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Measuring Atlas Radiation Backgrounds in the Muon System at Startup: A U.S. ATLAS Upgrade R&D Project

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THIS WORK IS AN ATLAS UPGRADE R&D PROJECT

PEOPLE: Currently, M. Shupe and M. Starr. Later, A. Savine and (partial FTE) graduate student. Also one undergraduate student, Matt Adams, contributing to DAQ programming.

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Aims and Scope of This Project

- **Measure neutron, photon, and charged particle fluxes and spectra in pulsed mode for sensitivity at low luminosity. Compare measured fluxes to FLUKA and GCALOR to "recalibrate" simulations.**

  → Reduce muon safety factors, for realistic R&D.

- Detector sets are in the C End at these locations:
  - (1) CSC region, Small Wheel, small r.
  - (2) TGC1, Big Wheel, small r.
  - (3) TGC2, Big Wheel, small r.
  - (4) Cavern end wall, level 6, near elevator.

  Soon: USA15, on wall facing ATLAS cavern.

- All backgrounds are mixed particle types, and broad-spectrum.

Arizona Radiation Backgrounds Detectors in ATLAS

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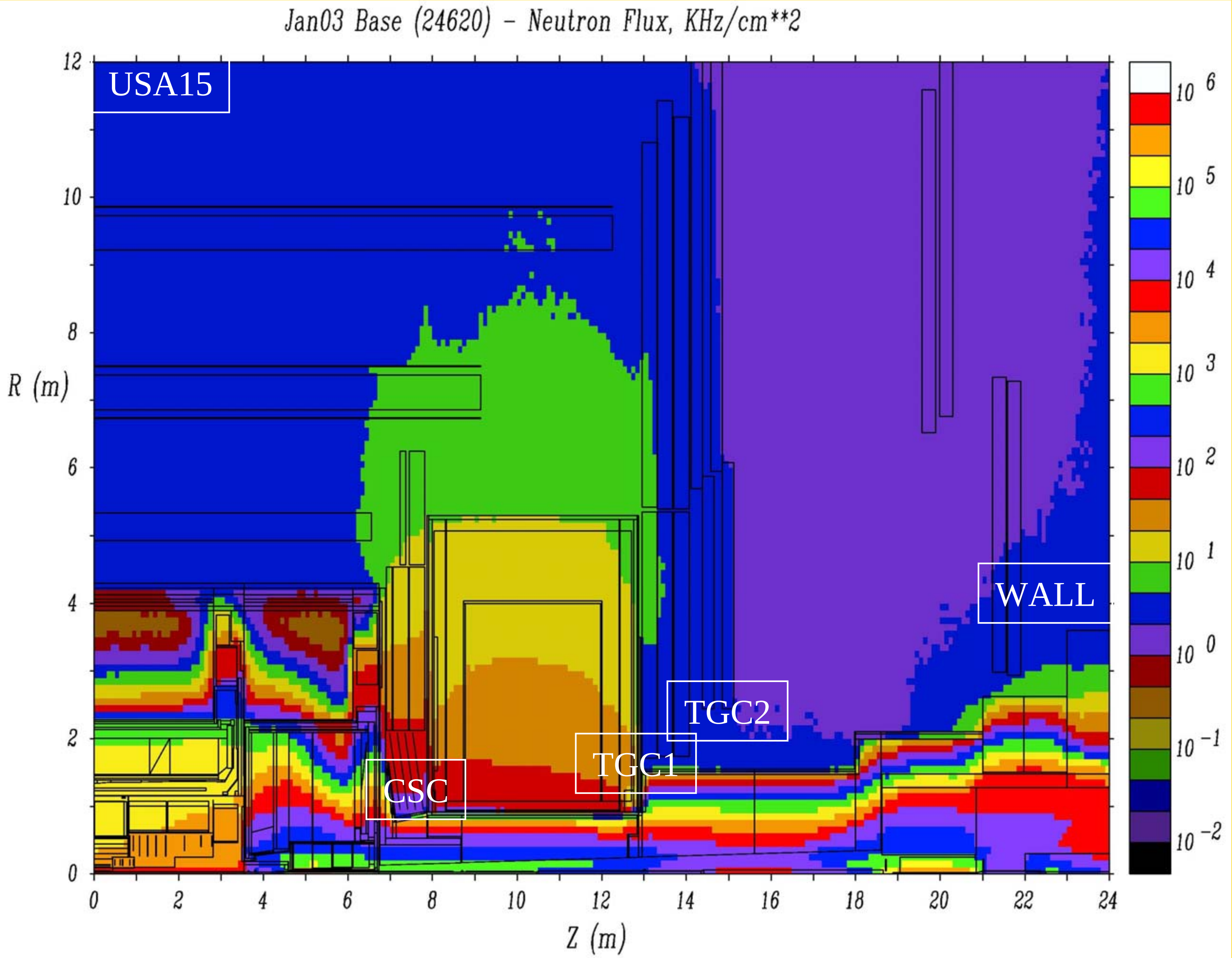

Detector Set Locations

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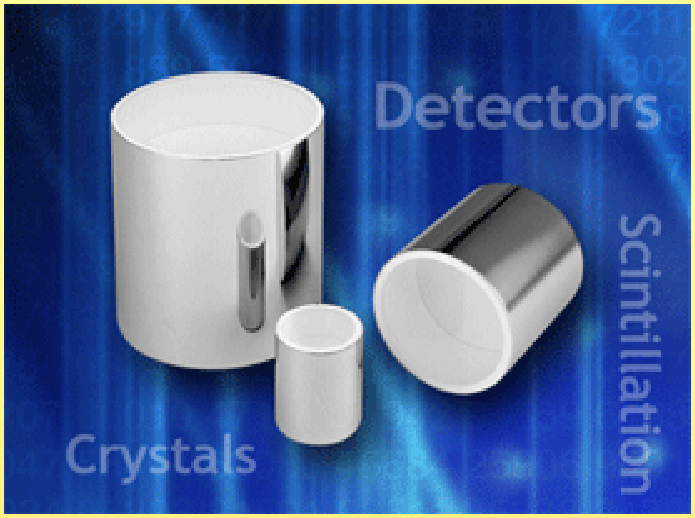
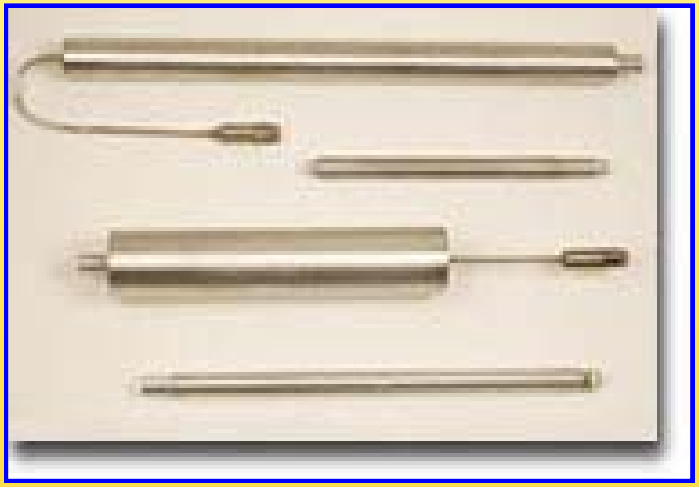
Detector Types

Scintillators: crystals, plastic wafers, or liquid cells: 1" x 1", coupled to PMT's. Some are doped with boron or lithium for thermal neutron detection.



Gas detectors (sealed): proportional tubes and ion chambers, some with doped gases or linings.



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Thermal Neutron Detectors

(1) Boron lined proportional tube: $n + {}^{10}B \longrightarrow {}^{7}Li + \alpha$

Li or α ionize heavily. Pulse-height discrimination minimizes γ and MIP backgrounds.

(2) Proportional tube with BF_3 gas: not as radiation resistant as (1), but cleaner signal separation.

(3) Boron doped plastic scintillator, on PMT:

Same reaction. Run beside undoped counter of same construction. Find n flux by subtraction.

(4) ZnS(Ag) plastic scint with ^{6}Li: Old favorite. Here the relevant reaction is $n + {}^{6}Li \longrightarrow {}^{3}H + \alpha$

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Fast Neutron Detectors

Fast neutrons in hydrogenic materials scatter elastically, producing slow recoil protons. Threshold ~ 1 MeV.

(1) Liquid Scintillator Cell, NE213:

PMT pulse-shape discrimination (PSD), is used to separate recoil proton pulses (large slow component) from photon and MIP pulses. PSD employs fast waveform recorders, and is becoming common practice in the nuclear physics community.

(2) NaI(Tl):

PSD can be applied to these standard scintillators as well, but the discrimination threshold is higher—above 10 MeV.

(3) ZnS(Ag) plastic scintillator (undoped):

Sensitive to recoil protons.

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Photon Spectroscopy

Atlas testbeam background fluxes were measured using a BGO crystal outside iron shielding, and were reported in 2000 by Chris Fabjan, Edda Gschwendtner, and Helmut Vincke. They demonstrated that mixed neutron and photon fluxes could be analyzed by convolving simulated spectra with the scintillation detector response.

Our scintillator choices:

(1) LSO Crystal:
St. Gobain PreLude 420 (LuYSiO:Ce) crystal
(cerium doped lutetium oxyorthosilicate),
high density (like BGO), thermally stable (unlike BGO).

(2) NaI(Tl) Crystal: "Old faithful".

We will apply PSD wherever possible to clean up γ spectrum by removing heavily ionizing protons, α's etc.

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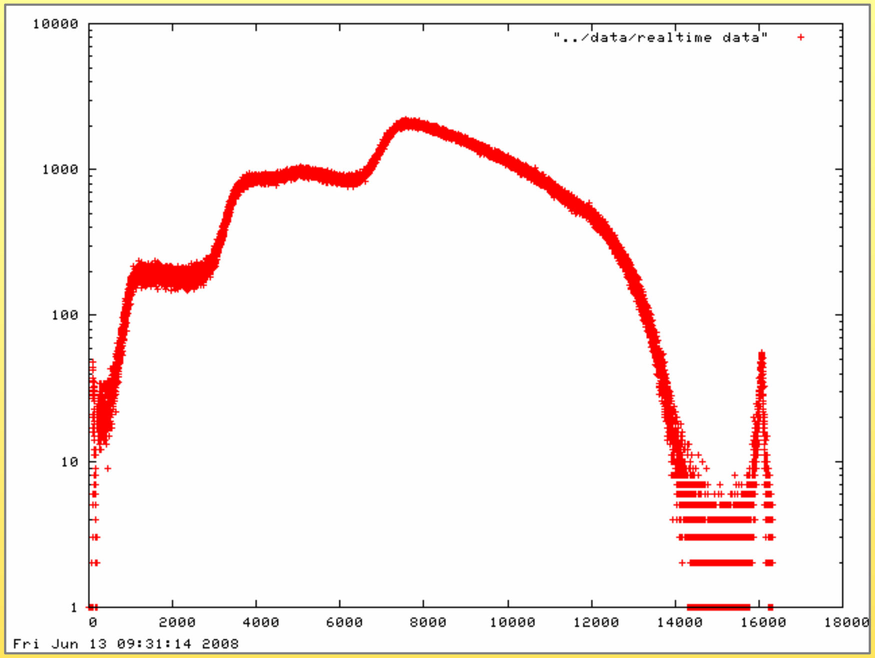
Detector Calibration at Arizona

- All detectors calibrated with Co60 and Cs137 gamma sources.
- First monitor set also tested with PuBe and Cf neutron sources at Nuclear Engineering.
- Spectra taken with cable lengths up to 100 m, the maximum needed for installation in ATLAS.

LSO Spectrum



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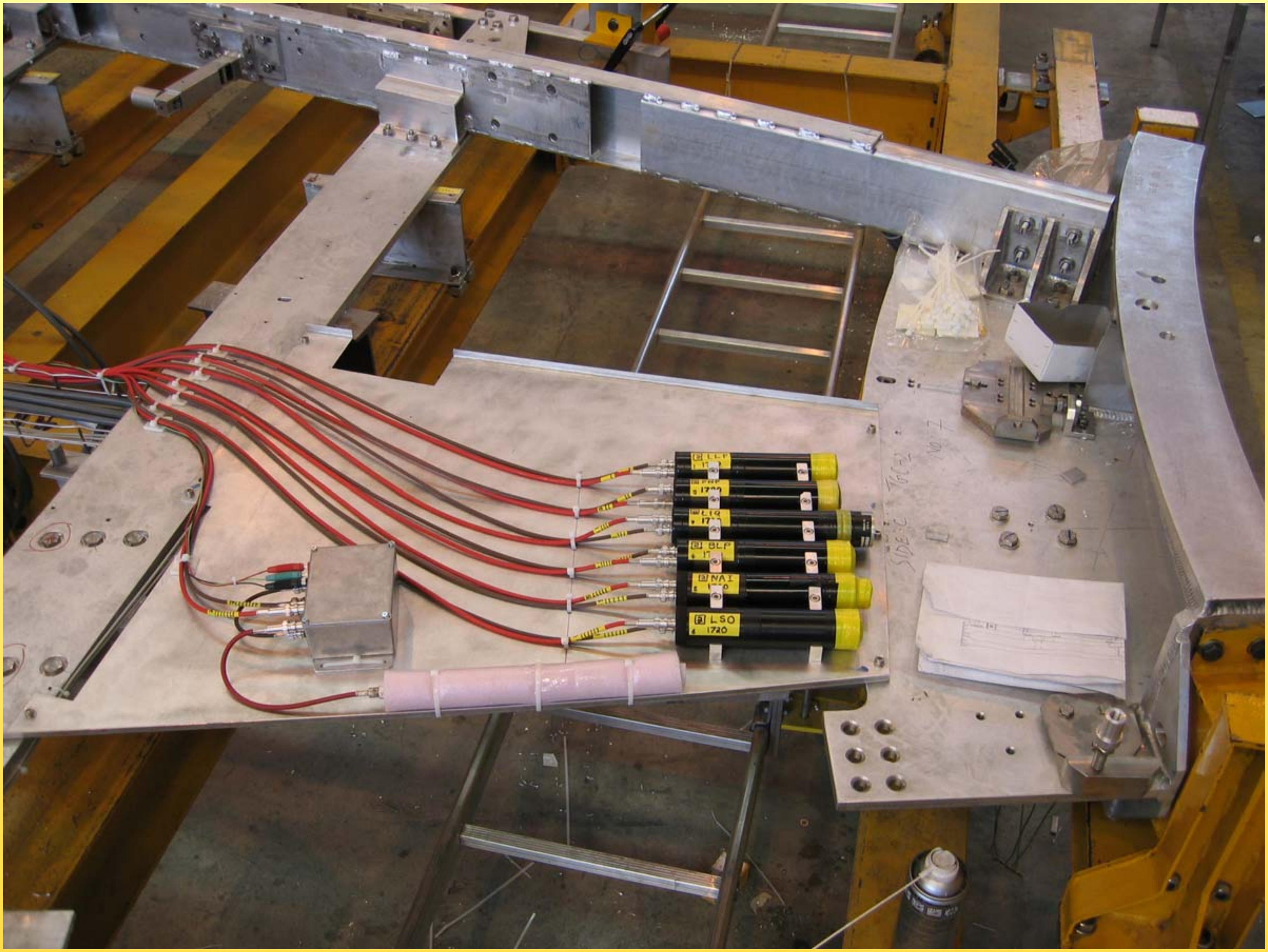
TGC2 Detector Set, Installed July, 2006.



Set:

LLP
FNP
LIQ
BLP
NAI
LSO

BPT

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Small Wheel monitors installed on surface – Bldg. 190

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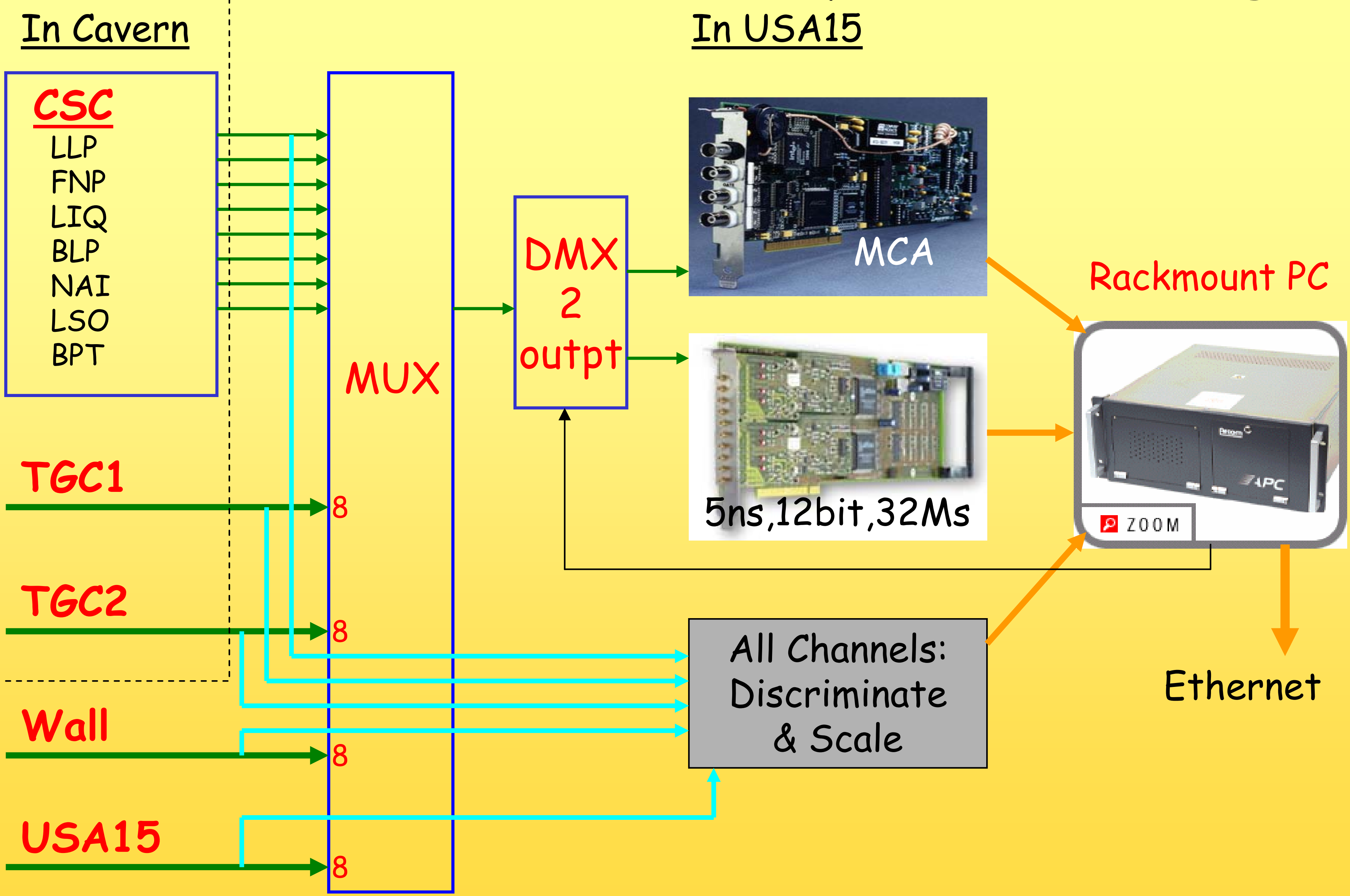
DAQ: Local and Remote, Analysis and Monitoring



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Fluxes, and Sensor Counting Rates

Fluxes in KHz/cm^2 at luminosity 10^{34}:

	n,therm	n,fast	γ<10MeV	γ>10MeV	h>10MeV
CSC Region	40.6	38.1	31.8	0.74	7.3
TGC1 Region	3.2	1.7	15.8	.061	.59
TAS region	1.5	1.3	1.82	.023	.078

EG: ^{10}B lined proportional tube with A = 70 cm^2, ε = .001, operating at a luminosity of 10^{33}, counting thermal neutrons, with pulse height discrimination against other backgrounds:

CSC: 284 Hz   TGC1 : 22.4 Hz   TAS: 10-20 Hz

Looks reasonable. We are applying this analysis to all sensors.

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Modes of Background Analysis

Quick Extraction of Thermal Neutron Rates

Detectors doped with lithium or boron are sensitive to thermal neutrons via reactions that lead to heavy fission products. The resulting spectra have characteristic peaks or shoulders that may be integrated to determine the number of thermal neutrons detected per unit time. Applying the detector efficiency factor for thermals to these interactions, one can determine the thermal neutron flux at the position of the detector—without doing further analysis.

Longer Term Analysis of Full Backgrounds

ATLAS backgrounds in the muon region consist primarily of photon and neutron fluxes, with smaller admixtures of other hadrons, and muons. Prediction of photon and neutron spectra is done by combining simulated spectra with detector response functions for all particle species, as has been done in previous ATLAS testbeam work. The measured spectra will contain characteristic features so that, with several different detector types, over some energy ranges it will be possible, by comparison with simulation, to deconvolute the backgrounds and "calibrate" the simulations. These improved simulations will lead to much greater accuracy in the predictions of Upgraded LHC backgrounds.

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Detectors in ATLAS

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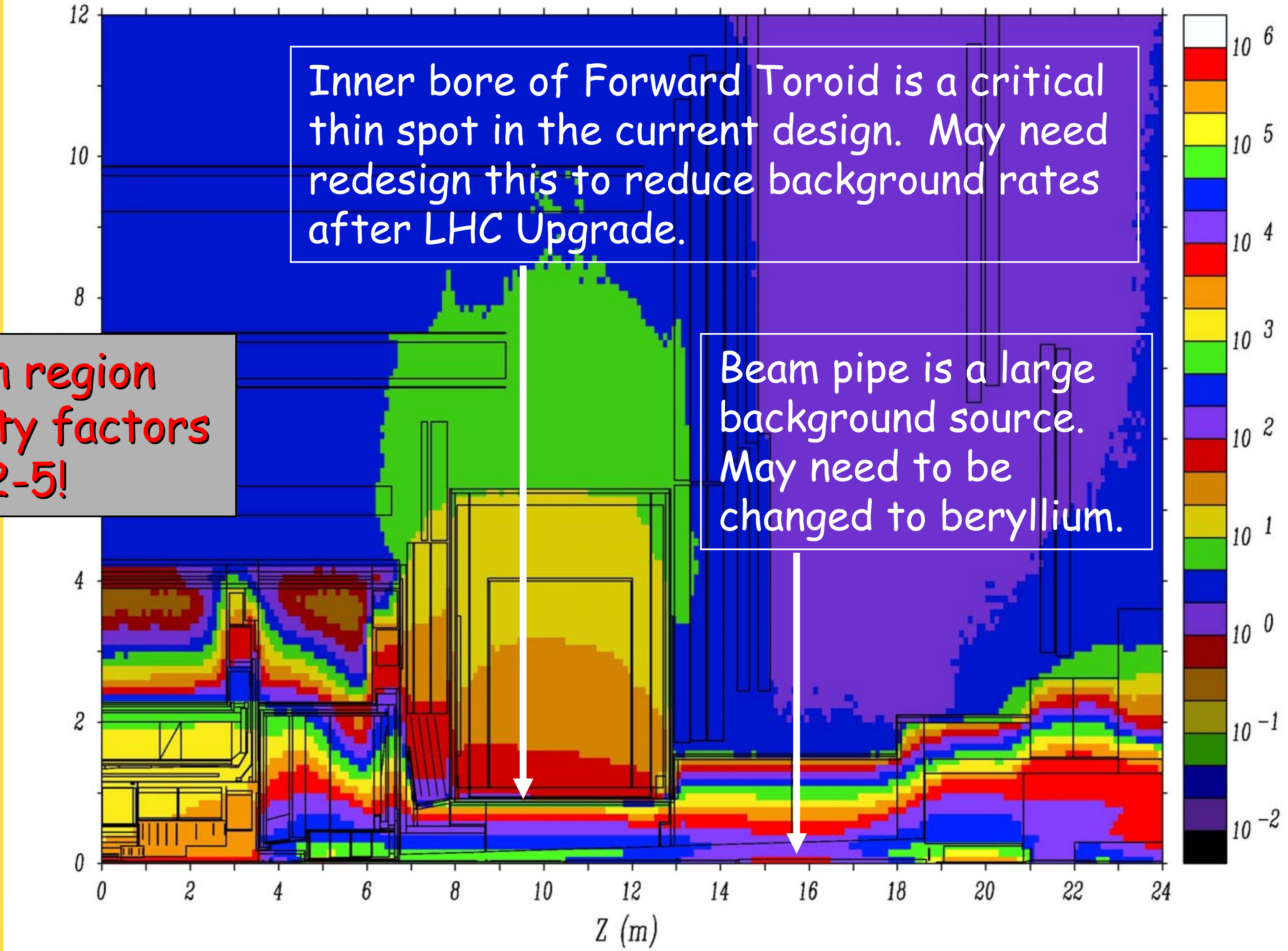
Note on LHC Upgrade Issues in the Muon System

Muon region safety factors are 2-5!



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Arizona Radiation Detectors Summary

- The primary aim of this project is to measure background fluxes in the ATLAS muon system as early as possible, to reduce safety factors and enable realistic upgrade engineering.
- Initially, the backgrounds may be dominated by beam gas collisions and halo particles. As luminosity rises, it will be possible to pick out the backgrounds due to collisions since their rates are proportional to instantaneous luminosity.