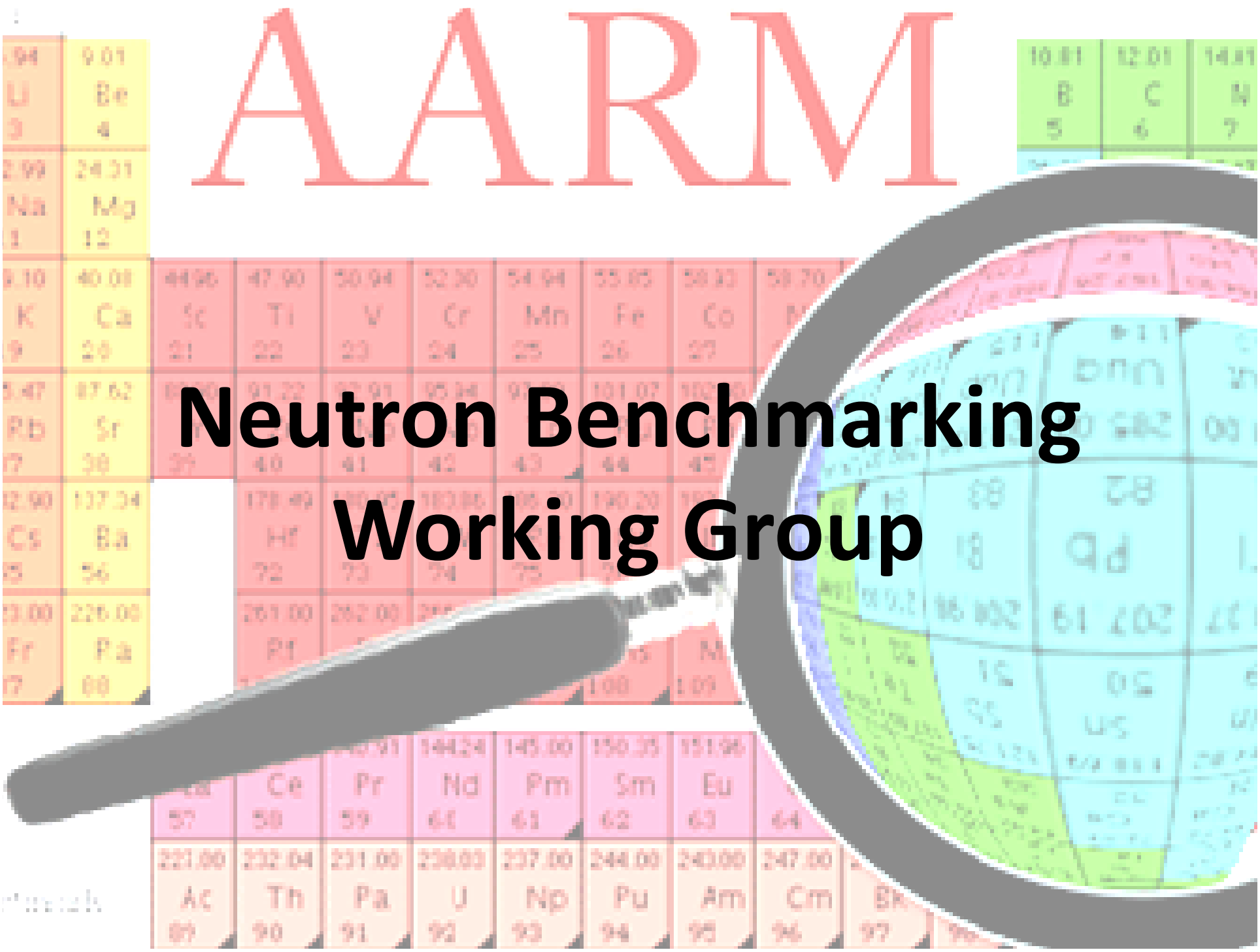

AARM
Neutron Benchmarking
Working Group

Introduction to Working Group

International collaboration of rare-event physicists interested in:

1. Improved understanding of neutron backgrounds (in general)
2. How best to measure, simulate, shield, and veto neutrons
3. Organization of data & use for physical constraints
4. Other muon-induced backgrounds (*e.g.*, bundles)

Working-group Chair → Ray Bunker
Working-group Co-chair → Anthony Villano

Working-group Wiki:

https://zzz.physics.umn.edu/lowrad/nmm

Meetings:

General-interest "summary" meetings → Fridays at 11 am eastern
Detailed data-analysis meetings → Tuesdays at 11 am eastern
Esnet 886388 (no pin) … *anyone interested is welcome to attend/present/discuss!*

Introduction to Working Group

Who …

Directly funded by AARM:

- Syracuse University → Ray Bunker, Yu Chen, Chris Nedlik, Richard Schnee
- U. of Arkansas at Little Rock → Anton Empl, Sarah Lindsay
- U. of Minnesota → Prisca Cushman, Matt Fritts, Sean Geldert, John Greavu, Joseph Jeffers, Anthony Villano
- U. of South Dakota → Dongming Mei, Chao Zhang, (Joel Sander)

Other active groups:

- Berkeley → Raul Hennings-Yeomans
- MIT → Adam Anderson, Julien Billard, Tali Feliciano, Alex Leder
- U. College London → Lea Reichhart
- Yale → Thomas Langford

Loosely affiliated groups:

- Case Western → Dan Akerib, Emily Dragowski, Chang Lee
- Regis University → Fred Gray
- Sandia/Livermore National Lab → Adam Bernstein, Caleb Roecker, Melinda Sweany
- U. Bologna → Marco Selvi
- UC Davis → Marc Bergevin, Mani Tripathi
- UC Santa Barbara → Harry Nelson

Working Group Activities

Neutron Detectors in the Soudan Mine: → **see Anthony Villano's talk tomorrow**

Neutron Multiplicity Meter (NMM) → high-energy neutrons at 2090 mwe

Primary effort → finalize measurement using 1st two years of data (ongoing)

Improved understanding of detector response:

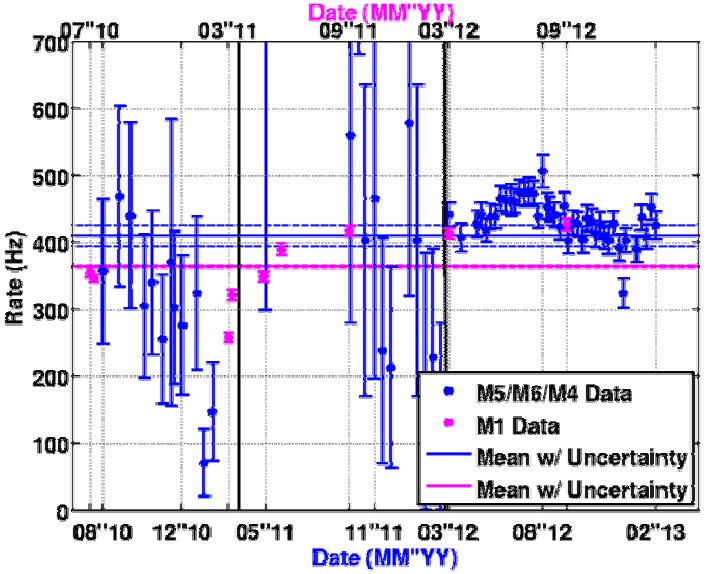
via Geant4 simulation starting with muons in rock

Detector stability via data-driven characterization

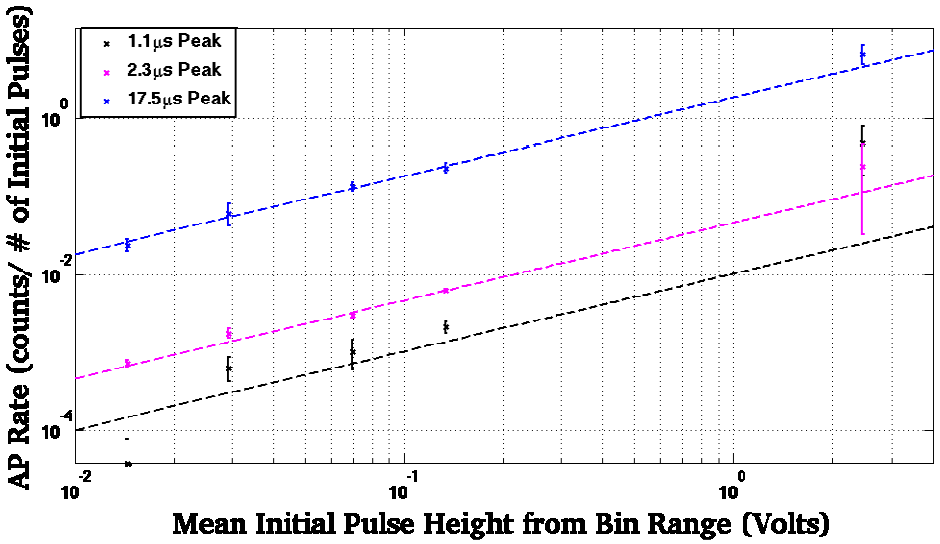
Effect of afterpulsing in large 20" PMTs

undergraduate analysis projects

Rate due to Background Gammas



Afterpulsing Rate vs. Initiating Pulse Height



Working Group Activities

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- Also, continued operations to improve stats & in concert with veto shield ↓

The Soudan full-cavern Veto Shield → showers, bundles & μ-neutron correlations

- Fully operational… working on stability and data management
- Established correlated GPS time stamps with NMM
- Developing general framework to permit correlations with other detectors
- Again → **see Anthony Villano's talk tomorrow**

Working Group Activities

Neutron Detectors in the Soudan Mine:

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U. South Dakota Liquid-scintillator Neutron Detector → medium- to high-energy neutrons

- Continued operation to improve statistics
- Continued development of data analysis & simulated response
- → **See Chao Zhang's talk tomorrow**

Working Group Activities

Friday Summary Meetings to explore wide range of topics:

- ^{3}He neutron-capture detector for monitoring reactor neutrons (MIT group)
- FaNS neutron spectroscopy for high-energy neutron benchmarking
  → **see Thomas Langford's talk tomorrow**
- WATCHMAN anti-neutrino monitoring (& high-energy neutrons)
  → **see Mark Gerling's talk tomorrow**
- Neutron yield in Pb using the ZEPLIN-III muon veto (L. Reichhart @ UCL)
- Medium- to high-energy flux of neutrons in the Davis cavern (USD group)
- Simulations to inform next-generation neutron-detector & -veto designs
- Further international collaboration (*e.g.*, with LVD and Edelweiss)
  →**see Marco Selvi's talk tomorrow (LVD)**
- Develop FLUKA model of the NMM for comparison to Geant4 (Arkansas group)

Thursday 3:30-6 pm Breakout Session
Identify topics and tasks

Neutron Benchmarking Topics

Measurements → **Thu 3:30-4:30 pm**

- Where are we now?
  - Which neutron/μ-related backgrounds are well measured?
    - Muon-induced neutrons
    - Others?
    - Organization of measurements and constraints?
- What remains to be done?
  - Which backgrounds are still poorly constrained?
    - High-energy neutron flux & energy spectrum *vs.* depth
      - → which production processes are least well constrained?
      - → topology with respect to parent muon/shower
    - Background from muon bundles
    - Long-lived isotopes from muon spallation & stopping muons
    - Radiogenic bencmarking
    - Others?

Summary papers:
Mei & Hime, PRD **73** (2006) 053004
Araujo *et al.*, NIM A **545** (2005) 398
Kudryavtsev *et al.*, NIM A **505** (2004) 688
Kudryavtsev *et al.*, Eur. Phys. J. A **36** (2008) 171
Wang *et al.*, PRD **64** (2001) 013012

Detector-specific papers:
KamLAND—Abe *et al.*, PRC **81** (2010) 025807
Galbiati & Beacom, PRC **72** (2005) 025807
Modaine—Kozlov *et al.*, Astropart. Phys. **34** (2010) 97
Zeplin III—Reichhart *et al.*, Astropart Phys. **47** (2013) 67
Borexino—Bellini *et al.*, JCAP **1308** (2013) 049
LVD—Persiani *et al.*, AIP Conf. Proc. **1549** (2013) 235

Spallation-source papers:
Chazal *et al.*, Nucl. Phys. A **663** (2000) 885
Marion *et al.*, NIM A **582** (2007) 611

Data – Part I → **Thu 4:30-5 pm**

- Existing data sets — can new measurements be made with existing data?
  - LVD, Borexino, and other large-volume detectors

Cross-collaboration with Simulation Working Group → **Thu 5-6 pm**

Friday 4-6 pm Breakout Session
Prioritize topics and plan future work

Neutron Benchmarking Topics

Data – Part II → **Fri 4-4:30 pm**

- Near-term expected data — what can/will we do with data from current experiments?
  - NMM, FaNS, WATCHMAN, USD detector, and others

Detector Technology → **Fri 4:30-6 pm**

- Pros & cons of different neutron-detection technologies
  - liquid scintillator *vs.* water
  - Gd *vs.* Li *vs.* B doping
  - modular *vs.* monolithic
  - *etc.*
- Design/proposal of next-generation neutron detector/facility for underground measurements
  - Also, neutron-veto design & prototyping
- Funding for underground benchmarking in general

Saturday 10:30 am – 12 pm
Integration into proposals, Consortium planning, and new integrative initiatives