Development of silicon tracking detectors for FAIR

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- Brief overview of FAIR
- Nuclear structure/astrophysics experiments R³B, EXL
- Antiproton-annihilation experiment PANDA
- Nuclear interaction experiment CBM





Facility for Antiproton and Ion Research



New international facility next to GSI

Unprecedented research opportunities:

Nuclear Structure & Nuclear Astrophysics Radiactive-ion beams from high-energy fragmentation

QCD-Phase Diagram: Nuclear & QGP Matter Heavy-ion beams 2 to 45 GeV/u

Hadron Structure, QCD-Vacuum & Medium Stored and cooled Anti-proton beams up to 15 GeV/c

Fund. Symmetries & Ultra- High EM Fields Antiprotons and highly stripped ions

Physics of Dense Bulk Plasmas Ion-beam bunch compr. + high-energy petawatt-laser

Materials Science, Radiation Biology Ion & anti-proton beams

14 partner countries so far:

Observers:

FAIR

http://www.gsi.de/fair

Nov. 2001:	FAIR Conceptual Design Report.
Jul. 2002:	FAIR recommended by german science council "Wissenschaftsrat".
Feb. 2003:	FAIR approved by ministry of education and research "BMBF".
Mar. 2006:	Fed. Government: FAIR in budgetary plan up to 2014.
Sept. 2006:	FAIR Baseline Technical Report.
Nov. 2007:	FAIR Start-up event
in 2008:	Foundation of the FAIR Company
First experin Completion	nents: 2012 in 3 phases: until 2016

Costs & Funding:

~1.2 billion € – 65% Germany,
10% State of Hesse, 25% Int. Partners

Start of the FAIR project on 7 November 2007

More than 1400 people attending the event.

Austria, Germany, Spain, Finland, France, Poland, Romania, Russia, Sweden, Great Britain and german State of Hesse

Officials from the FAIR partner states celebrating the launch of the start version.

RB experiment:

"Reaction studies with Relativistic Radioactive Ion Beams"

Physics and programs

- Structure of nuclear matter in its extreme states: Exotic nuclei
- Physics for nuclear energy / nuclear data and modeling, astrophysics

Goals of the experiment

- Complete reconstruction of the reaction kinematics with stable as well as radioactive beams
- Beam energies: 150 MeV - 1.5 GeV per nucleon

Physics and programs

- Nuclei far off stability
- Exploring new regions in the chart of nuclides: paramount interest in the fields of nuclear structure and astrophysics

Goals of the experiment:

- Complete reconstruction of lightion induced direct reactions in inverse kinematics
- Novel storage ring techniques and a universal detector system

- exclusive measurement of the final state:
 - identification and mom. analysis of fragments (large acceptance mode: $\Delta p/p \sim 10^{-3}$, high-resolution mode: $\Delta p/p \sim 10^{-4}$)
 - n, p, γ, light recoil particles
- applicable to a wide class of reactions

Si Recoil Tracker

- 2-layer silicon tracker
- $\sim 0.2 \text{ m}^2 \text{ area}$

First layer:

- double-sided Si micro-strip detectors
- 2.5 cm from target,
- thickness \leq 100 μ m, pitch 100 μ m
- energy resolution 50 keV (FWHM)

Second layer:

- double-sided Si micro-strip detectors
- 10 cm from target,
- thickness 300 μm, pitch 100 μm
- energy resolution 50 keV (FWHM)

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EXL

Detection systems for:

- Target recoils and gammas $(p,\alpha,n,\gamma...)$
- Forward ejectiles (p,n,γ)
- Beam-like heavy ions

Recoil detector

- 2 nearly spherical silicon detector layers
- ~3 m² area.

Si DSSD	⇒ ∆E, x, y
300 µm thick, sp	oatial resolution
better than 500 µ	ım in x and y,
$\Delta E = 30 \text{ keV} (FV)$	WHM)
Thin Si DSSD	⇒ tracking
$<100 \ \mu m$ thick, s	spatial reso-lution
better than 100 µ	ım in x and y,
$\Delta E = 30 \text{ keV} (FV)$	WHM)
Si(Li)	\Rightarrow E
9 mm thick, larg	e area
100 x 100 mm ² ,	
$\Delta E = 50 \text{ keV} (FV)$	WHM)
CsI crystals	⇒ E, γ
High efficiency,	high resolution, 20
cm thick	

R3B:

- 2-layer silicon tracker
- ~ 0.2 m² area
- 60 microstrip detectors of about 5 cm by 7 cm size
- Double-sided detectors with orthogonal strip pattern, read out from the same detector edge → double-metal routing layer on one side.
- Strip pitch: 100 µm or smaller.
- Detectors thickness: 100 µm (inner layer),

100-300 µm thickness (outer layers).

EXL:

- 2 nearly spherical silicon layers
- ~3 m² area.
- - ⊕energy resolution of 30 keV.
 - \$300 detectors with typical dimensions of 9 cm by 9 cm.
- - energy resolution of 30 keV
 - ⊕120 detectors of 9 cm by 9 cm size.
- Detectors operated in vacuum.

Anti-proton annihilation experiment PANDA

A next generation hadron physics detector

Cooled antiproton beams, energy 1.5 - 15 GeV, interacting with various internal targets.

Main physics topics:

- hadron spectroscopy, search for exotic charmonia states
- charm hadrons in the nuclear medium
- spectroscopy of double-hypernuclei and nucleon structure.

PANDA detector system:

- 4 acceptance,
- vertex detection: MVD
- particle id of Kaons, muons, e[±]
- electromagnetic calorimetry
- momentum resolution ~ δp/p = 1%
- high interaction rates of up to 20 MHz

Micro-Vertex Detector

Experimental tasks:

- Identification of D mesons
- Measurement of long-lived baryons and mesons (open charm and strangeness)

Design features:

- 5 space points forward of 90°
- 4 barrel layers
- 4 forward disks
- Outer 2 barrels and disks:
 - double-sided strips, ~0.6m²
- Inner barrels and disks:
 - hybrid pixels
- Smallest possible inner radius
- Fast and untriggered readout

pellet or cluster jet target

Detector Prototyping

Hybrid pixel detector layers:

ASIC "TOPIX":

- .13 µ technology
- pixel size 100x100 µm²
- high readout capability
- sufficient buffering to operate without trigger
- ToT to retain (some) energy information
- radhard within "typical" limits

Strip layers:

- double-sided sensors
- thickness ~200 µm
- orthogonal strips
- pitch of 50 100 µm
- typical barrel detector: 6 cm by 3.5 cm
- Iab-start: ITC detector, APV 25 chip
- readout: untriggered FEE required
 - \rightarrow synergy with CBM on "XYTER"

Sensor:

EPI for minimum material: < 100 µm thickness</p>

-	5 mm	-
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100-		20 L

PANDA MVD – Radiation load maps

n-equiv. fluence/cm²,

integrated over 1 year of PANDA operation

calculation with DPM event generator

 \sim 1/10 of radiation dose at LHC.

Compressed Baryonic Matter Experiment

- Fixed-target experiment at the SIS300 synchrotron
- High-rate heavy-ion collisions, projectile energies up to 45 GeV/nucleon
- QCD phase diagram in regions of large baryon densities and moderate temperatures

Topics:

- Deconfinement phase transition and high-µ_B QGP.
- Critical point.
- Hadron properties in dense matter.
- (rare) probes: e[±] and µ[±] pairs, vector mesons, strangeness and charmonium, open charm

Compressed Baryonic Matter Experiment

Silicon Tracking System

the mission ...

UrQMD generator: Monte Carlo tracks ...

+ micro vertex detection: presentation by M. Deveaux

... tracking nuclear collisions

- Au+Au interactions, 25 GeV/u, 10 MHz interaction rate
- up to 1000 charged particles/event
- Track densities \leq 30 cm⁻²

... and simulated hits in microstrip detector stations

Exploration of a system concept

Microstrip detector prototype CBM01, GSI-CIS 8/2007

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Pixel vs. Strip detectors

One central Au+Au event at 25 GeV/u, tracking station at z=30 cm

Track reconstruction

Central collision: Au+Au @ 25 AGeV (UrQMD)

Cellular automaton + Kalman filter algorithms

78 ms on Pentium 4 processor

Future: farm of multi-core processors

Reconstruction efficiency:

<1 % ghost tracks

Low mass detector

Radiation Environment

Situation:

FLUKA simulation:

Beginning STS system engineering

12k FEE chips $\rightarrow 6 - 12$ kW power FEE ASIC's operation at 1.8V \rightarrow current 3600 - 7200 A DAQ \rightarrow data rate ~30 GHz, ~200 GByte/s

- STS MVD beam pipe in a thermal enclosure.
- Extractable from the magnet for maintenance.
- Including infrastructure (cables, optical links, cooling)

Summary

International accelerator facility FAIR under preparation:

Unprecedented and new research opportunities in various fields for large scientific communities

Silicon detector systems will be important

Challenging:

some because small research groups go into new detector dimensions

some because truly demanding devices are required:

very high channel densities, high radiation environment, very fast readout, very low mass, pretty big (\rightarrow CBM)

Cooperations of the GSI/FAIR groups: e.g. on Sensors, FEE, labs

Input/advice from other experienced communities searched for:

One example: Planned are in-kind contributions from Finland to FAIR with rad-hard silicon strip detectors (incl. RD39-RD50 expertise)

backup slides

n-XYTER readout ASIC **DETNI - GSI**

Name

n-XYTER: Neutron - X, Y, Time and Energy ... Readout

Front-end

- 128(32) channels, charge sensitive pre-amplifier, both polarities ٠
- 30 pF detector capacitance, ENC 1000 e ٠
- self-triggered, autonomous hit detection ٠
- time stamping with 1 ns resolution (needed to correlate x-y views) ٠

Readout

- energy (peak height) and time information for each hit ٠
- data driven, de-randomizing, sparsifying readout ٠
- 32 MHz average hit rate ٠
 - 128 channel version (Si,GEM): ~ 250 kHz hit / channel
 - 32 channel version (MSGC):
- 1 MHz hit / channel

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