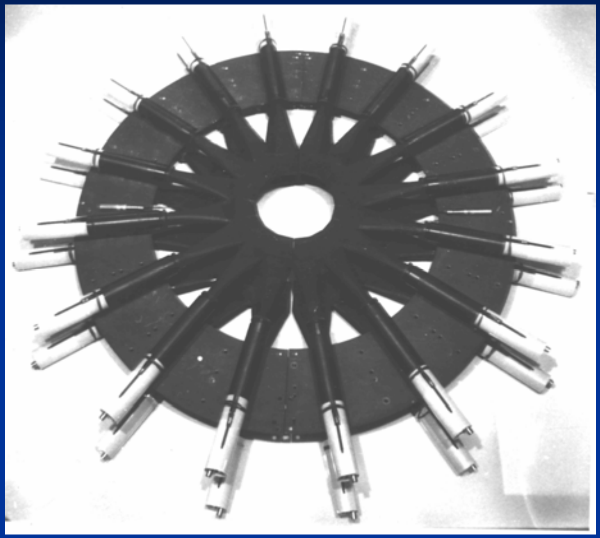
**7) Analyzing nuclear fragments characteristics versus the centrality (change of behaviour comparing to the peripheral collisions is expected), universality of multifragmentation.**

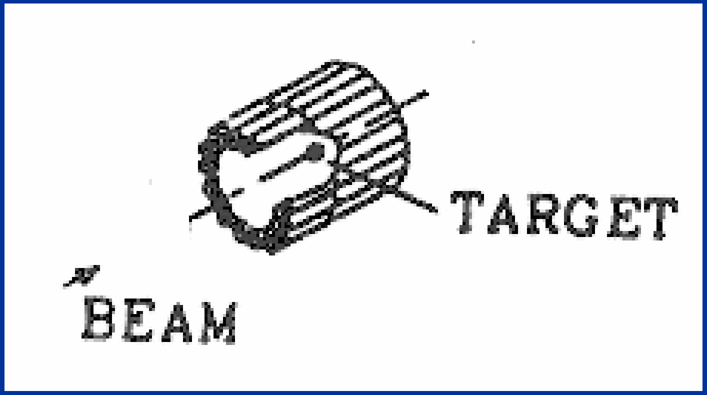


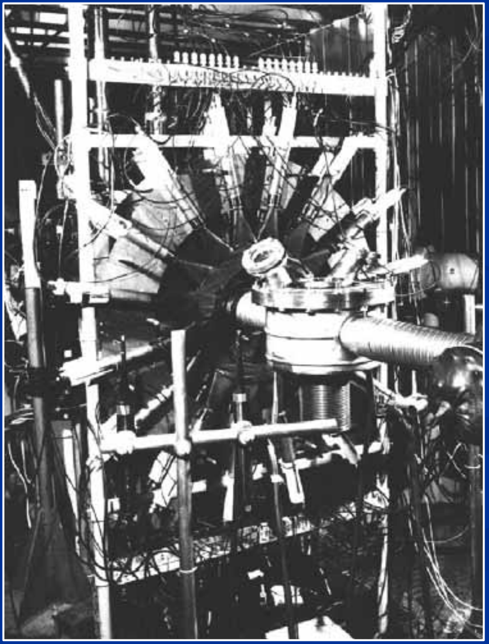

**FAZA – Setup for study of Nuclear Multifragmentation Induced by Relativistic Light Ions**

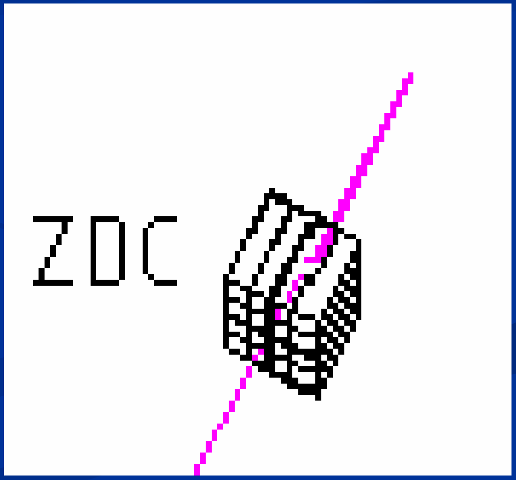
**8) Energy and atomic number scanning for all characteristics of central heavy nuclei collisions (this might allow one to obtain information on the equation of state of strongly interacting matter in the transition area), difference between central collisions of light nuclei and peripheral heavy ion collisions.**

# Detectors of centrality

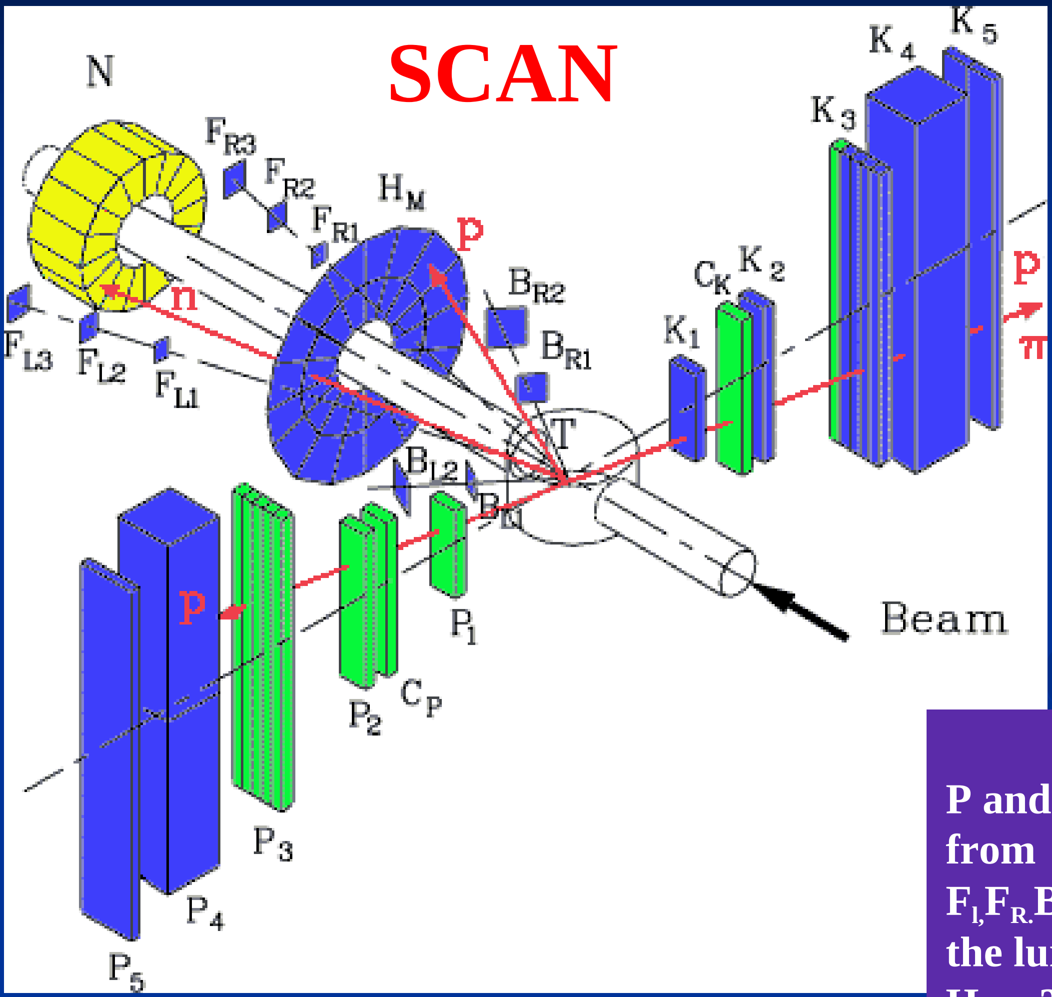






**9) Studying the system size, lifetime, freeze-out duration, expansion time in the HBT analysis (noticeable volume expansion is expected if the mixed phase is formed), scanning in atomic number and energy.**




$P_3$,$P_2$,$P_1$,$C_p$,$C_k$ are assembled.

**Subsystems:**

**P and K-arms - for detection $p\pi^-$ or $pp$ pairs from $S^+_{11}$ decay;**

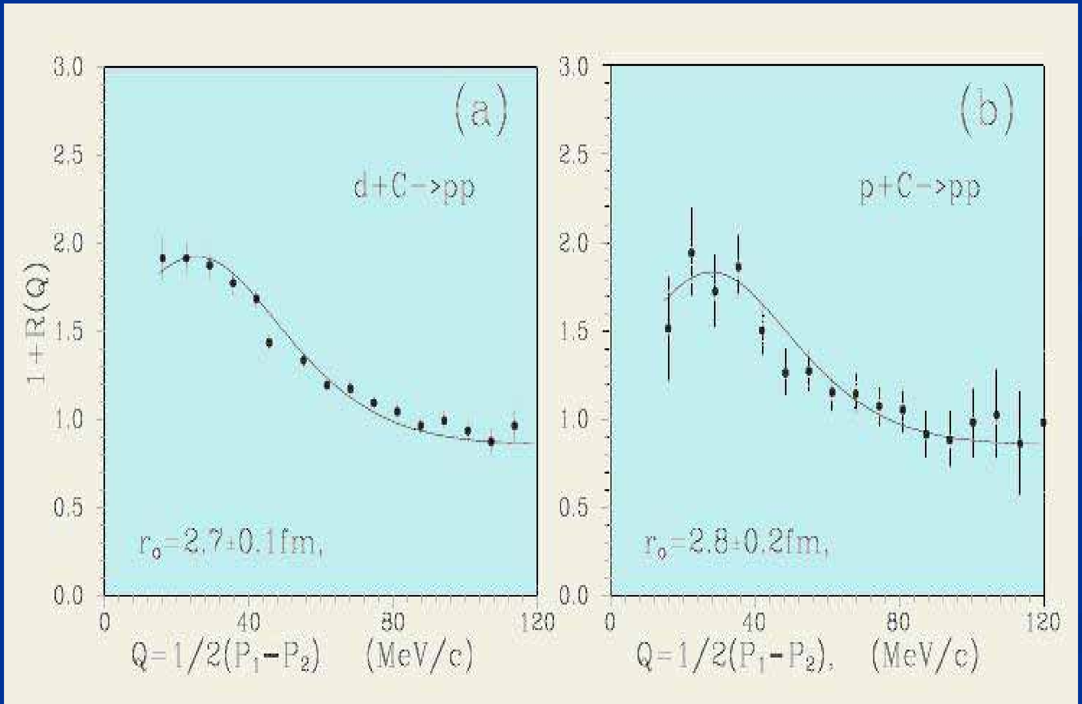
**$F_l$,$F_R$,$B_R$,$B_L$ - 4 monitors for measurement of the luminosity;**

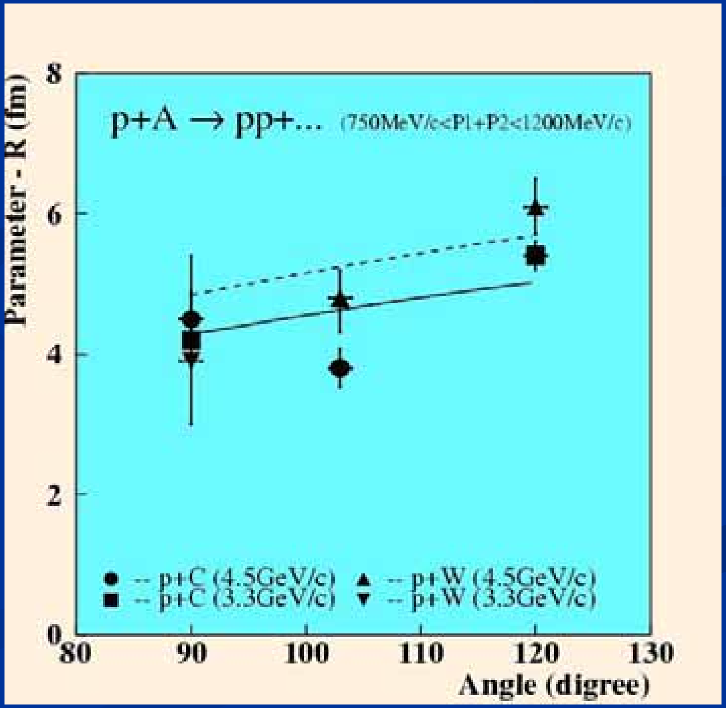
**$H_m$ - 32channels hodoscope for detection of forward proton;**

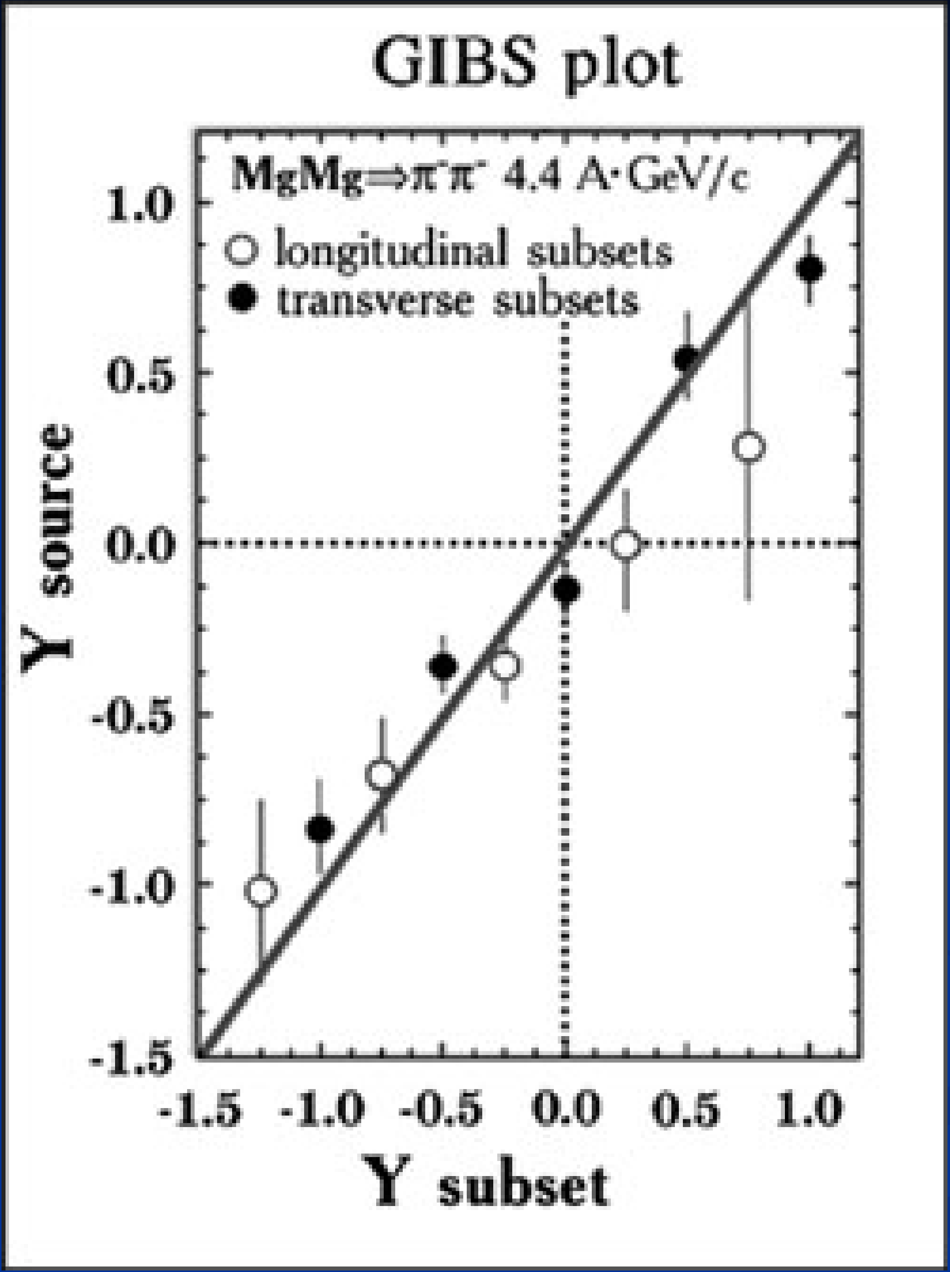
**N - neutron detector (to be construct)**

# SCAN - results

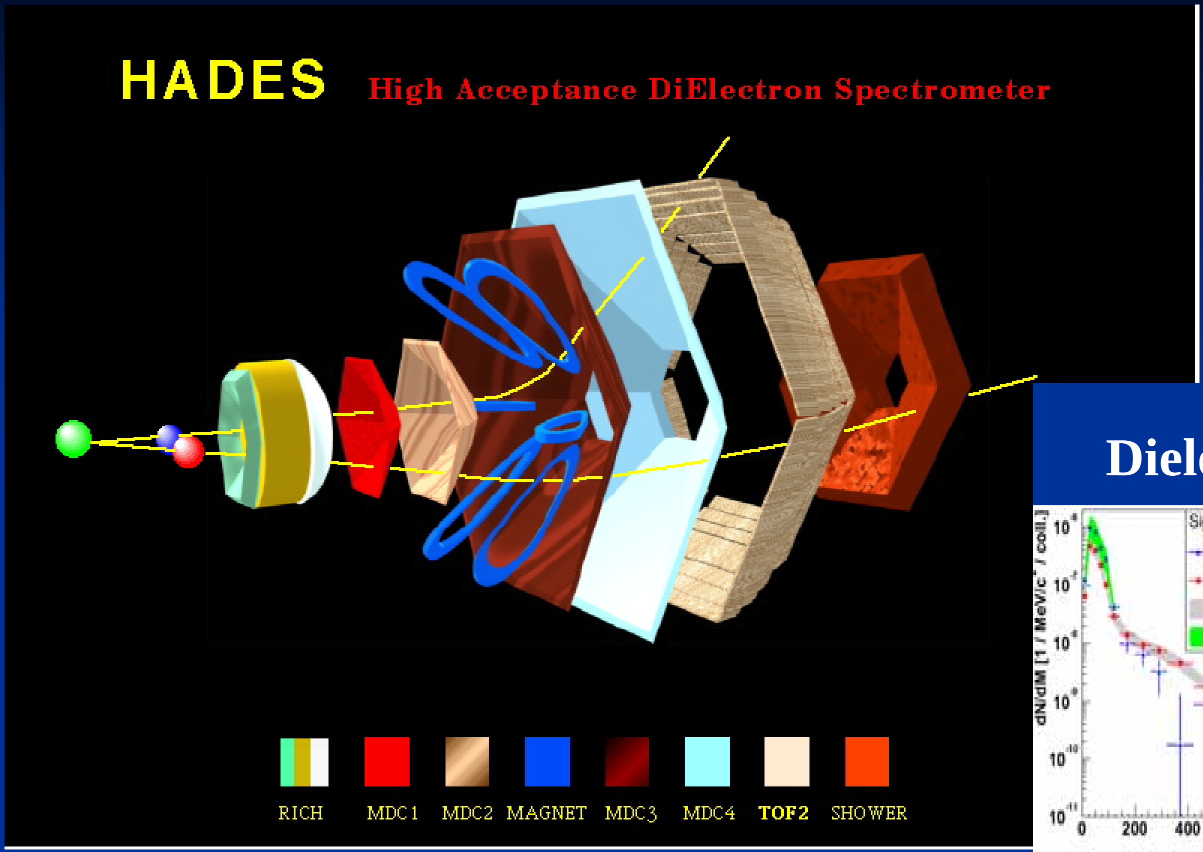
- The radius of the emission zone is insensitive to the type of primary particles
- A radii is slowly growing with increasing the measurement angle



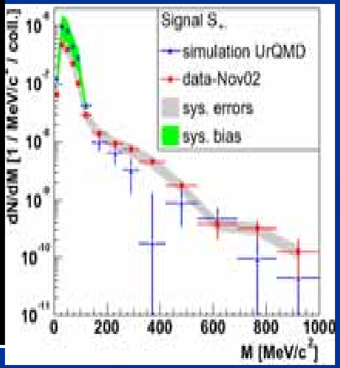




GIBS plot
MgMg⇒π⁻π⁻ 4.4 A·GeV/c
longitudinal subsets
transverse subsets
Y source
Y subset
1.0
0.5
0.0
-0.5
-1.0
-1.5
-1.5 -1.0 -0.5 0.0 0.5 1.0

# External detectors

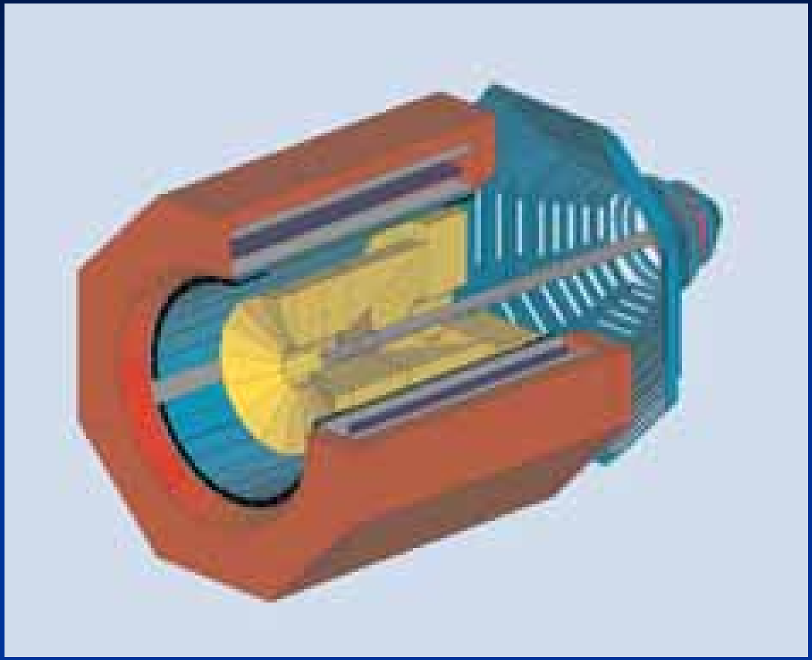


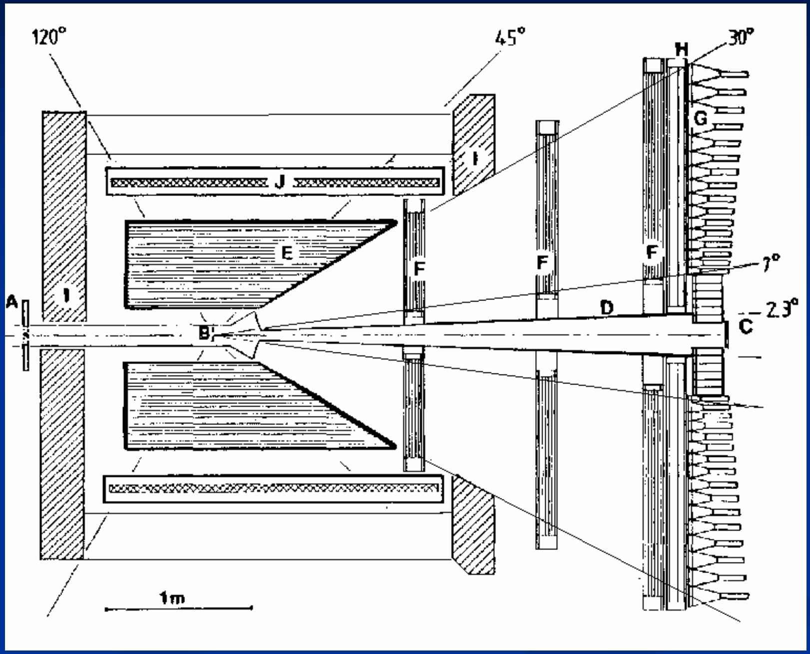

**Dielectrons C+C 2.2AGeV**

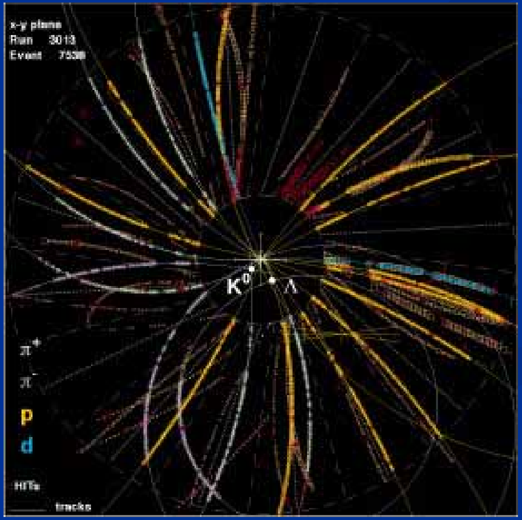



**Spectrum of effective mass of $e^+ e^-$ pair (red color). There is a good agreement with simulation**

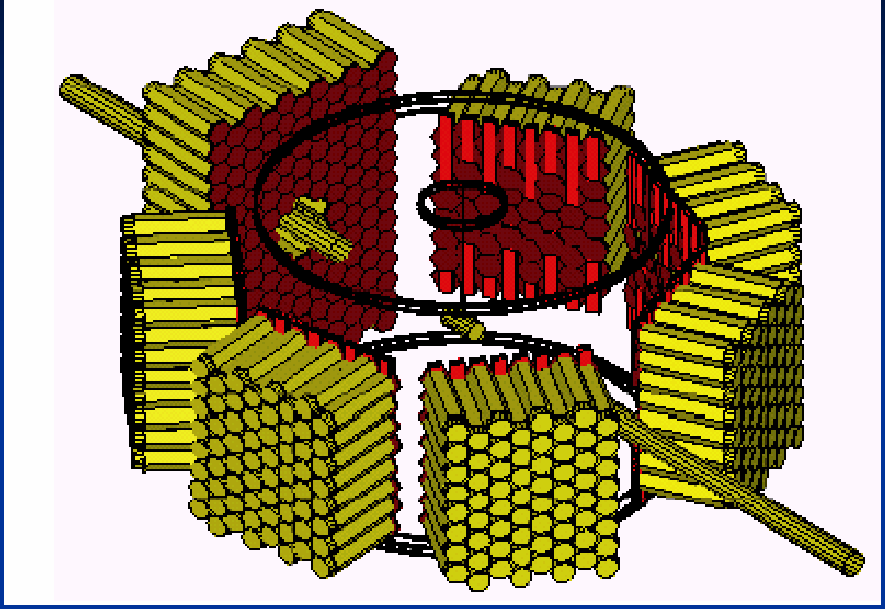
# FOPI Detector (GSI)



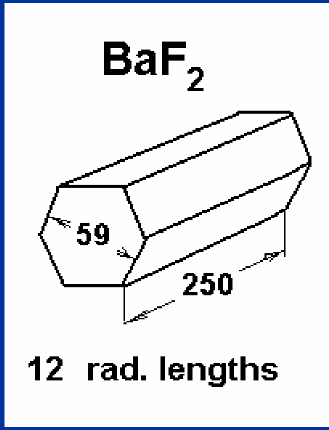


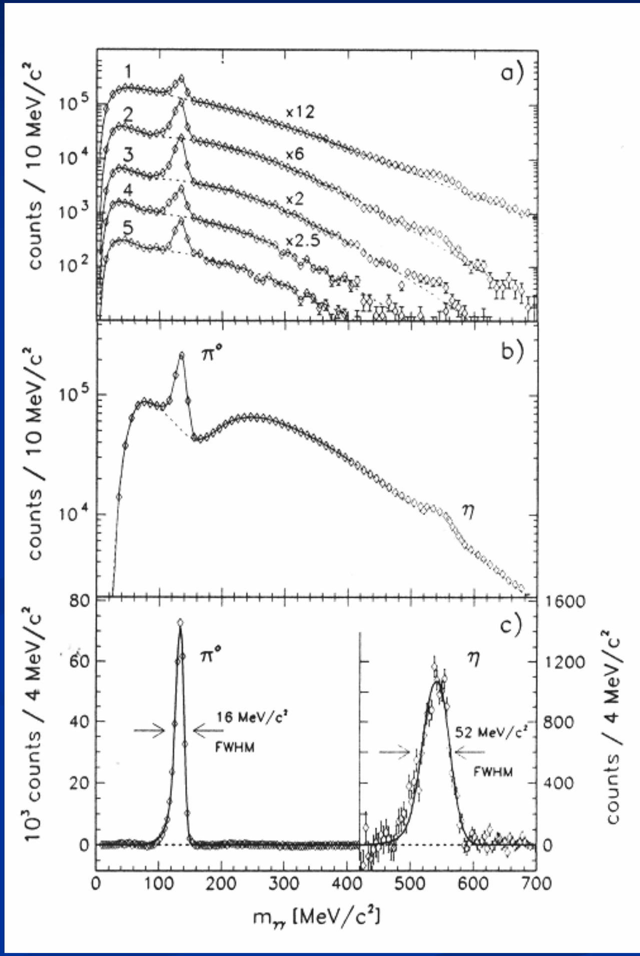



# TAPS

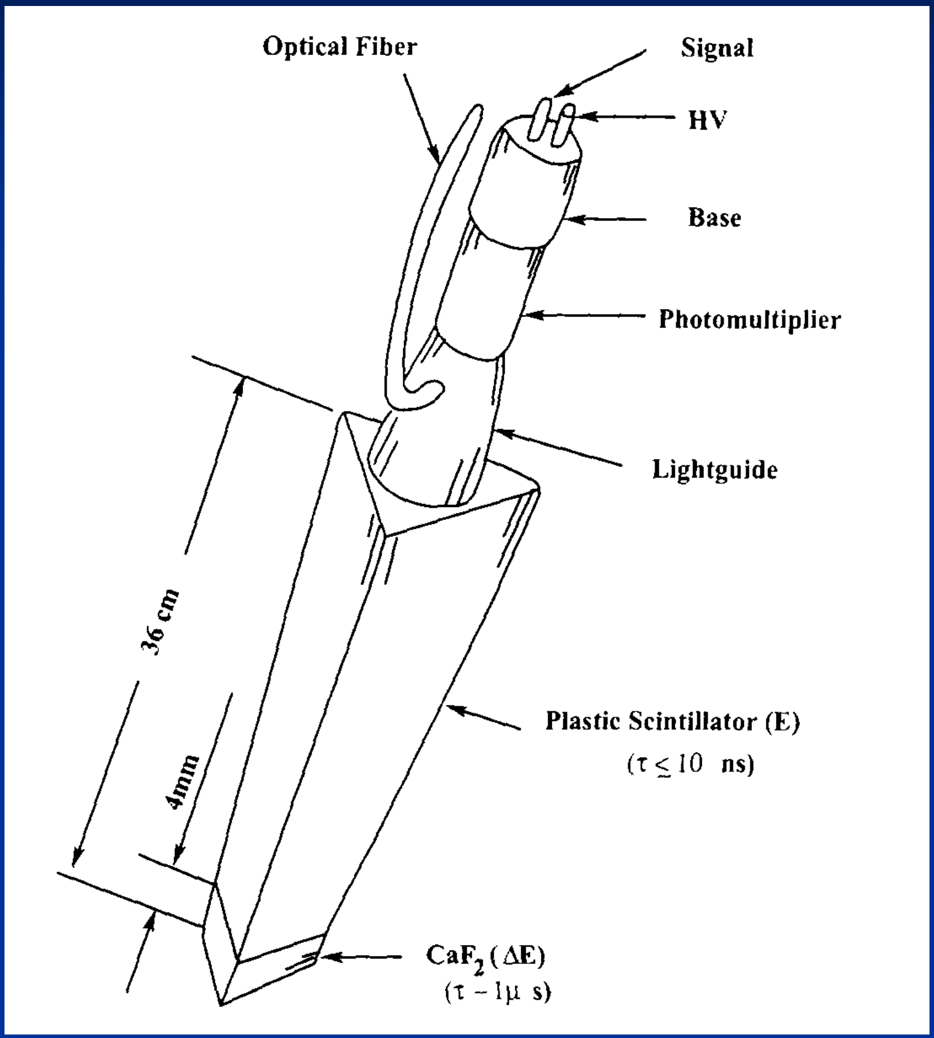


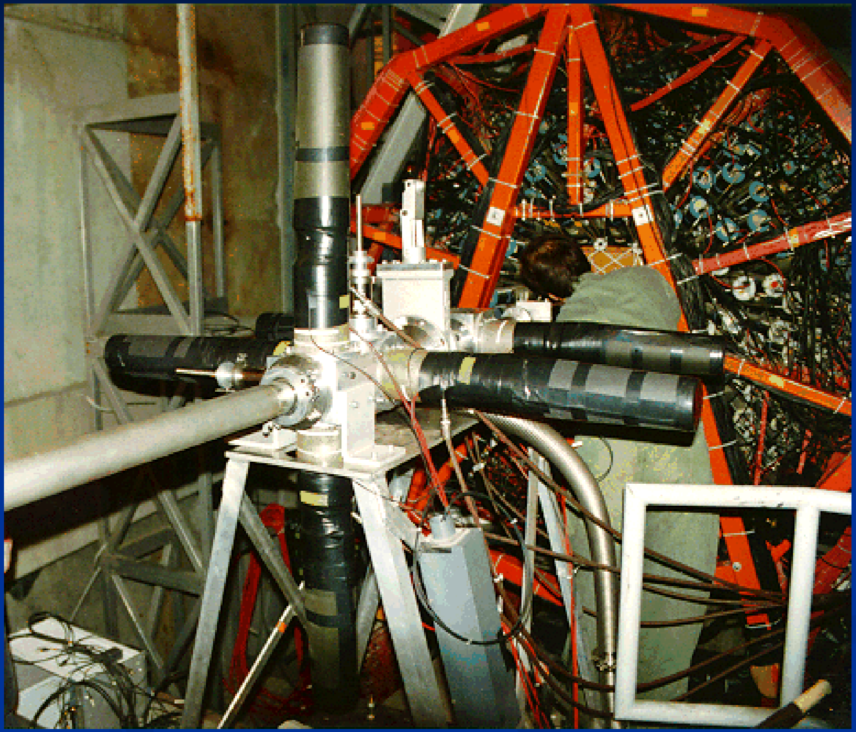
**Setup of the TAPS detector at the Mainz MAMI accelerator.**

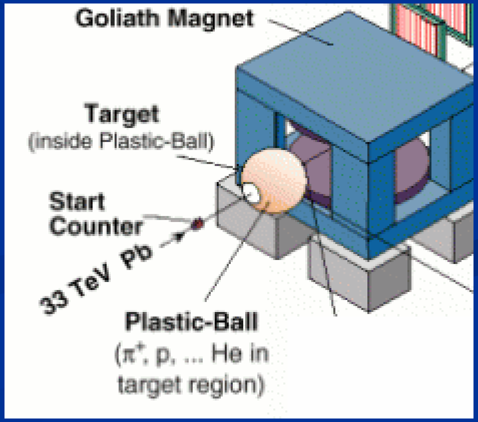


Start Counters and Front Side of Plastic Ball






**KVI, Groningen, Netherlands**

The Plastic Ball surrounds the target nearly compltely.

It consists of 655 detector modules, that provide particle identification via *DE-E* measurement. Every *DE-E* module consists of two scintillator types with very different timing constants. The inner scintillator section is a *4 mm* thick Eu-doped CaF2 crystal measuring the energy loss signal . For the emission of the scintillation light the CaF2 has a characteristic decay time of *~1ms* and is read out by using the *E* counter as a lightguide. The E counter is a plastic scintillator of 356 mm length. The timing constant is approximately two orders of magnitude smaller, so that 90% of the scintillation light is gathered within 10 ns. The plastic scintillator has also components with longer decay times (*120 ns*). Hence the analysis of the pulse shape allows the measurement of both signals with one photomultiplier.

# MRS

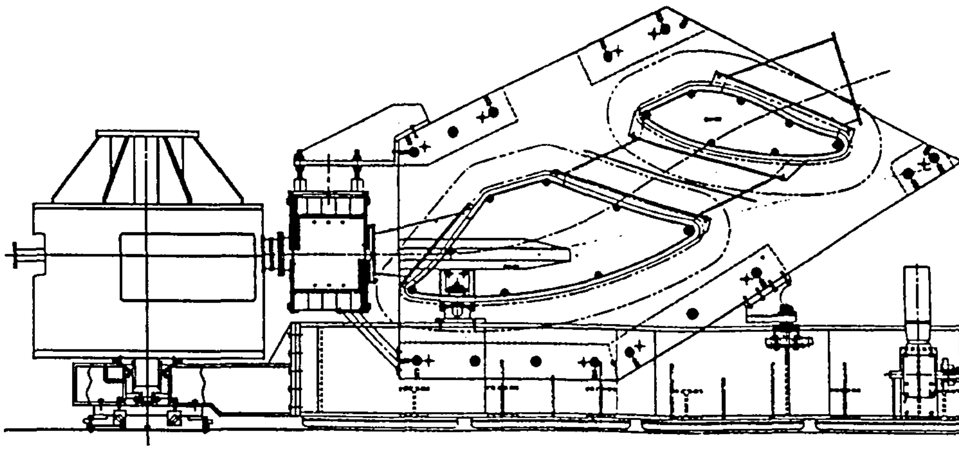


Table 1: **Main parameters of the MRS**

| | | |
|---|---|---|
| 1. | Overall dimensions (length, width, height), m | 9.25 * 4.0 * 5.5 |
| 2. | Optical configuration | $QD\vec{D}$ |
| 3. | Momentum range, GeV/c | 0.2–1.8 |
| 4. | Nominal momentum (B=17 kG), GeV/c | 1.5 |
| 5. | Momentum acceptance, $\Delta p/p$, % | ±20 |
| 6. | Momentum resolution, $\delta p/p$. % | 0.08 – 0.2 |
| 7. | Solid angle, msr | 7 – 9 |
| 8. | Horizontal acceptance angles, mr | ±60 |
| 9. | Vertical acceptance angles, mr | ±40 |
| 10. | Total weight, tons | 118 |
| 11. | Electrical power consumption, kW | 350 |
| 12. | Voltage, V (consumption, kW) | |
| | Q | 123 (100) |
| | D | 204 (161) |
| | $\vec{D}$ | 127 (89) |
| 13. | Water flow, l/min | 460 |

Los Alamos National Laboratory

# VBLHE Road Map

| Main Directions | Tasks | | 2006 – 2007 – 2008 – 2009 – 2010 – 2011 – 2012 – 2013 – 2014 – 2015 |
|---|---|---|---|
| Basic Research | Heavy Ions | | MIXED PHASE of Nuclear Matter |
| | | | Nonperturbative QCD, Cumulative Processes |
| | Polarization | | Deuteron Spin Structure |
| | | | Fundamental Role of Three Nucleon Forces |
| | | | Nature of Nucleon Spin |
| | Light Nuclei | | Phase Transitions in Nuclear Matter |
| | | | Clustering in Stable and Radioactive Nuclei |
| | Research in other Centers | BNL | RHIC (STAR, PHENIX) PHENIX- large $P_t$, STAR – polarization |
| | | CERN | SPS (NA49) anti-p, d |
| | | | LHC(CMS, ALICE) CMS – Heavy Ions, ALICE – Heavy Ions at Ultrarelativistic Energy |
| | | GSI | SIS (HADES) – Resonances in Dense Medium |
| | | | FAIR (CBM, PANDA) CBM – E/M processes & polarization, PANDA – anti-p |
| Applied Research | Life Sciences | | Med-Nuclotron → Clinical Center |
| | | | Medical Accelerator |
| | | | Radiobiological Investigations, Space Medicine |
| | Energy problems | | Transmutation, Accelerator-Driven System |
| | | | Heavy Ion Driver for Thermonuclear Fusion |
| Development of The Nuclotron Accelerator Complex | Heavy Ions A≥200 | | Development of KRION |
| | d↑, $^3$He↑, I >$10^{10}$ p/cycle | | New polarized source |
| | $I_{p,d} > 10^{13}$ p/cycle | | BOOSTER |
| | Secondary beams | | Beam Lines |
| | Control & Diagnostics | | Diagnostic, Control Systems & etc. |
| Educational Prog. | Yang physicist training | | NPEEC - Nuclotron Physical Experimental Educational Center |

# Schedule and estimation of expenses

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| Setup | | | | | | |
| Simulation | | | | | | |
| Data taking | | | | | | |
| Data analysis | | | | | | |
| Cost (k$) | 50 | 150 | 120 | 50 | 50 | 30 |

# Conclusions

- Research of the mixed phase of the nuclear matter can be begun already with the available equipment at the Nuclotron. It is possible to execute an estimation of background conditions and to optimize installations.
- However maybe more effectively to concentrate efforts on use of the one upgrading setup.
- Attracting of external setups is possible also.
- The first physical results can be expected in 2007-2008.
- Financial support of experiments within 2005-2010 in volume not less than 450 k$ is necessary.

*Thanks for attention!*