High Energy Physics
in Poland

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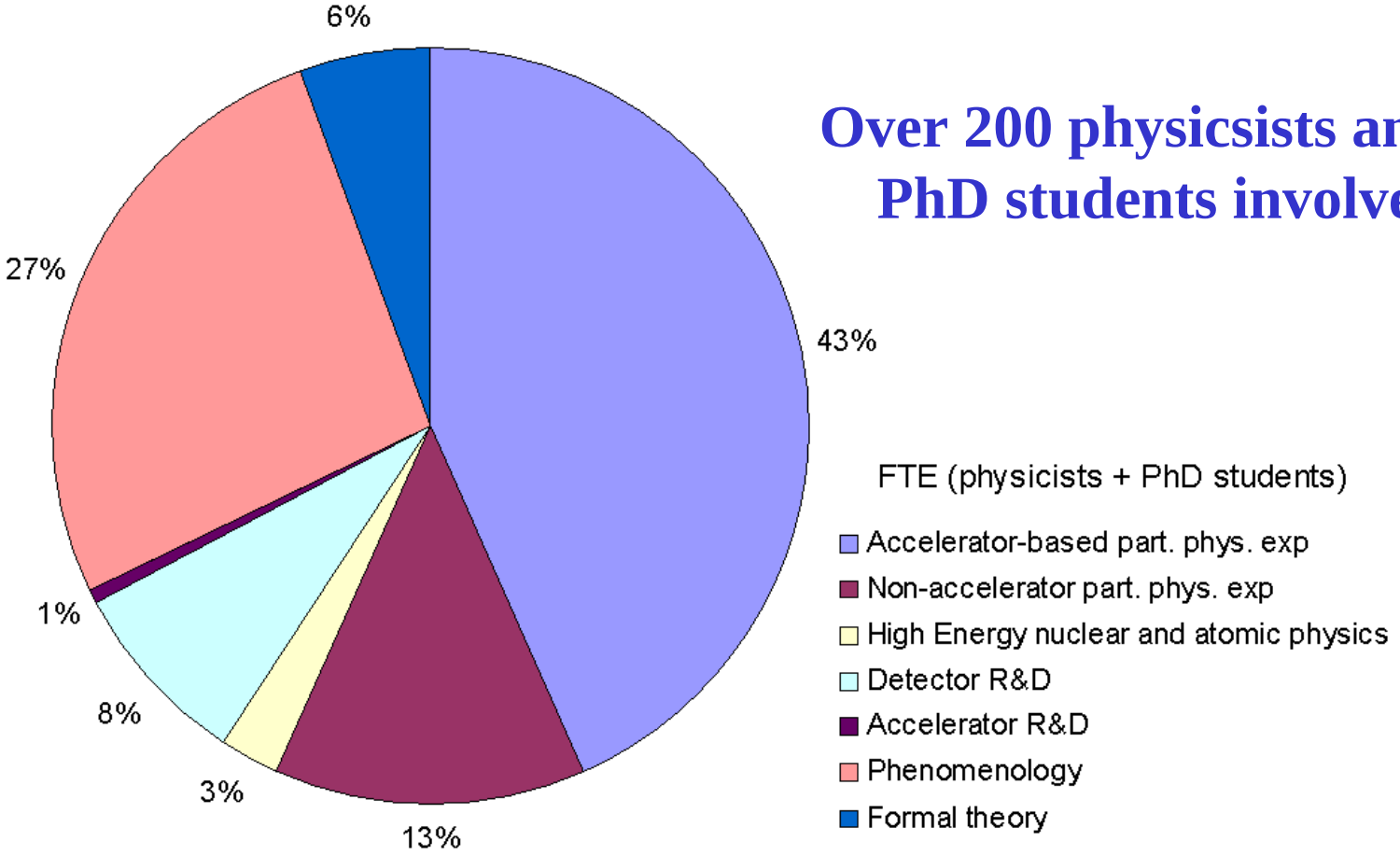
University of Warsaw

ASPERA Polish National Day

22 April 2009

Introduction

- **ECFA HEP Poll 2009** (preliminary results)



Over 200 physicsists and PhD students involved

Introduction

Selected for this presentation:

- **Accelerator-based particle physics experiments**
  - LHC experiments (ALICE, ATLAS, CMS, LHCb)
  - HERA experiments (H1, ZEUS)
  - Belle, COMPASS
- **High energy nuclear physics experiments**
  - experiments at RHIC (PHOBOS, STAR)
  - experiments at CERN (NA49, NA61/SHINE)
- **Detector R&D**

  and preparation for future experiments at ILC

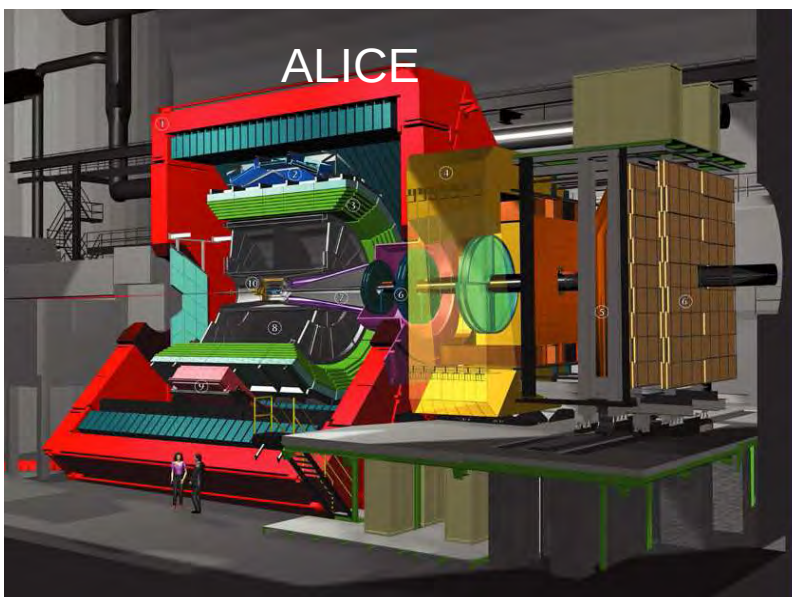
covering only most important activities...

ALICE

A Large Ion Collider Experiment – dedicate heavy-ion experiment at LHC

Polish Institutes:

- Institute of Nuclear Physics, Cracow
  - 6 physicits
  - 1 diploma student
- Institute of Nuclear Studies, Warsaw
  - 3 physicists
  - 2 PhD students
  - 3 physicists from other institutions
- Warsaw Technical University
  - 4 physicists
  - 1 computer scientist
  - 2 PhD students
  - 3 diploma students

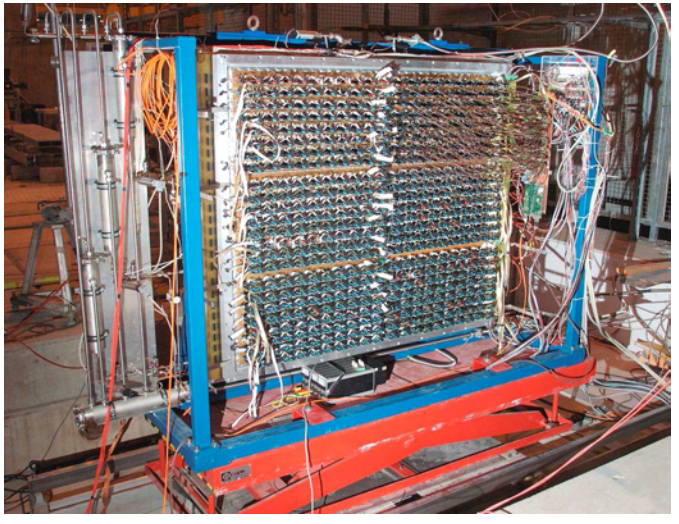


Hardware contribution

Polish Institutes were involved in the design, simulation and construction of two detectors:

- Time Projection Chamber (TPC) – the main tracking device
- Photon Spectrometer (PHOS) – high resolution electromagnetic calorimeter

TPC endcap, readout sectors are visible

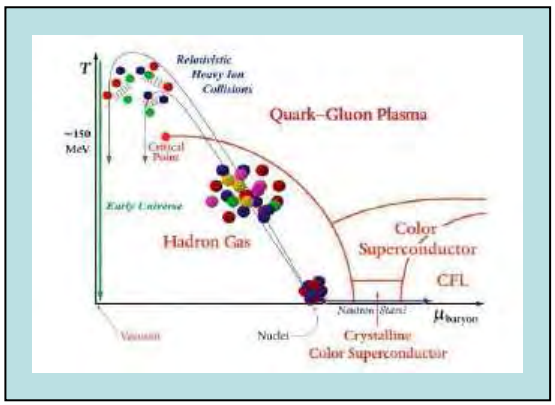


PHOS test module, $PbWO_4$ crystals are visible

Financial contribution – 1 MCHF (1/2 - TPC,1/2 - PHOS)

Physics

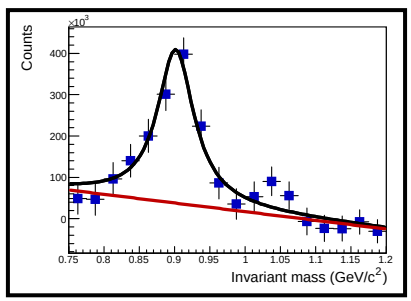
The main goal is a study of hot quark matter under the extreme conditions



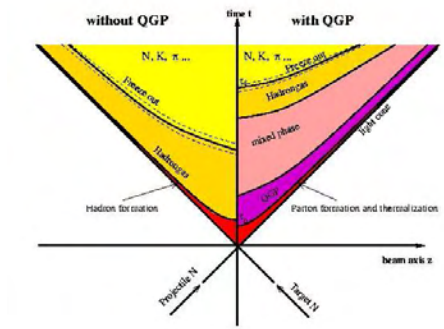
QCD phase diagram;
phase transition??, which order

Fields of interests of Polish Institutes:

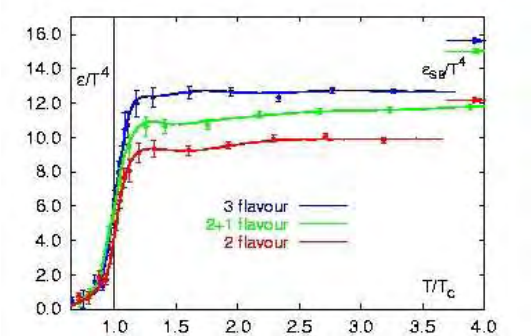
- strangeness production
- femtoscopy
- direct photons and diphotons
- heavy flavors



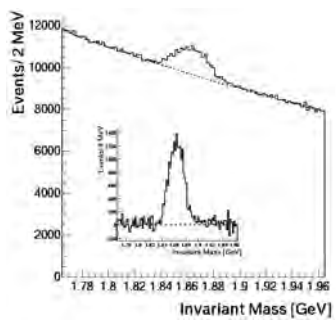
K* reconstruction, ALICE simulation



HBT and system evolution



Lattice QCD suggests „crossover”



D-meson reconstruction, ALICE simulation

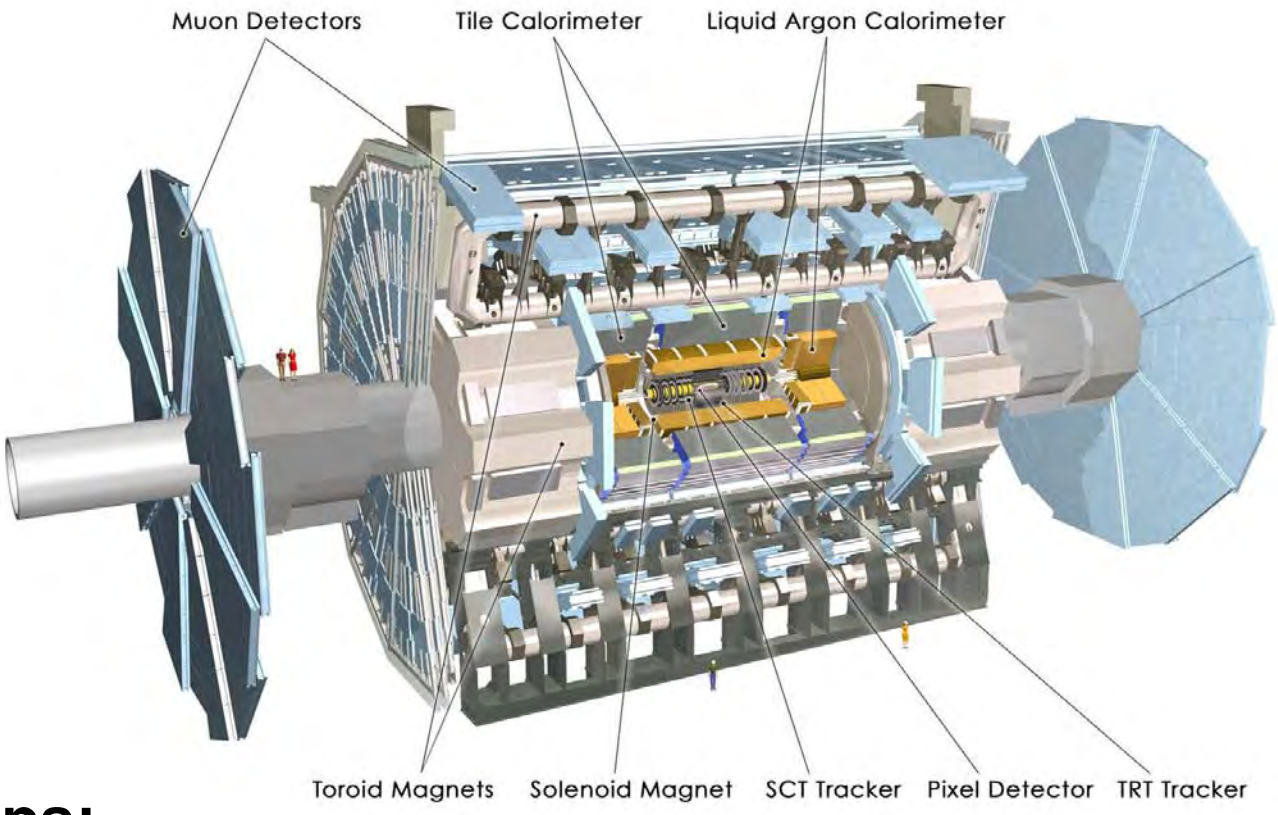
femtoscopy of identical bosons provides the information about freezout and emission time

from the SPS data:

$\tau_f \approx 7-9\ fm$

$\tau_{em} \approx 2-4\ fm$

ATLAS Experiment at the CERN-LHC



ATLAS Collaboration:

37 countries
169 institutions
2500 scientific authors

ATLAS Polish groups:

Institute of Nuclear Physics Polish Academy of Sciences, Krakow
17 physicists, 4 engineers, 6 graduate students

Faculty of Physics and Applied Computer Science, University of Science and Technology, Krakow
6 physicists, 2 engineers, 2 graduate students

ATLAS Experiment at the CERN-LHC

CONTRIBUTIONS OF KRAKÓW ATLAS GROUPS TO THE DETECTOR CONSTRUCTION:

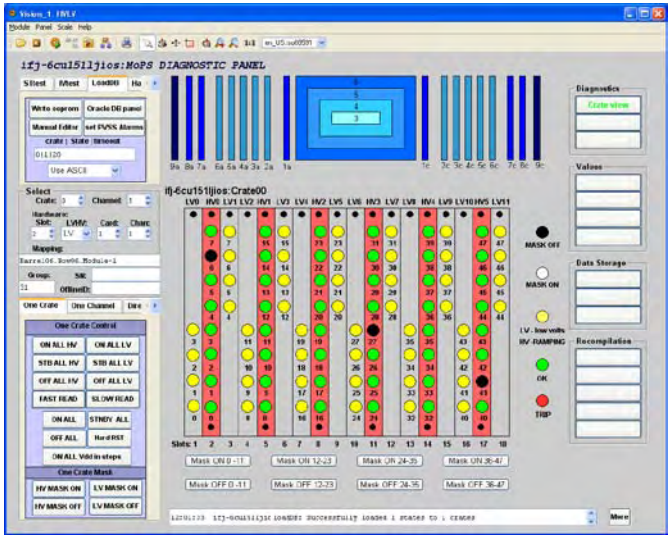
ATLAS Inner Detector

SCT (SemiConductorTracker)

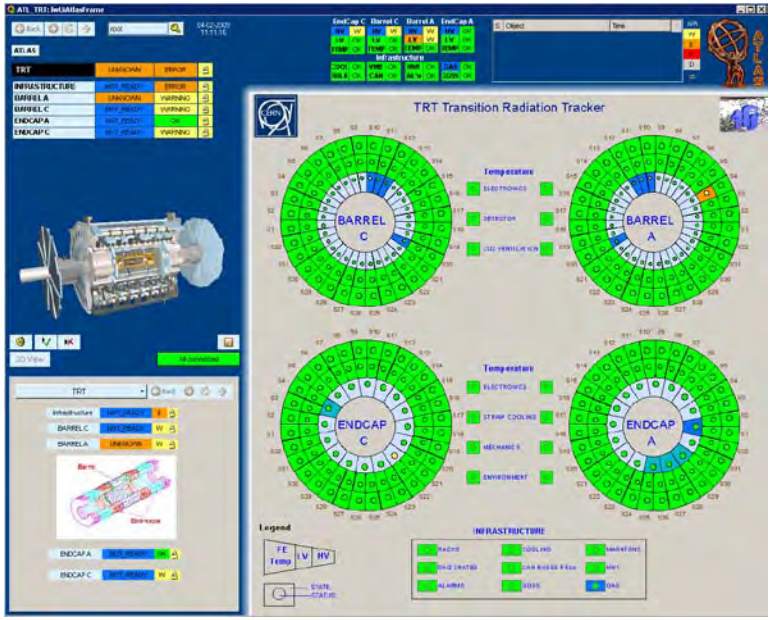
- Design of the ABCD3T readout chip
- Design, prototype and tests of HV PS
- Design of the crate's backplane
- Design of the crate controler
- Programming HV PS fimware
- Programming SCT DCS

TRT (Transition Radiation Tracker)

- Design and implement the TRT
- Design, build and test GGSS
- Design of the LV & HV PS
- Integrate TRT DCS into global DCS



SCT PVSS EXAMPLE OF
A POWER SUPPLY SYSTEM CONTROL PANEL



TRT SERVICES SOFTWARE

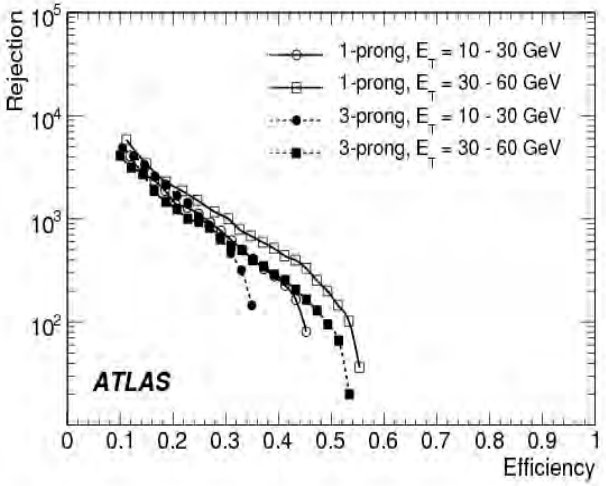
ATLAS Experiment at the CERN-LHC

CONTRIBUTIONS OF KRAKÓW ATLAS GROUPS TO THE ATLAS RESEARCH PROGRAM:

p+p PHYSICS

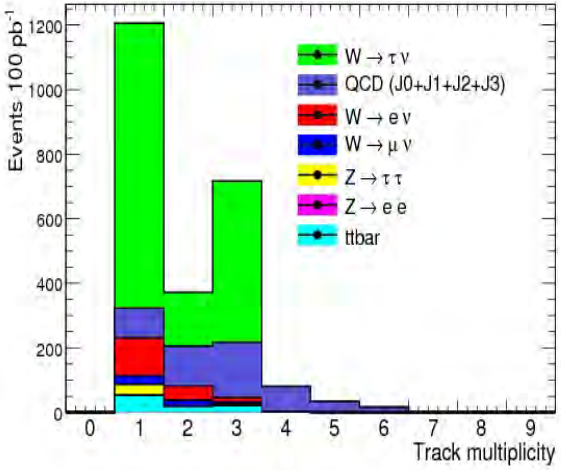
- **physics with tau leptons in final state**

→ signature offers rich physics program for SM Higgs, MSSM Higgs, SUSY



Expected performance for tau efficiency and QCD jets rejection

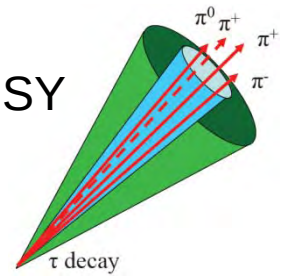
ATLAS Collab, JINST 3, S08003, 2008



First events with tau leptons.

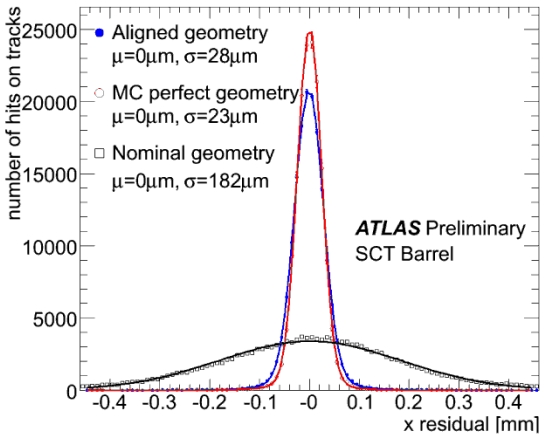
Expected observability of $W \rightarrow \tau\nu$ with $100 pb^{-1}$

ATLAS Collab, CERN-OPEN-2008-020



- **track-based alignment of the Inner Detector**

Example results from the cavern cosmic alignment (Dec 08):



Rφ residual distribution before and after alignment compared to the perfect MC in the SCT detector.

Warsaw CMS Group

- Institute of Experimental Physics, University of Warsaw,
  - Soltan Institute of Nuclear Studies, Świerk
  - Institute of Electronics Systems, Warsaw U. of Technology

~20-25 physicists, PhD students, engineers and technicians

Group responsibilities:

- **Hardware**

  Design, tests, production (~3/4) and integration of the L1 RPC Muon Trigger System PACT- electronics, firmware, on-line software, emulation off- line software

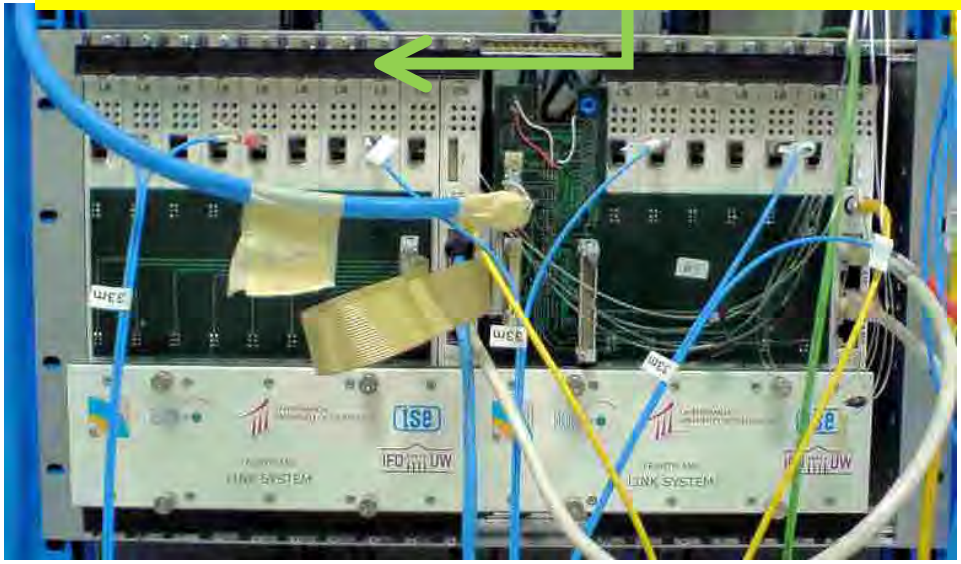
  - Link System on the CMS detector UXC55 (1700 boards in 96 casettes),
  - Trigger electronics in the USC55 (14 VME crates, 108 Trigger Boards,…)

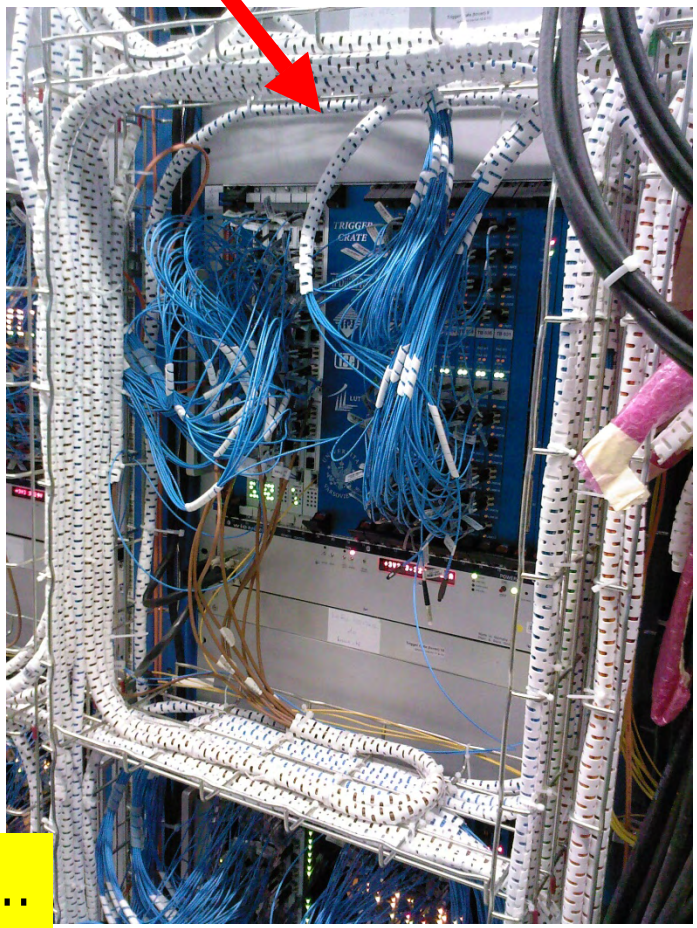
- **Analysis -Various subjects in Beyong the Standard Model Physics:**
  - Long lived Massive Charged Particles (like GMSB NLSP stau; see example),
  - WW and ZZ scattering at high masses,
  - Detection of KK states in Extra Dimensions Modelss through their decays into muon pairs.

Link System on the detector

Trigger crate in USC55

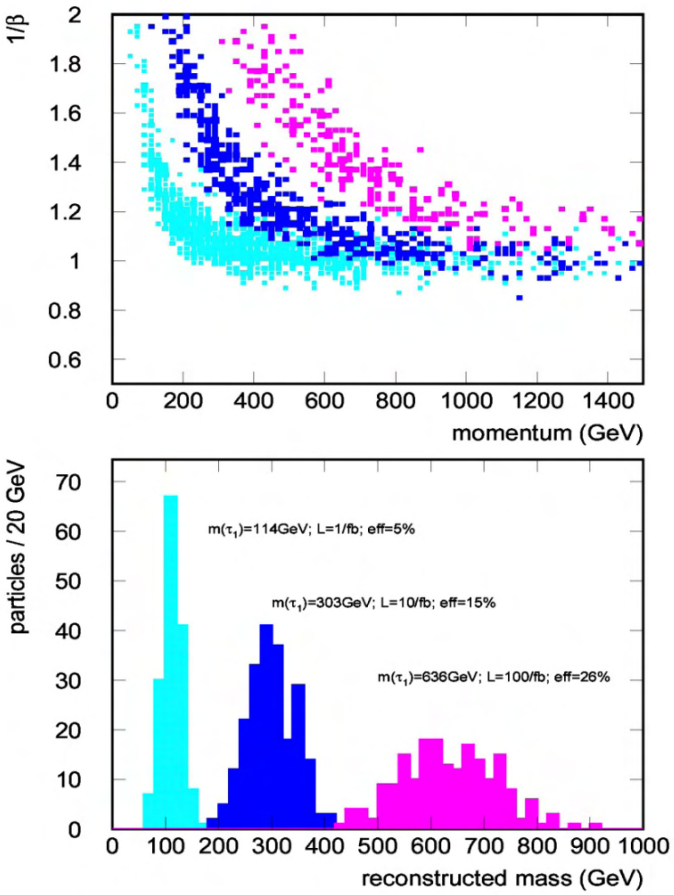
96 Link Board Boxes, 1700 boards





12 Trigger Crates, 108 TB ...

Stau mass reconstruction



CMS

Some details of the GMSB model

The masses of squarks and gluinos for this set of parameters are O(4 TeV). The cross section for gauginos, which are lighter, dominates.

The staus have masses 114, 303, 636 GeV.

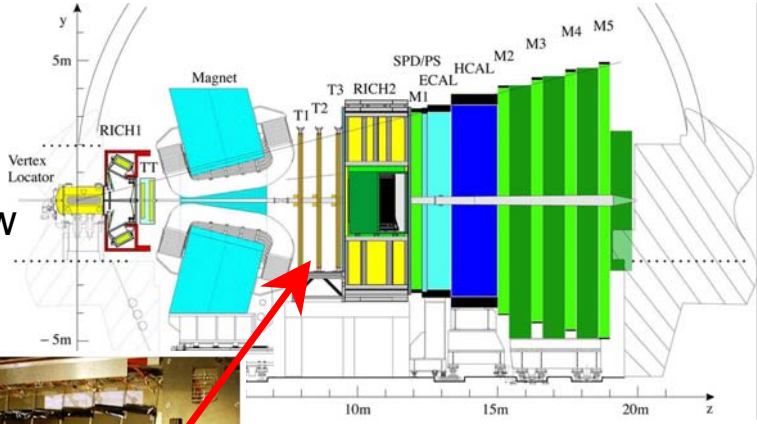
The cross sections of 1 fb for superpartners are sufficient to see the signals.

Drift tubes of the muon detector used as the time-of-flight (TOF) detector

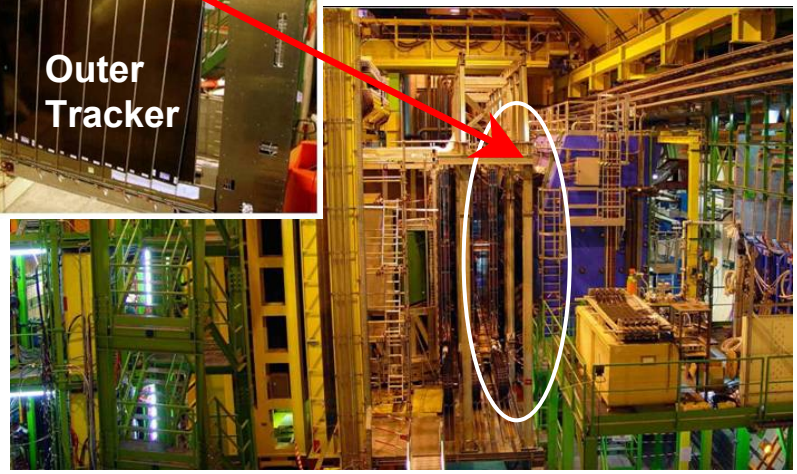
mass determination for heavy charged particles

– Large Hadron Collider beauty experiment

- Study of CP violation for B and B_s mesons.
- Search for rare B i B_s decays.
  - Precision measurements to find the effects of New Physics



- Polish teams in LHCb – 20 persons (incl. 3 PhD students)
  - Krakow – IFJ PAN (G. Polok) and WFiIS AGH (B.Muryn)
  - Warsaw – IPJ (M. Szczekowski)
- Contribution (from 1999)
  - Design and production of Outer Tracker
  - A system for monitoring of OT layers position
  - “Timing and Fast Control” for DAQ
  - Development of trigger algorithms
  - Simulation and reconstruction software
  - Tools for data analysis



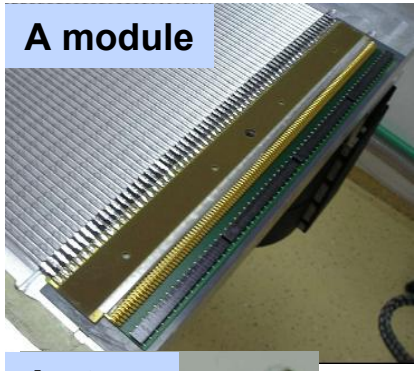
Construction of Outer Tracker

Production of panels

Production of modules

Tests

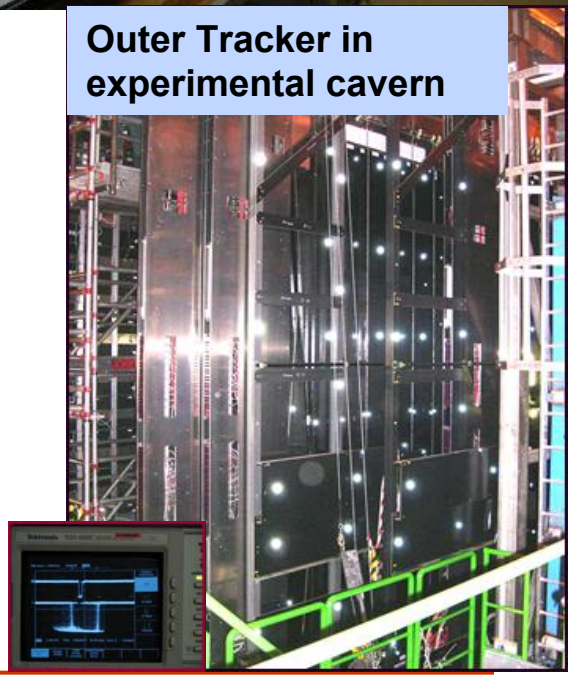
A module



A straw

- **Polish contribution**
  - Prototypes of OT module
  - Technology of production
  - Production of panels (1000 m^2)
  - Production of modules
  - Design of readout electronics
  - Design of OT mechanical support
  - Position monitoring system

Outer Tracker in experimental cavern



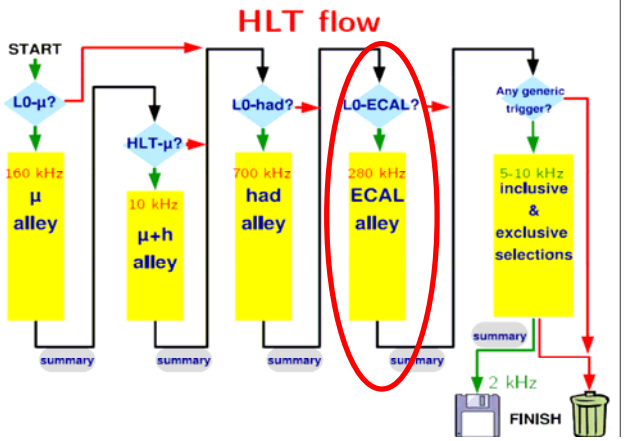
Status since September 2008

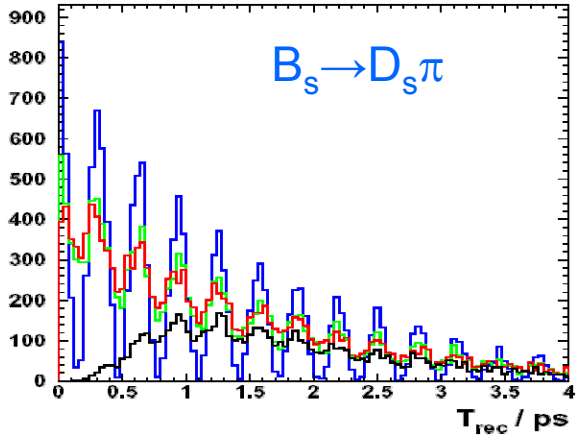
- OT is ready for data taking
- Integration with central DAQ system completed – detection of cosmic rays, first events taken from beam injection tests.

Simulation, reconstruction and analysis software

- Development of trigger algorithms
  - Design of electromagnetic alley of HLT
- Detector optimization
- OT simulation software.
- Reconstruction algorithms:
  - Primary vertices
  - Short tracks
- Tools for data analysis
  - Study of systematic effects
  - Signal selection algorithms
- Physics program of polish groups
  - Measurements of CP violation in:
    - B decays to pair of vector mesons (e.g. $B_s \to J/\psi\varphi$)
    - $B_s \to \eta_c\varphi$, $B_s \to \chi_c\varphi$, $B_s \to J/\psi\eta$, $B_s \to J/\psi f_0$
    - $B \to DK$, $B \to D^*a1$
  - Search for new physiscs
    - Rare decays: $B_s \to \mu^+\mu^-$

High Level Trigger (HLT)





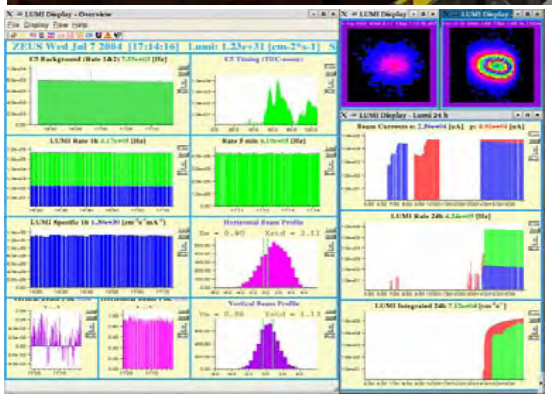
ZEUS experiment at HERA, DESY, Hamburg

Study of fundamental interactions in high energy $e^{\pm}p$ scattering

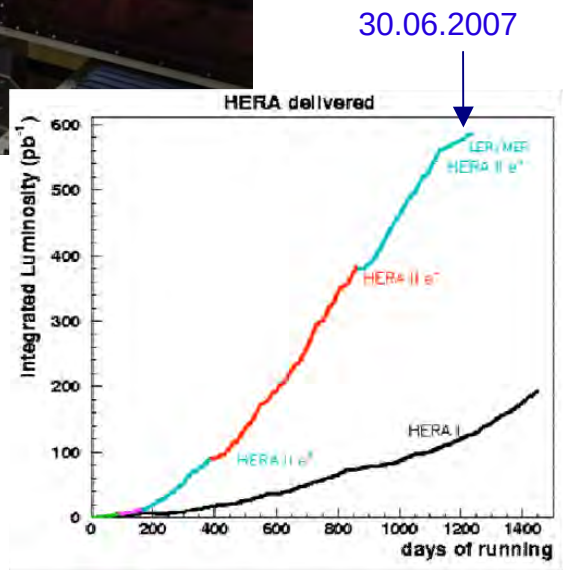
- **Institute of Nuclear Physics Polish Academy of Sciences, Krakow (5)**
- **Faculty of Physics and Applied Computer Science, University of Science and Technology, Krakow (6)**
- **Institute of Experimental Physics, University of Warsaw (5)**

Hardware contributions:

Luminosity monitor (Cracow)



E_p=820/920 GeV	0.5 fb^{-1}
E_p=460 GeV	14 pb^{-1}
E_p=575 GeV	7 pb^{-1}

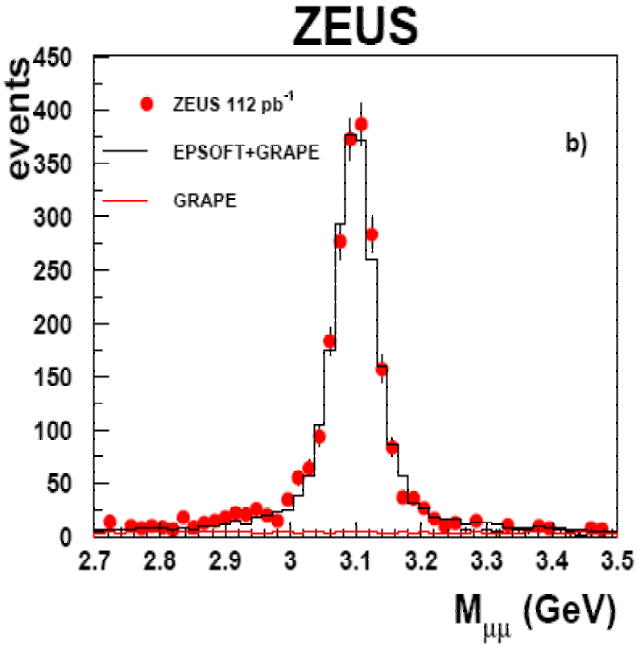


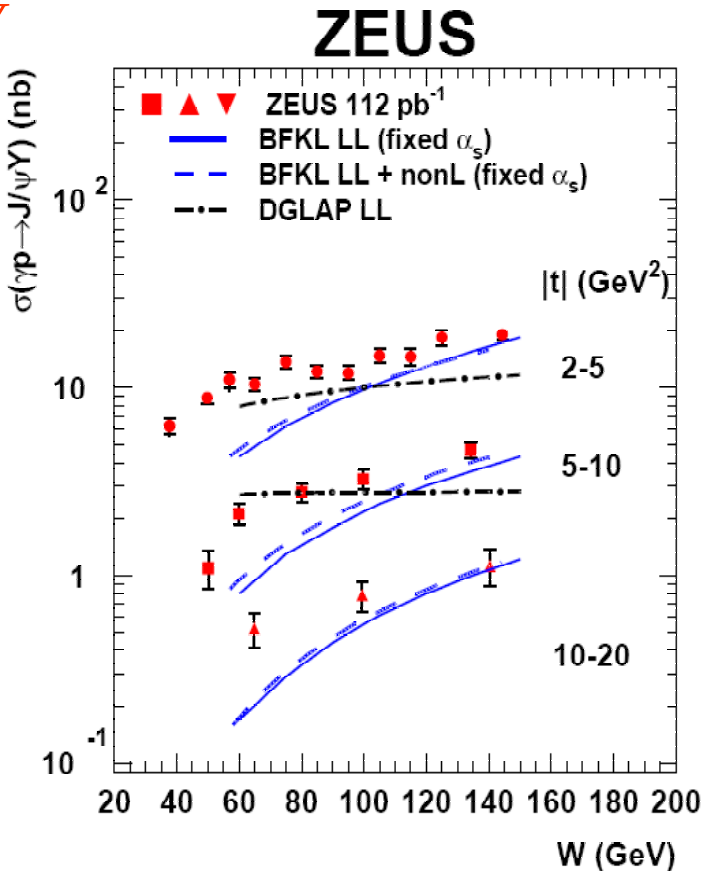
Backing Calorimeter and Veto Wall (Warsaw)

ZEUS experiment at HERA, DESY, Hamburg

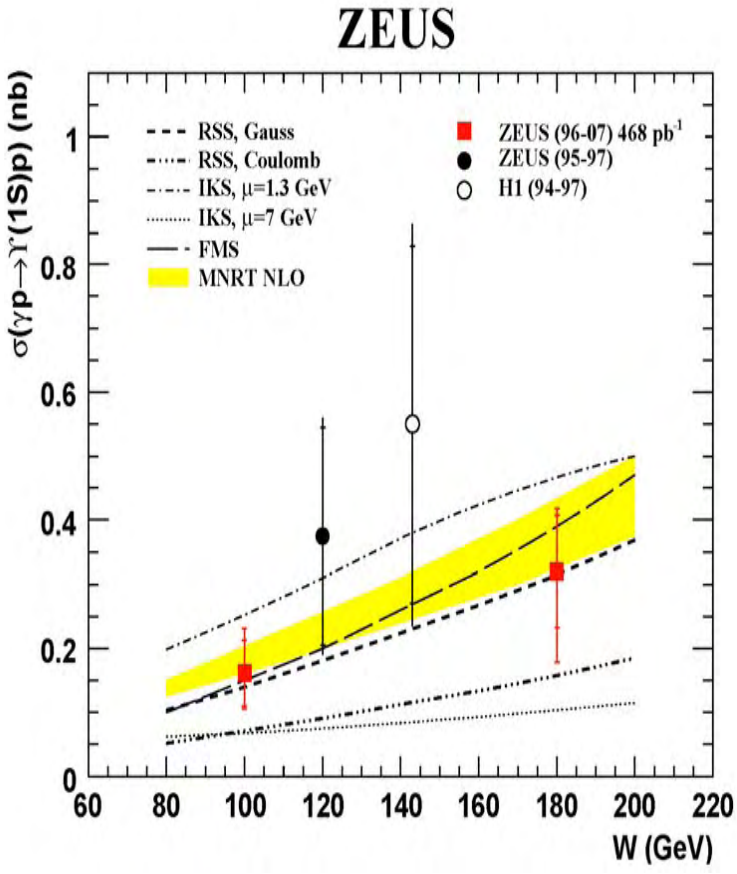
Diffractive J/ψ photoproduction (with proton dissociation) at large *t*

$\gamma p \rightarrow J/\psi Y \rightarrow \mu^+ \mu^- Y$





Exclusive ϒ(1S) photoproduction



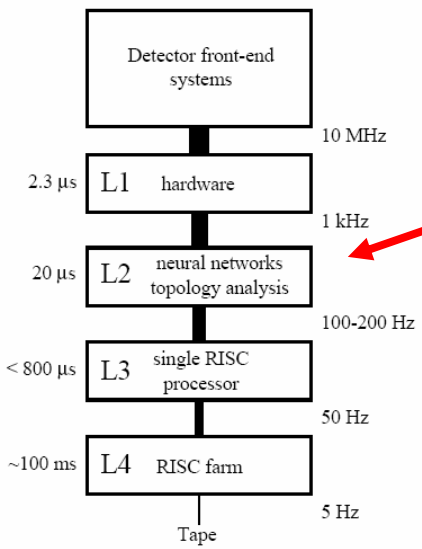
Strong rise of the cross section with energy as predicted by perturbative Quantum Chromo Dynamics kwantowej (pQCD) !

Kraków H1-Group : contributions to hardware and basic software of the experiment

➢LAr Calorimeter :

- •Cooled Faraday boxes for analog electronics
- •Cabling
- •DAQ software
- •DAQ cards (projects)
- •Parts of the reconstruction program for LAr calorimeter

➢Second Level Topological Trigger (L2TT)



The Second Level Topological Trigger of the H1 Experiment at HERA I

D. Hoffmann [a], E. Banaś [b], C. Beigbeder [c], R. Bernier [c], D. Breton [c], J. C. Bizot [c], A. Ducorps [c], L. Goerlich [b], M. Jacquet [c], J. Martyniak [b], S. Mikocki [b], G. Nowak [b], J. Turnau [b]

[a] *Centre de Physique des Particules, IN2P3/CNRS, Université de la Méditerranée, Marseille, France*

[b] *Institute for Nuclear Physics, Cracow, Poland*

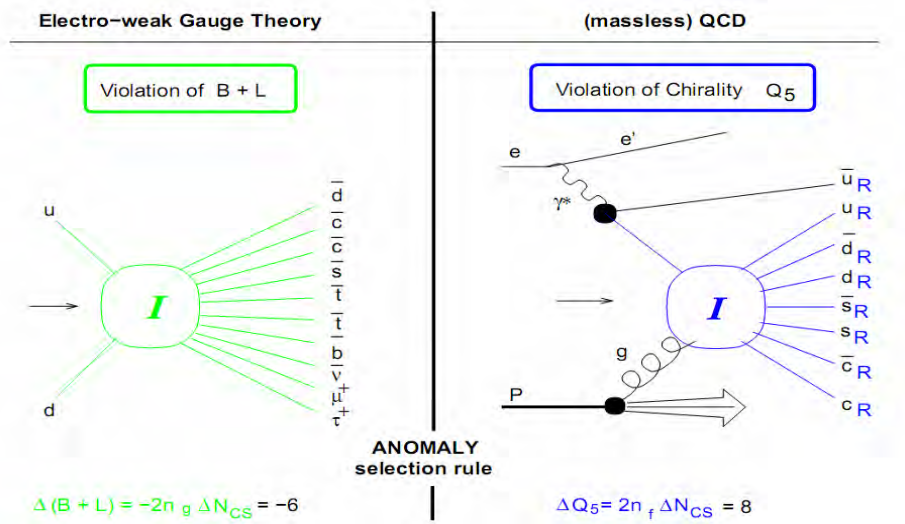
[c] *Laboratoire de l'Accélérateur Linéaire, IN2P3/CNRS, Université de Paris-Sud, Orsay, France*

Kraków H1-Group : Data Analysis

•1992-2008 : Hadronic final states at low Q^2 : small-x physics, strangeness production search for instantons

•2008... Hadronic final states at high Q^2 DIS : search for instantons, azimuthal asymmetry (T-odd contributions ?)...

QCD Instanton : Tunnelling processes between different vacua, fundamental prediction of Non-Abelian gauge theory.



Expected large x-section in ep !

Up to now only upper limits

Connection to matter-antimatter asymmetry

Possible connection to azimuthal asymmetry in DIS (spin and high x_F)

Belle Experiment

Precision tests of the Standard Model and New Physics searches at the high-luminosity frontier

KEKB uest for CPV kekb.jp

$e^+e^- \rightarrow \Upsilon(4S) \rightarrow \bar{B}B$

data taking since 1999

L_{peak}= $1.7\times10^{34}/cm^2/s$

>1 milion $\bar{B}B$-pairs/day

L_{int} = 895 fb^{-1} (as of April 2009)

Belle Collaboration:

~400 scientists from 60 institutes

Institute of Nuclear Physics PAN *since 1993*

- 5 PhD physicists;
- 3 electronics eng.;
- 3 PhD students. *(as of April 2009)*

Main achievements and highlights:

- first observation of CP violation in beauty sector and quantitative confirmation of the Kobayashi-Maskawa mechanism;
- new observations of rare B decays with b→s and b→d transitions;
- first observations of exclusive (semi)leptonic B decays to final states with τ lepton;
- first evidence of $\bar{D}^0$-D^0 mixing;
- many new resonances with charm…

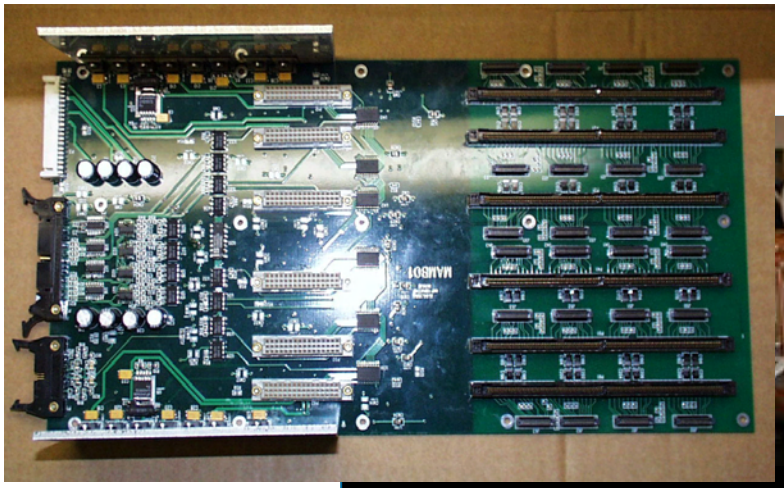
Belle Experiment

Polish contributions to the Belle detector

main focus: Silicon Vertex Detector (SVD)

- HALNY - DSP-based readout modules for SVD1;
- master and repeater boards for SVD2;
- adopting the SVD readout chain to the modularized pipeline readout electronics system for SVD3 (for the SuperBelle project);
- SVD calibrations and alignment…

HALNY – readout module for SVD1



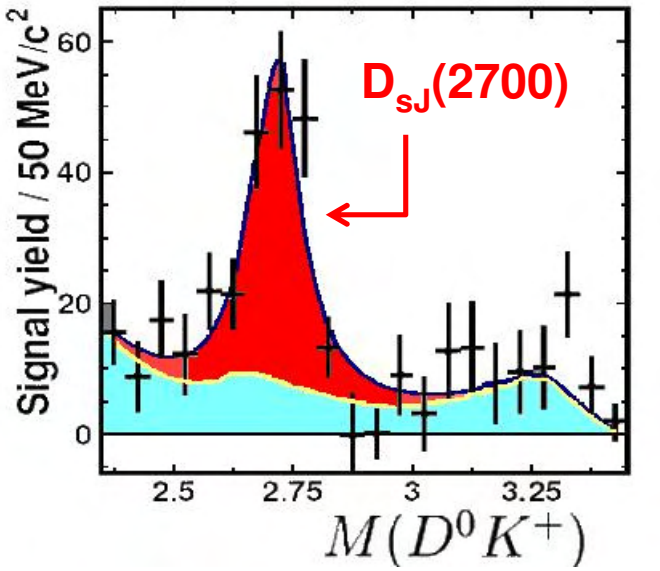
master and repeater boards for SVD2

Belle Experiment

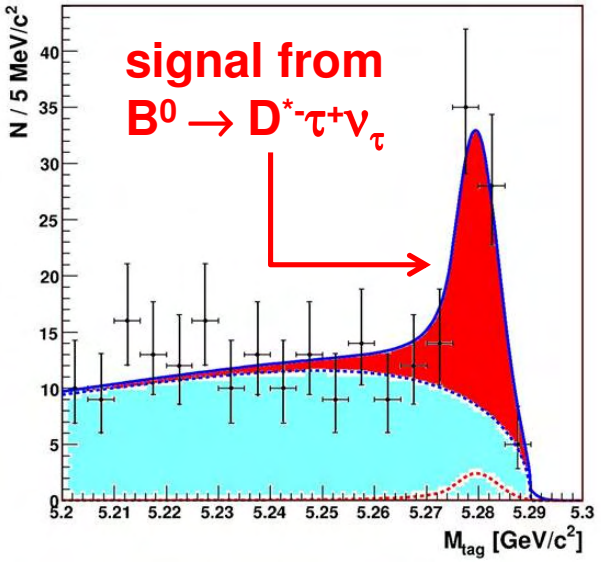
Polish contributions to physics analysis

- hadronic B decays with b→s transition (*e.g.* B→φK$^{(*)}$);
- semileptonic B deacys with b→cτν$_\tau$ transition: ⇒ first observation of semitauonic B decay in exclusive mode
- charm spectroscopy:

⇒ discovery of $D_{sJ}(2700)$ resonance in $c\bar{s}$ system



J. Brodzicka *et al.* (Belle Collab.)
Phys. Rev. Lett. **100**: 092001 (2008)



A. Matyja *et al.* (Belle Collab.)
Phys. Rev. Lett. **99**: 191807 (2007)

COmmon Muon and Proton Apparatus for Structure and Spectroscopy

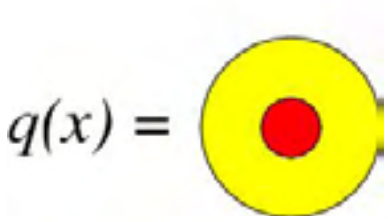
Exp. NA58 at the CERN SPS; $\sim$ 250 physicists, $\sim$ 30 institutes

Takes data since 2002; planned for 2010 +

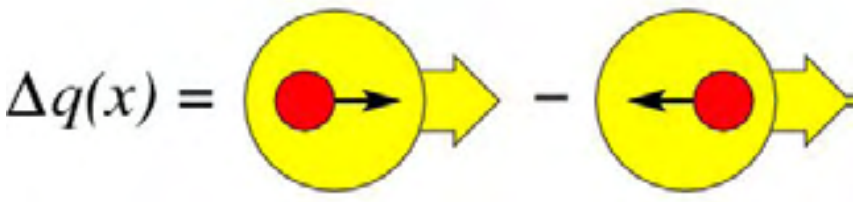
From Poland: University of Warsaw, Warsaw University of Technology, and Institute for Nuclear Studies (total 16 persons)

Main goals of COMPASS

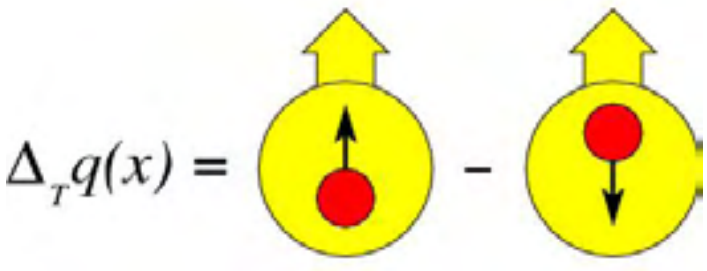
- Spin–dependent parton distributions in the nucleon



Quark momentum DF;
well known (unpolarised DIS $\rightarrow F_{1,2}(x)$).



Difference in DF of quarks with spin parallel or antiparallel to the nucleon spin;
known, helicity (polarised DIS $\rightarrow g_1(x)$).

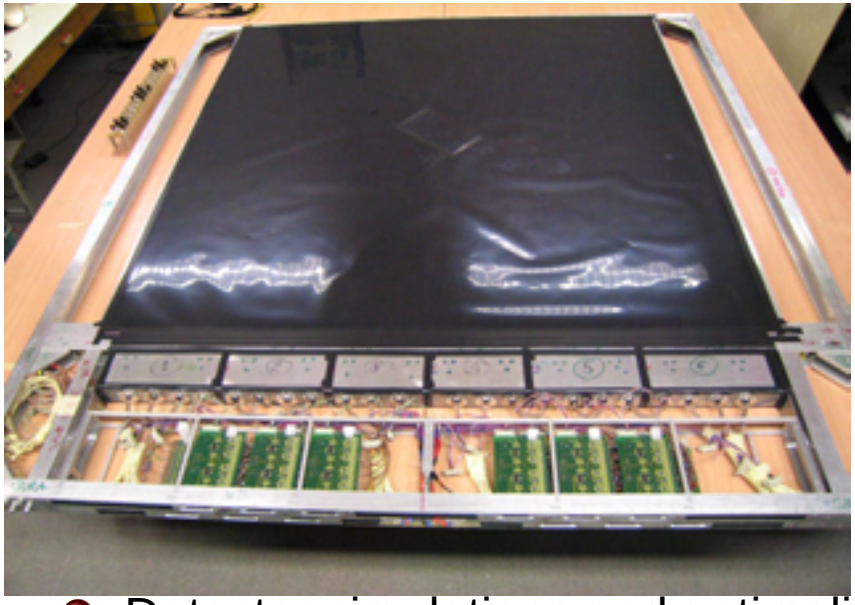


Difference in DF of quarks with spin parallel or antiparallel to the nucleon's spin in the transversely polarised nucleon;
unknown, transversity
(polaris. SIDIS $\rightarrow A_{Collins}$)

- and in particular solving the "proton spin puzzle":

$$\frac{\hbar}{2} = J_q + J_g = \left(\frac{1}{2}\Delta\Sigma + L_q\right) + (\Delta G + L_g)$$

Warsaw hardware and software contribution



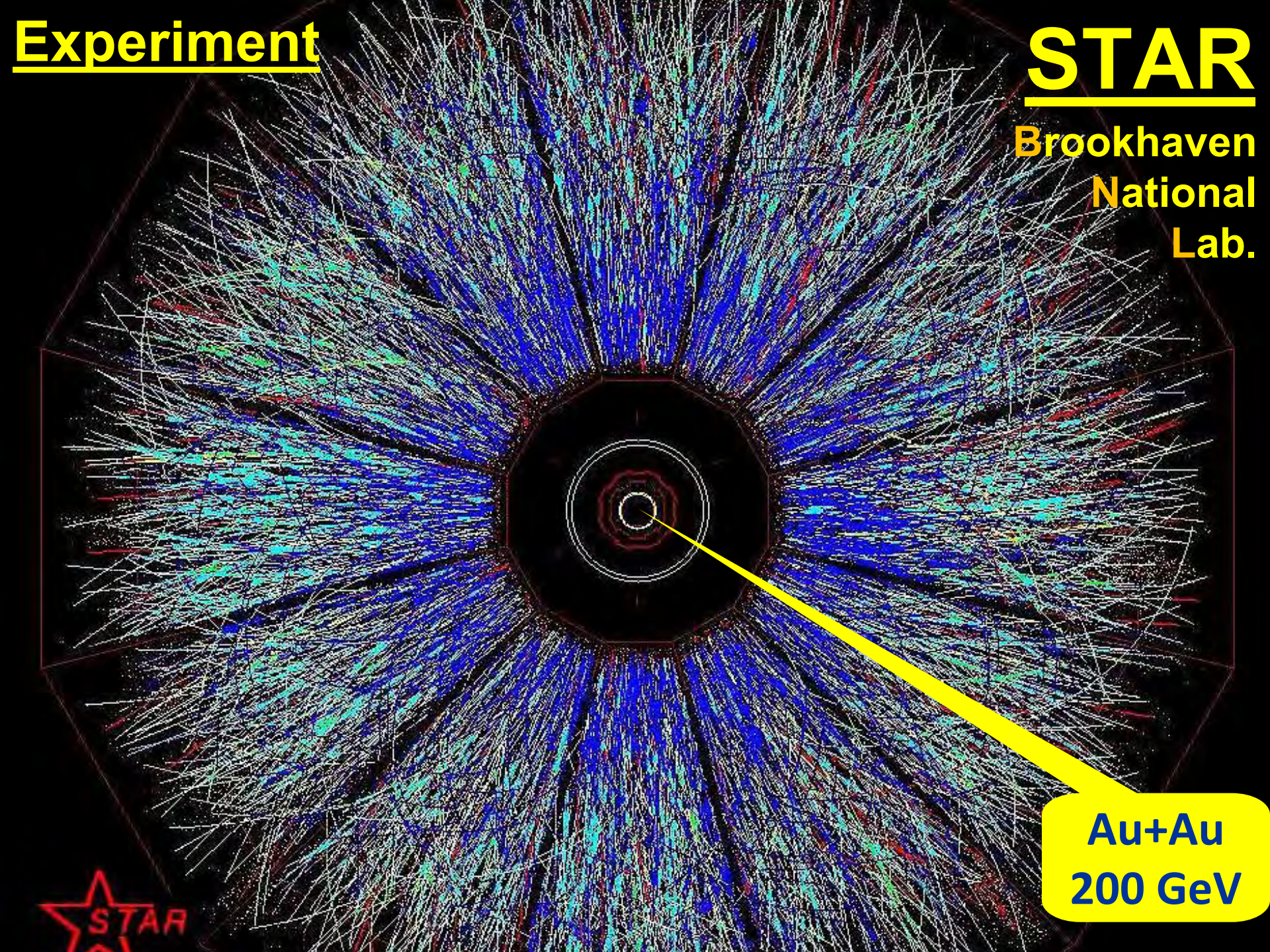
- Two inclined SciFi planes
- Each plane 176 channels, 4 fibers/ch.
- 12.3$\times$12.3 cm active area
- Efficiency $\sim$97% (standard)
- Gain $\sim$5% in D^0 statistics at low Q^2 ($\equiv$ 15 days of data taking in 2 years).

- Detector simulations and optimalisation
- Responsibility for the whole detector alignment for $\sim$3 years
- Responsibility for the radiative correction calculations
- Analysis of the open-charm production $\Longrightarrow$ extraction of ΔG (also in NLO)
- Analysis of the high-p_t hadron production $\Longrightarrow$ extraction of ΔG
- Inclusive analysis $\Longrightarrow$ extraction of g_1 at low Q^2
- Semi-inclusive analysis $\Longrightarrow$ extraction of Δq
- Exclusive vector meson production
- Participation in setting up COMPASS II for 2010+

Experiment

STAR

Brookhaven National Lab.



Group from Warsaw University of Technology in STAR

General info:

Members (2009): staff: 4, PhD: 2, students: 5

Finished PhD: 2, MSc: 12

Team Leader: Tomasz PAWLAK

Physics:

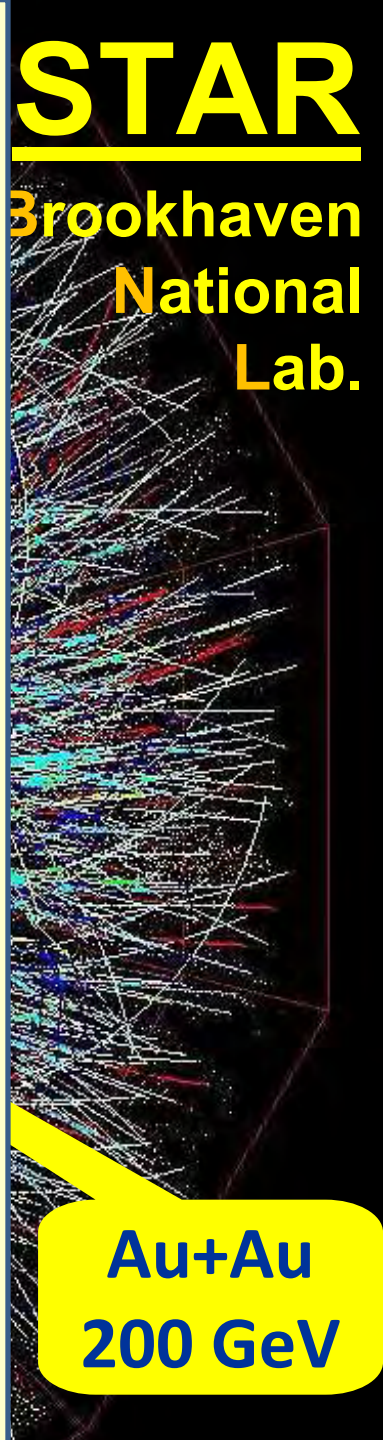
1.Correlation Femtoscopy – analysis of hadron correlations at small relative velocities and studies of space-time development of particle emission process in heavy ion collisions

2.Search for a hidden charm (J/psi) as a signature of the phase transition to the state of Quark-Gluon Plasma

Service work:

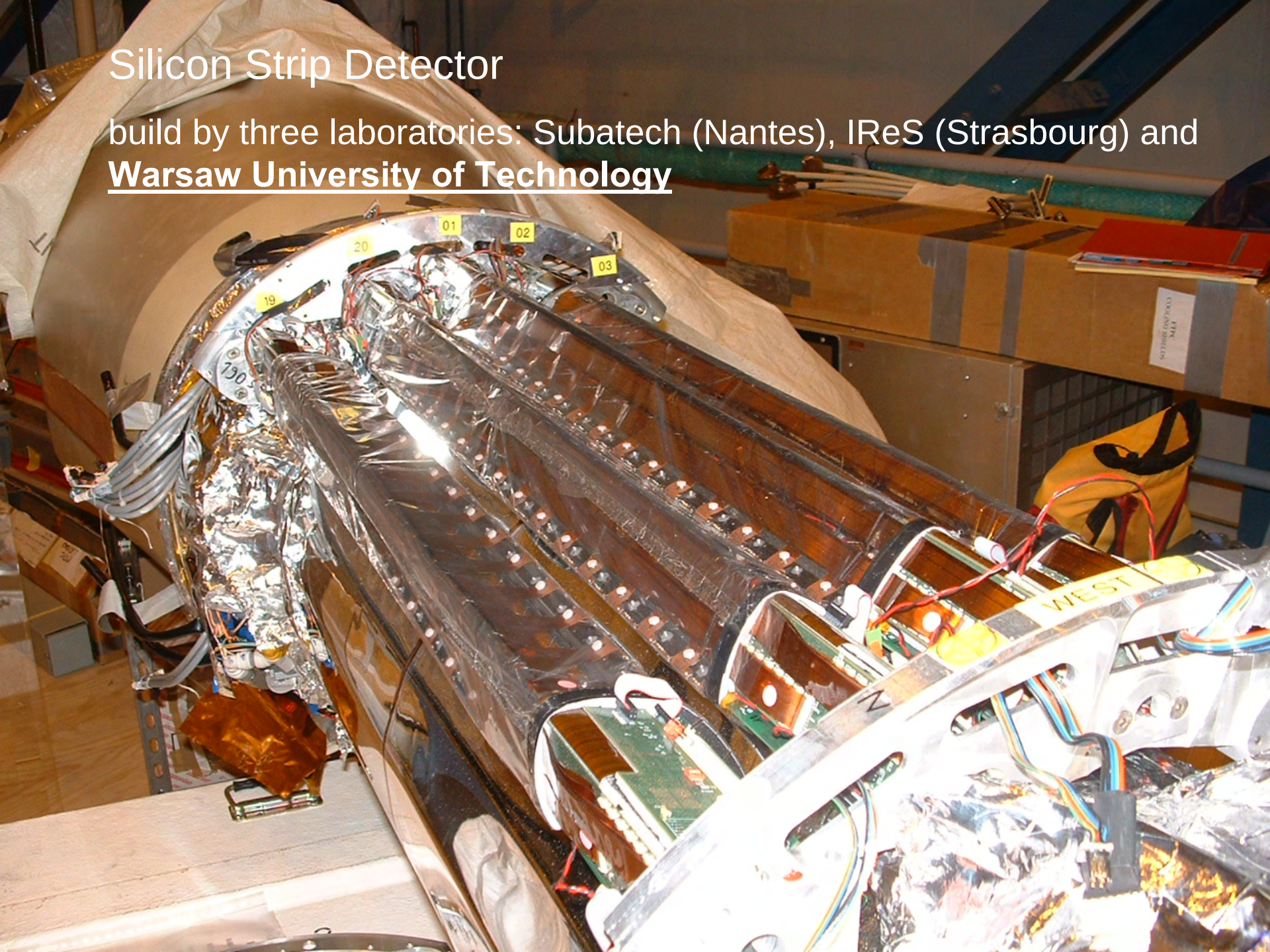
1.Shifts at BNL

2.Hardware: Silicon Strip Detector, Software: file catalog



Silicon Strip Detector

build by three laboratories: Subatech (Nantes), IReS (Strasbourg) and **Warsaw University of Technology**

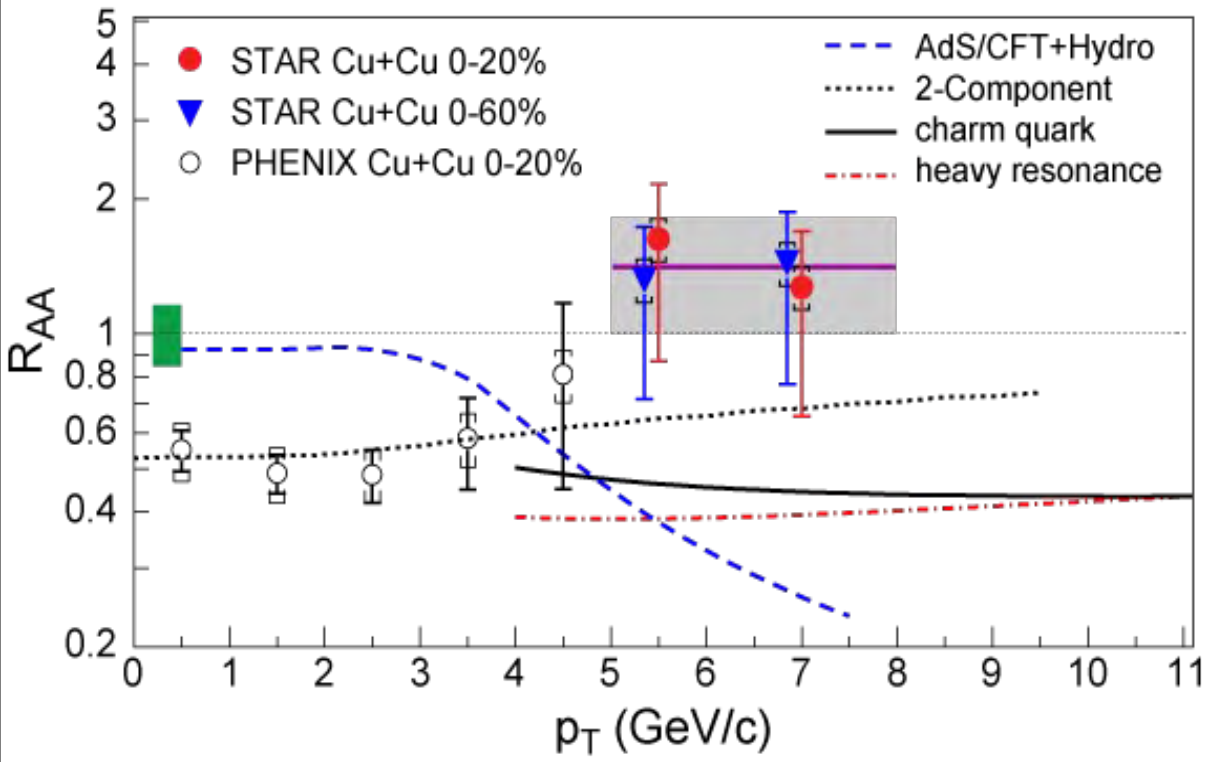


[4]

J/ψ production in Au+Au and Cu+Cu collisions

Nuclear modification factor R_{AA}

STAR Preliminary



Consistent with no suppression at high p_T:

$R_{AA}(p_T>5$ GeV/c) = 1.4± 0.4±0.2

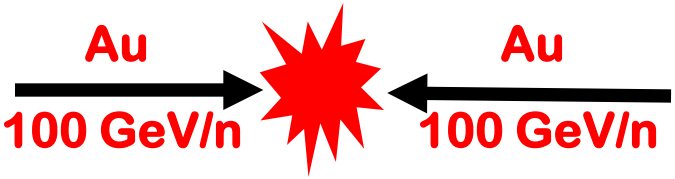
Indicates R_{AA} increases from low to high p_T

PHOBOS Experiment at the BNL-RHIC

International Collaboration:
USA, Poland (IFJ PAN-Krakow) and Taiwan

PRIMARY AIM:

Search for manifestations of new physics phenomena expected to occur in heavy ion collisions at the highest accelerator energies.



OVERVIEW

2000 – 2005 data-taking
2004 – co-discovery of a near-perfect fluid
in 2005 at the head of the AIP Top Physics Stories
2005 – data-taking has come to a close
2005 – 2010 data analyses

PHOBOS Team: 44 physicists and 18 graduate students

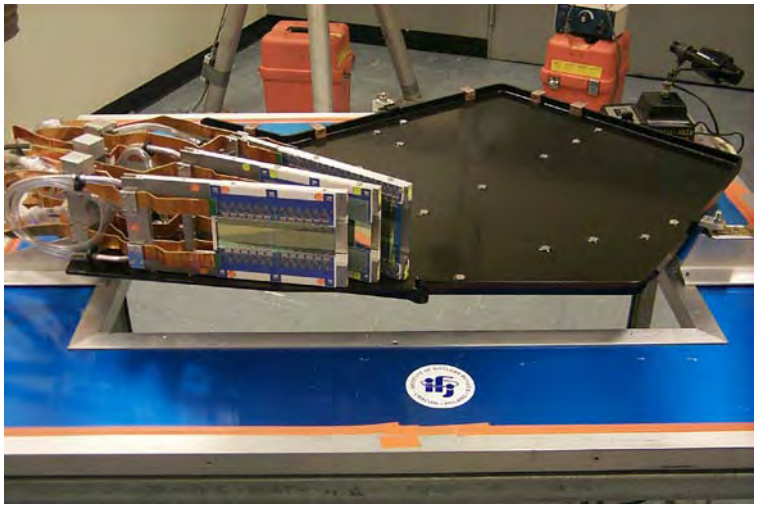
Group from the Institute of Nuclear Physics Polish Academy of Sciences:
5 physicists and 1 graduate student (+ undergraduate students)

PHOBOS Experiment at the BNL-RHIC

Polish contribution to the detector construction:

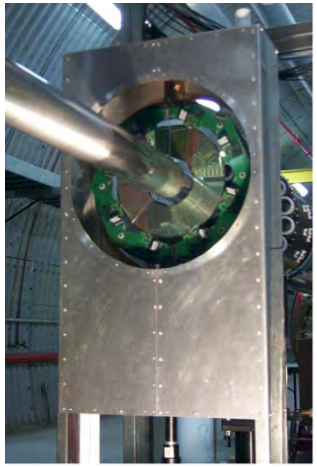
~30% of the total detector cost (~2M$)

12 engineers and technicians from IFJ PAN



Support structure for the multi-layer Si spectrometer

Support structure for the octagonal multiplicity detector



Support structure for the ring multiplicity detectors

- **Design and construction of the mechanical support structures**
- **Design and construction of the cooling system for Si detectors**

Si cooling system

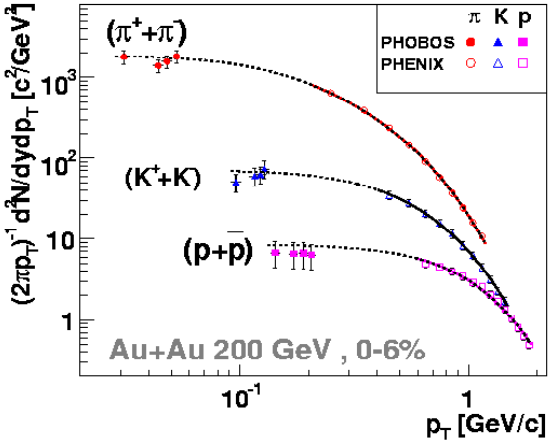
PHOBOS Experiment at the BNL-RHIC

Polish contribution to the PHOBOS physiscs reseach programm:

- Development of the software analysis tools
- Detector geometry description
- Monte Carlo production
- Analysis of particle production at very low transverse momenta
- Study of the collective flow effects
- Study of fluctuations and correlations in multi-particle final states

SELECTED PHYSICS RESULTS:

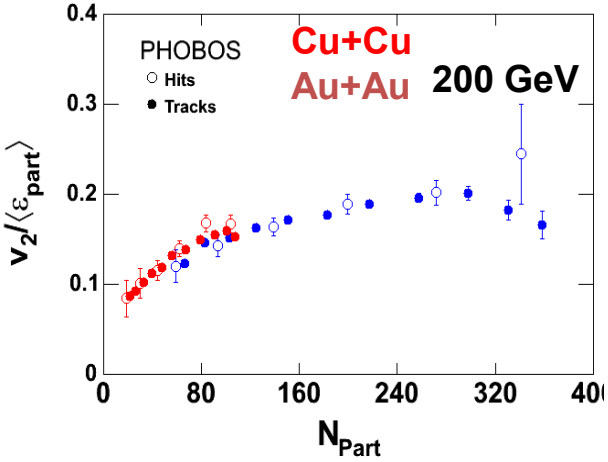
UNIQUE PHOBOS MEASUREMENTS OF PARTICLE PRODUCTION AT VERY LOW p_T



No anomalous enhancement; strong radial flow effects

J. Phys. G35 (2008) 104131

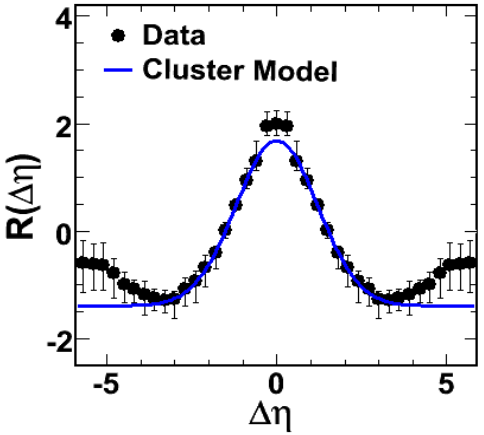
FINAL-STATE MOMENTUM ANISOTROPY



Unification of the elliptic flow results when scaled by the participant eccentricity

Phys. Rev. Lett. 98 (2007) 242302

TWO-PARTICLE ANGULAR CORRELATIONS

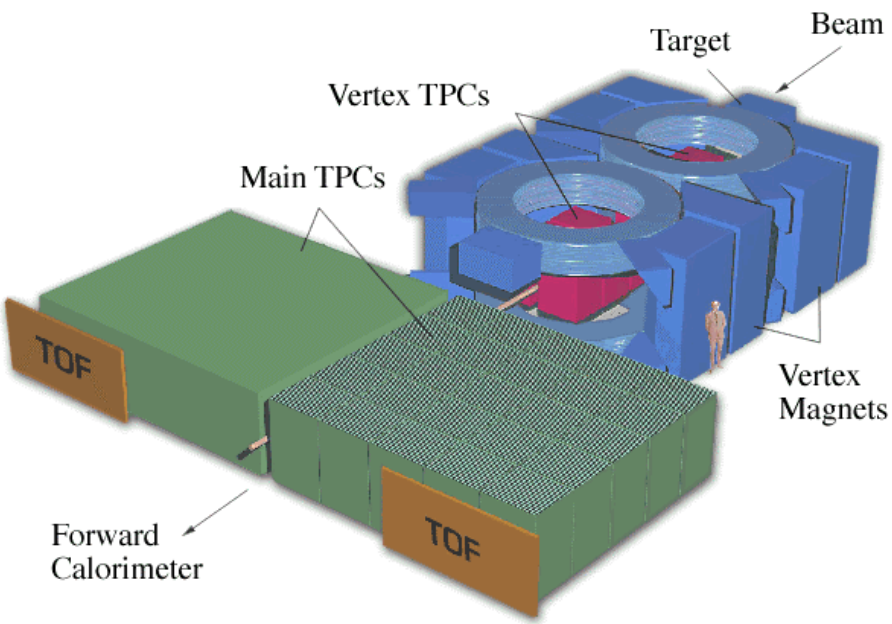


At freeze-out particles tend to be produced in clusters

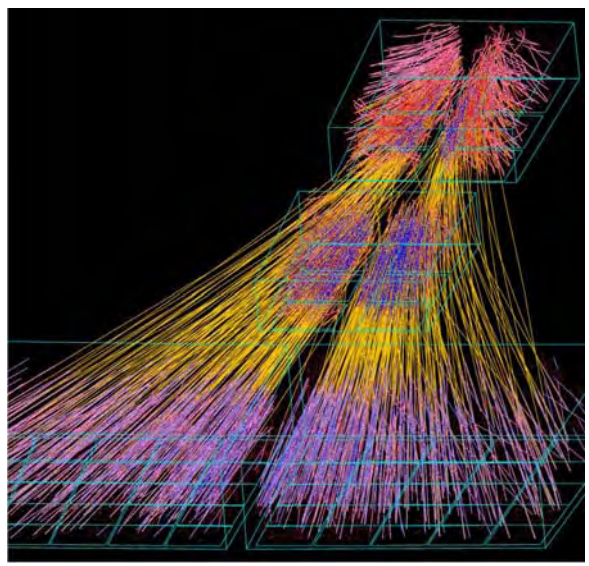
J. Phys. G35 (2008) 104142

NA49 experiment @ SPS

Studies of A-A, p-A & p-p collisions at 20-160 *A*GeV



Search for Quark-Gluon Plasma



Spokeperson: P. Seyboth MPI, München & UJK, Kielce

Pb – Pb @ 158 *A*GeV

Polish Contribution to NA49

	Polish Institutions	Number of physicists
1	Jan Kochanowski University, Kielce (UJK)	6
2	Institute of Nuclear Physics, Kraków (IFJ)	5
3	Institute for Nuclear Studies, Warszawa (IPJ)	3
4	University of Warsaw, Warszawa (UW)	1
5	Warsaw University of Technology, Warszawa (PW)	5

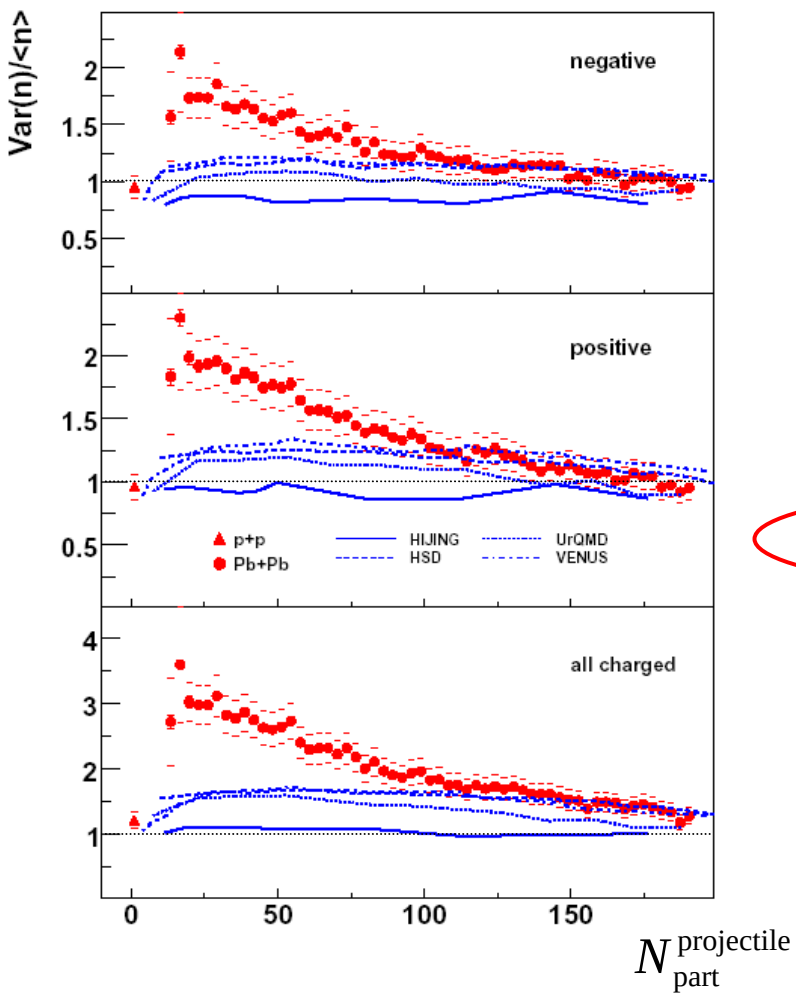
Hardware contribution: Low voltage electronics for TPC detectors

Contribution to analysis of data:

- *Charged hadron production in p-p & A-A collisions* – IFJ
- *Transverse characteristics of hadron production in p-p & A-A collisions* – IPJ
- *Transverse momentum event-by-event fluctuations in A-A collisions* – UW, PW, UJK
- *Long-range correlations of charged hadrons in A-A collisions* – PW
- *Multiplicity fluctuations in A-A collisions* – UJK
- *Elliptic flow of strange particles* – UJK

Multiplicity fluctuations at fixed projectile N_{part}

A-A @ 158 AGeV



$N_{part}^{projectile}$ - number of participants from a projectile fixed by 0° calorimeter

$$\langle n \rangle \sim N_{part}^{projectile}$$

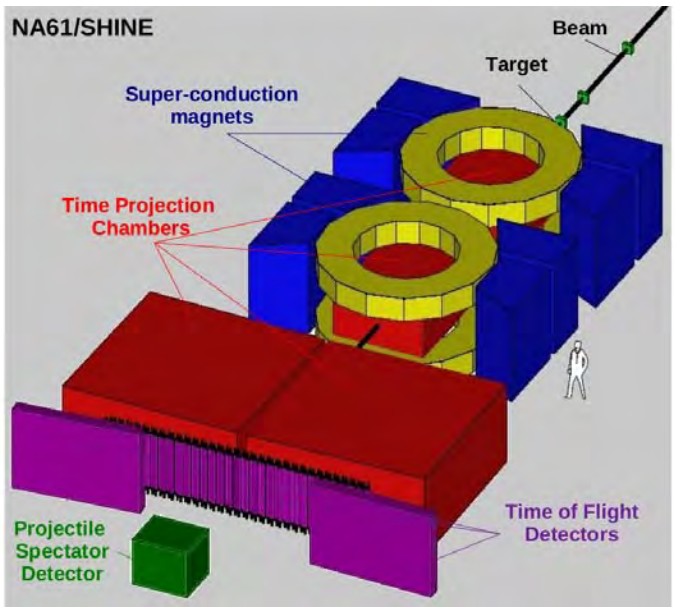
$$\mathrm{Var}(n) \equiv \langle n^2 \rangle - \langle n \rangle^2 \propto N_{part}^{projectile}$$

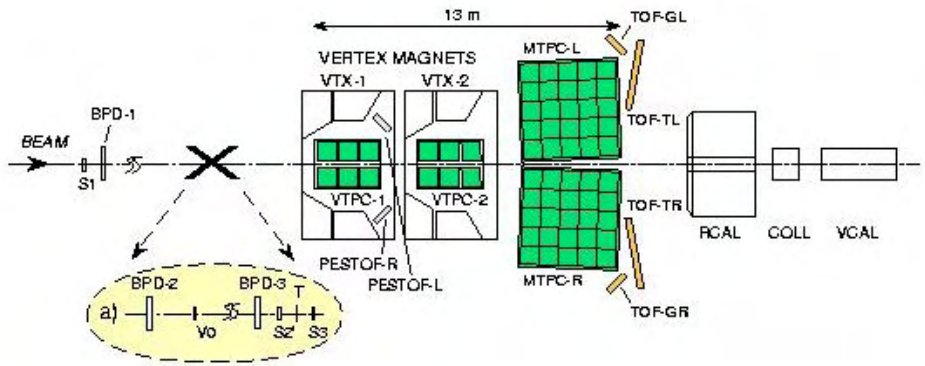
A-A collision is not a superposition of N-N interactions

C. Alt et al. [NA49 Collaboration], Phys. Rev. **C75**, 064904 (2007)

SHINE NA61 experiment @ SPS

Studies of p-p, p-A & A-A collisions at 20-160 *A*GeV





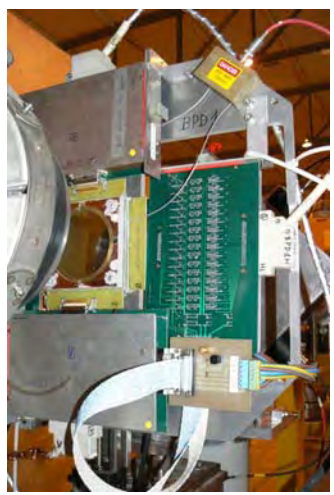
Spokeperson: M. Gaździcki IKF, Frankfurt & UJK, Kielce

Polish Contribution to NA61/SHINE

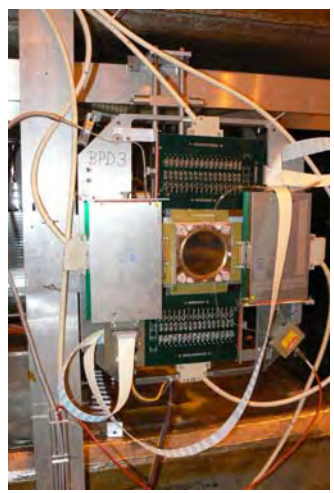
	Polish Institutions	Number of physicists
1	Jan Kochanowski University, Kielce (UJK)	7
2	Jagiellonian University, Kraków (UJ)	7
3	University of Warsaw, Warszawa (UW)	7
4	Warsaw University of Technology, Warszawa (PW)	5
5	Institute for Nuclear Studies, Warszawa (IPJ)	7
6	University of Silesia, Katowice (US)	6

Hardware contribution

- Gas system of TPC detectors - UW
- Beam Position Detectors (BPD) - UJ
- Detector Control System - PW
- Charge detector for secondary ion beam - UJ
- Projectile Spectator Detector (PSD) - UW

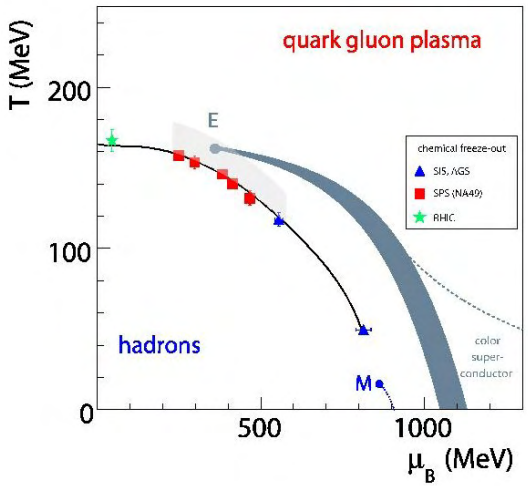


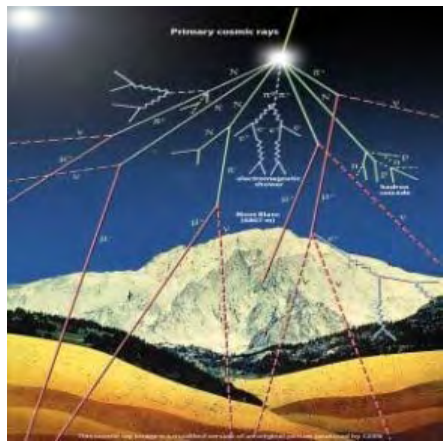
BPD1



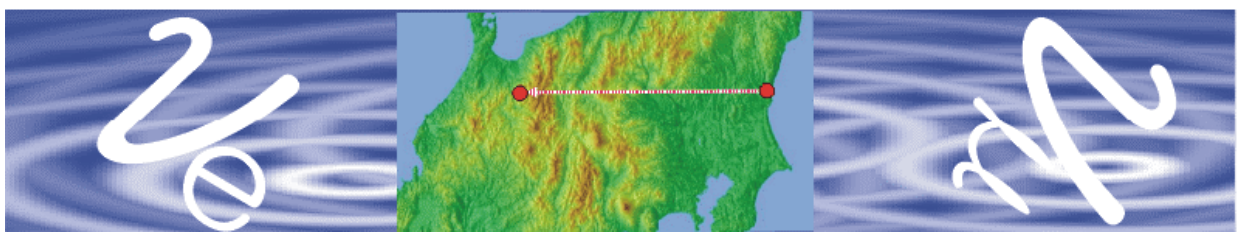
BPD3

Physics goals of NA61/SHINE





- Search for QCD critical point of strongly interacting matter
- Study the onset of deconfinement in A-A collisions
- Measure hadron production at high p_T in p-p & p-Pb collisions
- Measure hadron production in p-C for T2K & cosmic-ray physics



Polish Network for Physics and Technology of High Energy Linear Accelerators (FiTAL)

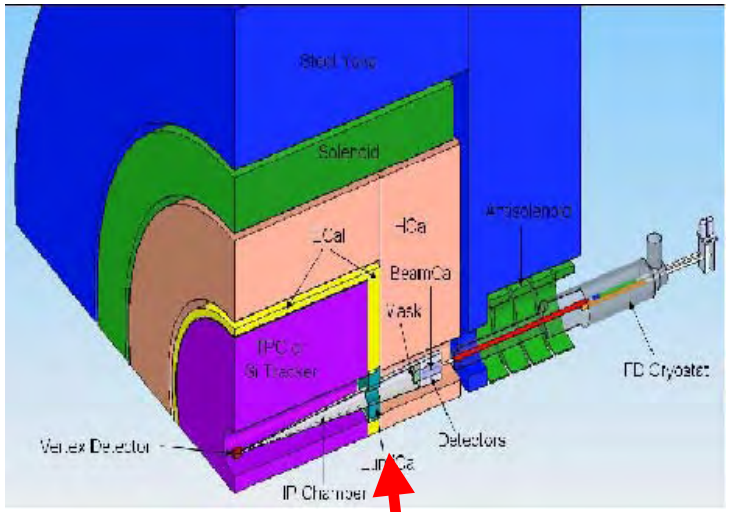
- **Established in October 2007 in order to conduct joint research and development activities related to the projects of the future high energy linear e^+e^- accelerators.**
- **Partners:**
  - Institute of Nuclear Physics PAN, Cracow
  - The Andrzej Soltan Institute for Nuclear Studies, Świerk
  - Faculty of Electrical, Electronic, Computer and Control Engineering, Technical University of Łódź
  - Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, Cracow
  - Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Cracow
  - Faculty of Physics and Applied Informatics, University of Łódź
  - Faculty of Physics, Uniwersity of Warsaw
  - Faculty of Mathematics, Physics and Chemistry, University of Silesia, Katowice
  - Faculty of Mechanical and Power Engineering, Wrocław University of Technology

Ultra High Vacuum Cathodic Arc Deposition – UHVCA

- **Technology of Thin Superconducting-films deposition upon metallic surfaces developede in The Andrzej Soltan Institute for Nuclear Studies, Świerk**

  - deposition of pure niobium (Nb) layers upon surfaces of RF accelerator cavities
  - deposition of pure lead (Pb) layers, to be used as photo-cathodes in electron injectors.

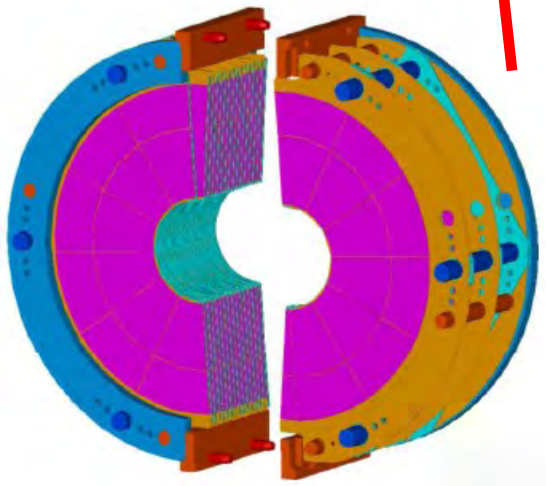
Detector R&D

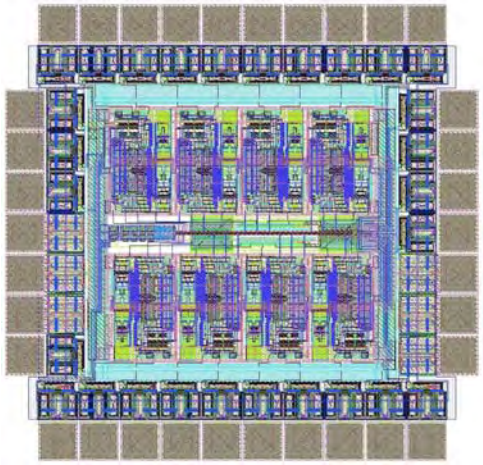


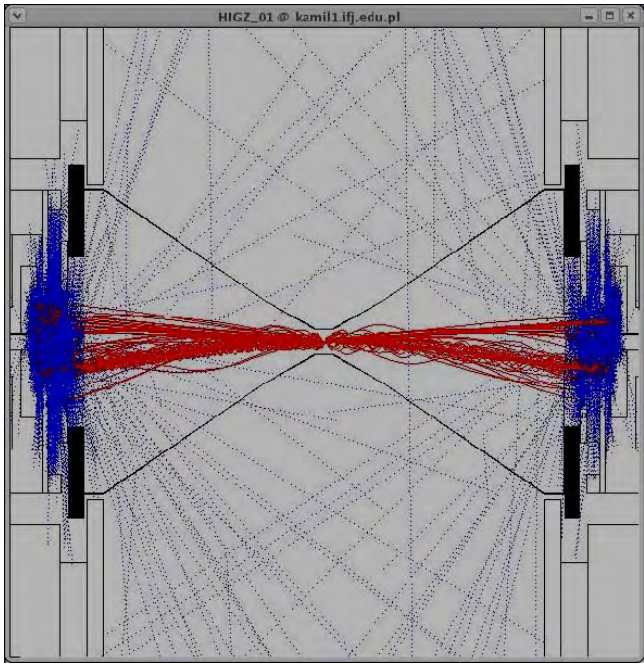
Detector concept, prototype tests, simulation studies and electronics design for the luminosity detector at ILC

(AGH and INP Cracow)

FCAL Collaboration, EUDET Project (FP6)







Summary

On accelerator-based experiments:

- **Focus on LHC experiments**
  - significant contributions to hardware, software and analysis
  - waiting for first physics results
- **Continue researches in other areas, where large expertise exists**
  - deep inelastic scattering (HERA analysis, COMPASS)
  - presicion measurements (Belle)
  - relativistic heavy ion collisions (at RHIC and CERN)
- **Prepare for future challenges**