TIGRESS Auxiliary Detectors

Gordon Ball, TRIUMF

GRETINA Auxiliary Detector Workshop
Washington University, St. Louis MO
January 28-9, 2006
TIGRESS 32-Fold Segmented HPGe Clover Detector

Four ~40% n-type HPGe crystals close-packed in a four-leaf clover geometry. 32-fold segmentation of the outer contacts provide position resolution.
TIGRESS Configurations

Maximum Efficiency
“HPGe Forward”

Optimal Suppression
“HPGe Back”

\[ r_{Ge} = 11.0 \text{ cm} \]

\[ r_{Ge} = 14.5 \text{ cm} \]
\[ r_{BGO} = 11.0 \text{ cm} \]
TIGRESS Digital Signal Processing

10-channel (TIG-10) DSP modules designed and produced at Université de Montréal.

- Master FPGA
  - Crystal triggering
  - Real-time pulse shape analysis

- Local FPGA

- Flash ADC
  14-bit, 100 MHz

Analogue Front End

10 Channels: 1 HPGe crystal (core + 8 outer segments) or ½ a Compton Suppression Shield
TIGRESS In-Beam Test

July 27-Aug 1, 2005

Five 10-Channel TIG-10 DSP Modules

Derived Energies, time stamps, digital CFD times, plus

50, 1 μs 100 MHz digitized waveform captures per event.
TIGRESS Timeline

**2006**

**ISAC I**

Fundamental Symmetries:
Superallowed Fermi β Decays
Rn Electric Dipole Moment search

**ISAC II**

Nuclear Structure:
Evolution of Nuclear Shell Structure Pairing Correlation far from Stability
Mirror Nuclei and Isospin Symmetry
Coulomb Excitation with Bambino and Bragg/PPAC
Fusion Evaporation reactions with CsI(Tl) and neutron detector arrays

**2007**

**2008**

**Nuclear Astrophysics:**
Structure studies of astrophysically important states
Transfer reactions with EMMA/SiA
# TIGRESS auxiliary detectors

Collaboration currently pursuing 8 auxiliary detector systems (+electronics pool)

## Funded/existing

**Argonne PPAC**
- Carpenter@ANL

**BAMBINO**
- Wu@LLNL / Cline@Rochester

**Highly-segmented Si CD**
- Chen@McMaster

**Bragg**
- Fulton, Barton@York

**Si barrel**
- Fulton, Barton@York

**TIG electronics pool**
- Austin@St. Mary’s

## Proposed/to be proposed

**Super-CHICO**
- Wu@LLNL / Cline@Rochester

**CsI**
- Ressler@SFU

**Neutron detectors**
- Garrett@Guelph

**EMMA**
- Davids@TRIUMF

**Gas-filled Solenoid**
- Savajol@GANIL
Argonne PPAC

For first COULEX in-beam experiments

Dimension of 42×42 cm
Active area of 930 cm$^2$
Position sensitive in two dimensions
20 data channels
Ready in Summer 06
Bambino: detectors and electronics

Si CD detectors to be used for light-ion COULEX
- Funded by DOE through LLNL $294k

Based on commercially available CD-S2 silicon detectors.
Two such detectors mounted 3 cm from the target for both forward and backward hemispheres, \( \approx 1.15\pi \) sr.
24 sectors in \( \theta \) each for angles between 20\(^{\circ}\) and 49\(^{\circ}\) and between 131\(^{\circ}\) and 160\(^{\circ}\). 16 sectors in \( \phi \) for 360\(^{\circ}\) coverage.
- 40 channels

Electronics: 80 channels; preamplifier: 8-channel/box, 10mV/MeV gain
Wave forms digitized with TIG-10
Bambino: status

Three CD-S2 with \( \approx 150 \, \mu \text{m} \) thickness were ordered and received.

A custom-made test chamber was ordered and received.

10 8-channel preamplifiers were ordered and received. The same for all the connecting cables and feedthroughs.

Test for the detectors and accessories will be completed by early 2006.

A target chamber to accommodate Bambino and targets will be designed and built in University of Rochester for first ISAC-II experiments in early fall 2006.

Wu@LLNL / Cline@Rochester
Highly-Segmented Silicon CD Detector

For COULEX, transfer, etc., requiring higher angular resolution than BAMBINO – 160 channels

(Dimensions in mm)

Chen@McMaster
York Bragg detector

Isobaric contaminants in the beam can be a major challenge in extracting absolute cross sections

Need event-by-event $Z$ identification of interacting nuclei

Bragg detectors typically have about $1/40$ $Z$ resolution

York group design is based on conical geometry with large angular acceptance, $15^\circ$–$55^\circ \rightarrow 0.5$ m diameter at entrance

Transmission tube at $0^\circ$ to allow for beam dump

Fulton, Barton@York
Bragg detector

Front PPAC resolution of $2^\circ$ in $\theta$

2) Doppler reconstruction

3) Response calibration

4) Angular distribution and energy measurements

Segmentation $5^\circ$ in $\theta$ and $30^\circ$ in $\phi$ in anode to allow for high count rates (10k in each segment, total of 96 segments)

Fulton, Barton@York
Barrel Detectors: Learning from TIARA

Si Barrel Detector
\[ 36^\circ < \theta_{\text{lab}} < 144^\circ \]

Forward Annular Si
\[ 5.6^\circ < \theta_{\text{lab}} < 36^\circ \]

VAMOS

Beam

Backward Annular Si
\[ 144^\circ < \theta_{\text{lab}} < 168.5^\circ \]

Target Changing Mechanism
York Si barrel

Proposed Si barrel improved version of the TIARA design
Two Si detectors enabling PID with $\Delta E/E$ method
5 cm long detectors to be placed forward or backward of the 90° position
Thin (140 mm) $\Delta E$ detector and a thick (1000 mm) E detector
Detectors can be used overlapping (for transfer), or independently covering forward and backwards angles (for COULEX)

8-fold segmentation of the 8 sides

256 channel readout by TIG

Proposal funded beginning June 2006

Fulton, Barton@York
CsI array for charged-particle tagging

CsI array for COULEX, fusion evaporation, etc.

Probable array geometry – similar to HYBALL but with increased segmentation at forward angles – 108 detectors

Wave forms digitized with 50 MHz 12bit TIG48

NSERC equipment request submitted Fall 05

Ressler@SFU
Super-CHICO

COULEX studies for A>30, deep-inelastic, fusion-fission, etc.

Longer-term detector development of new avalanche detector to have a position resolution of 2 mm

With a thin target, detection of both scattered and recoiling nuclei in kinematic coincidence

- unique tag
- information for Doppler-shift corrections

“Green-light” from LLNL provided success of BAMBINO programme

Wu@LLNL / Cline@Rochester
SuperCHICO – a pixelated avalanche counter

- γ-ray resolution improved from ~1% to ~0.3 – 0.5% for the next generation of highly segmented Ge arrays and the sensitivity improved from μbarn production cross section to nbarn.
- Spherical chamber with a radius of 12.7 cm (fit into the cavity of TIGRESS).
- Two hemispheres and eight segments for each hemisphere.
- Both θ and φ coordinates defined by the pixelated cathode board and the goal is ≈ 2 mm position resolution.

- Solid-angle coverage ≈ 2π sr. with a minimum flight path ≈ 9 cm.
- Downstream electronics and gas handling system among recycled from CHICO but replaced by FADC’s and computerized gas handling system eventually.
Neutron detector array

For tagging on $n$ produced in reactions
Liquid scintillator for PSD separation of $n$ and $\gamma$
$E_n$ by TOF
- ISAC-II accelerator 85 ns pulse separation, 200 ps width

BC-537 (deuterated scintillator, like BC-501A)
- good PSD, also very asymmetric nature of n-d scattering gives a pulse height proportional to $E_n$
  - over-determined kinematics for better discrimination of true multiplicity $k$ events vs. multiple scattering

Small deuterated detector acquired and tested as $f(E_n)$, compared with “normal” liquid scintillator
CFI proposal to be submitted Jan 2006

Garrett@Guelph
Neutron scintillator tests
Instrumented Beam Dump for TIGRESS in the Stand-alone Configuration
**Beam dump ++: Identify / select reaction products**

- Double focussing device
- Angular acceptance: ± 30 mrad
- Energy acceptance: ± 30%

- Increase the solid angle
- Selectivity

**Solenoid:**

Acts as a lens generating an image of the target downstream with different focal length for beam particles and reaction products

- Increase easily the angular acceptance up to ± 10°
- Fill the Solenoid with gas (He) ⇒ charge state equilibration
- Transport reaction products to a small area for identification

- Deep inelastic
- Symetric fusion evaporation
- Fusion-fission

_Herve Savajol_  
GANIL
TIGRESS plus EMMA

EMMA (ElectroMagnetic Mass Analyzer)
a recoil mass spectrometer
to detect and identify heavy recoils produced in transfer and fusion-evaporation reactions induced by the heavy radioactive beams of ISAC II
EMMA: Specifications

Double-focusing mass spectrometer
Separates beam from recoils
Disperses recoils according to mass/charge
$\Delta M/M = \pm 4\%$
Solid angle = 10 msr
$\Delta E/E = \pm 18\%$
Beam suppression > $10^{10}$
Mass resolution = 400
TIG electronics pool

All auxiliary detectors will have signals processed by TIG modules, either directly or after initial analogue processing

Need a pool of TIG modules

☐ Don’t expect that external collaborators will provide TIG’s

Proposal to CFI for 540-channels of TIG-10 and TIG-48

Positive response from CFI on $334,089 total request