Wikipedia: “Muons were discovered by Carl D. Anderson & Seth Neddermeyer at Caltech in 1936”

“Who ordered that?!?” – I.I. Rabi, 1937

Actually seems to have been first observed in a cloud chamber in Rostock Germany in 1933!

Kunze, P., Z. Phys. 83, (1933) 1

“The other double trace of the same type (figure 5) shows closely together the thin trace of an electron of 37 MeV, and a much more strongly ionizing positive particle which a much larger bending radius. The nature of this particle is unknown; for a proton it does not ionize enough and for a positive electron the ionization is too strong. The present double trace is probably a segment from a "shower" of particles as they have been observed by Blackett and Occhialini, i.e. the result of a nuclear explosion.”
With a large area muon detector at mid-rapidity…

Physics:
- di-muon pairs from QGP thermal radiation, quarkonia, light vector mesons, resonances in QGP, and Drell-Yan production
  excellent mass resolution would separate different upsilon states
- single muons from the semi-leptonic decays of heavy flavor hadrons… e+muon correlation to distinguish heavy flavor production from initial lepton pair production
- advantages over electrons:
  - no γ conversion
  - much less Dalitz decay contribution
  - less affected by radiative losses in the detector materials

How could this be achieved?
- Hadron shielding is magnet backlegs and BEMC (~7X₀)
- Precise timing! start from upVPD, fast TOF hit + fast MTD hit, TPC + HFT matching
- Low-level trigger capability!
Multi-gap Resistive Plate Chamber (MRPC): gas detector, avalanche mode inexpensive, easy to build, but precise timing

The detectors cover the steel magnet backlegs and leave the φ-gaps uncovered.
Acceptance: ~45% at |η|<0.5

118 modules, 1416 readout strips, 2832 channels

Proven detector technologies
MRPC detectors & STAR-TOF electronics
Outline:
- MRPCs and “trays”
- Prototypes in runs 9-11
- The full system
- Run 12, 13, and 14 installations
- Some surprises from Run-13
- Summary
MRPCs fabricated at USTC, Tsinghua, and VECC
Tray Mechanics built in Houston & Austin
Tray Assembly at UT-Austin
MTD9 & MTD THUB

Three MTD11 trays (craned into place)

From East side looking West

backleg 1
backleg 26
Cosmic ray trigger
Total resolution: 109 ps
Start resolution (2 TOF hits): 46 ps
Multiple scattering: 25 ps
MTD intrinsic resolution: 96 ps
System spatial resolution: 2.5 cm, dominated by multiple scattering

pure muons
average $p_T$: ~6 GeV/c

10-gap module
$\sigma$: 109 ps

10-gap module
$\sigma$: 2.5 cm
### Project Schedule and Institutions

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10% installation for Run12, 43% for Run13, 80% for Run 14. Finish the project by Mar, 2014

**MTD institutions:** Brookhaven National Laboratory, University of California-Berkeley, University of California-Davis, Rice University, University of Science & Technology of China, Texas A&M University, University of Texas-Austin, Tsinghua University, Variable Energy Cyclotron Centre

**US institutions:** the electronics, the assembly of the trays and the operation of the detector

**Chinese and Indian institutions:** the fabrication of the MRPC modules
US DOE Proposal:
15 “5-packs” over the top
2 “5-packs” just under equator
11 “3-packs” below
...118 MTD trays total
...N/S & E/W symmetric

implemented in STAR geant simulations framework

http://www.star.bnl.gov/cgi-bin/protected/cvsweb.cgi/pams/geometry/mutdgeo/mutdgeo4.g?rev=1.2

also see http://wjllope.rice.edu/~MTD/MTDintegration.pdf
Muon Telescope Detector

Installation stages

Summer 2011: 3 BLs, 13 trays
Summer 2012: 15 BLs, 75 trays
Summer 2013: 11 BLs, 37 trays
+ 2 BLs, 10 trays

Proposal: 118 trays
Target now: 122 trays
Muon Telescope Detector

Full System Installation Locations

above STAR

BEMC PMT boxes

below STAR

BEMC crates
Trays on 3 backlegs installed by STSG

Then all cabling added afterwards.
This took ~1.5 man-months (!)

Anthony Kesich
Chengming Du
Chi Yang
WJL

Thirteen MRPCs…

28: tsu, tsu, tsu, tsu, tsu
27: ust, tsu, tsu, tsu, ust
26: xxx, ust, ust, ust, xxx

USTC and Tsinghua modules grouped together on single HV supply channels


System ran fine throughout Run-12.

(One problem w/ 28-3 HV polarity fixed mid-run)
By Nov. 13th, 63% of the MTD system was installed at STAR for Run 2013, electronics commissioning is on-going. Superseded the milestone (43%) for Run 2013.

new gas distribution system, new monitoring and controls station, MTD trigger development …MTD standing on its own… (less an extension of TOF)
Installation of the trays “below STAR” is in progress now!

Nine BLs inside the “cradle”
Lowest 3 of these must be installed when STAR is in the Assembly Building, and require special hardware

Two BLs just outside the cradle (BLs 11 and 21) require ~5” radial standoffs…

Installation is generally going well...

For BLs 8 and 24, special hardware will be needed to avoid the magnet bus covers.
This hardware is not yet designed...
These trays cannot be “centered” on the magnet backleg steel i.e. some of the active area is in the gap between backlegs
Will the higher fluxes there make these trays inoperable?
68 TLDs of two types were installed all over the WAH on May 22, 2013

Are fluxes near phi-gaps hugely larger than behind the BL steel?

Results indicate that the fluxes in the gaps are not significantly larger than those behind the steel...

So MTD trays can go on 8 and 24 once we determine a mechanical mounting scheme...
We were quite worried about the very high noise rates seen during Run-12.

Began adding “H-foam” to the trays during the assembly at UT, & before Run-13,
Lots of new shielding in the east and west tunnels added by C-AD...
New reversible-flow gas distribution system with precise control...

803-839: pp 500 GeV run
860: gas flow doubled from 50 to 100 ccm per gas loop
866: gas flow increased to 180 ccm, gas flow direction reversed, end of U+U run
888: cooling loop added to tray 28-5
These changes appear to have helped!
During run-13, there was a catastrophic beam-loss event that tripped all of STAR. April 9, 2013 17:52 EST

We would learn over the following ~months that this event took out more than half of the MTD electronics (“MINO”) in the system!

During this shutdown, all of the MINO boards on installed trays were removed, and these plus all MINOs on new trays were modified to double the number of electrostatic discharge protection devices.
Fabrication of MRPCs at USTC and Tsinghua is complete
They work well
~10 MRPCs at VECC (Kolkata) in progress

Run-13 was a serious commissioning run
~64% of the full system installed
DAC autorecovery implemented
Slow controls interfaces
Development of timing triggers

Installation is going well
Top of STAR is done
Bottom of STAR is underway now
Project is on-track for completion on time.

Dealing with damage from a major beam loss event
All electronics removed and revised
Dosimetry indicates BLs 8 & 24 will be possible

谢谢您的款待