# A Novel and Compact Muon Telescope Detector at STAR for Dilepton Program at RHIC

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Outline:

- **Introduction and physics motivation for STAR-MTD**
- **Simulation**
- **R&D results**
- **Conclusions**

**http://www.star.bnl.gov/~ruanlj/MTDreview2010/mtd.htm**

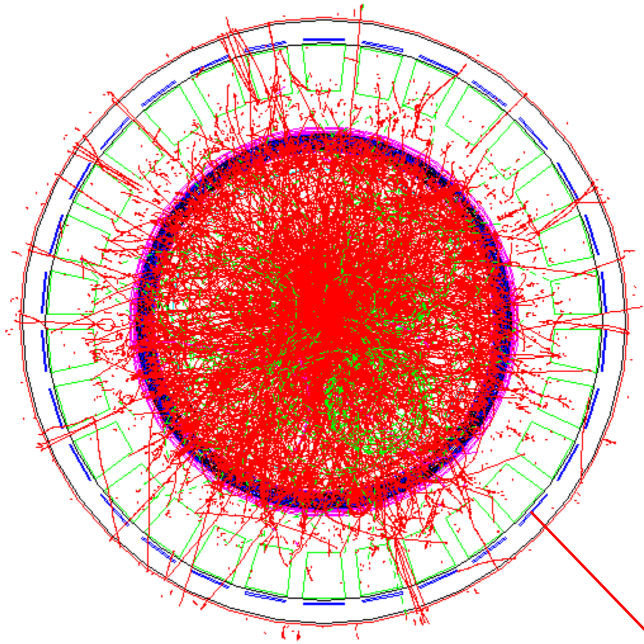
**http://www.star.bnl.gov/~ruanlj/MTDreview2010/MTD_proposal_v14.pdf**

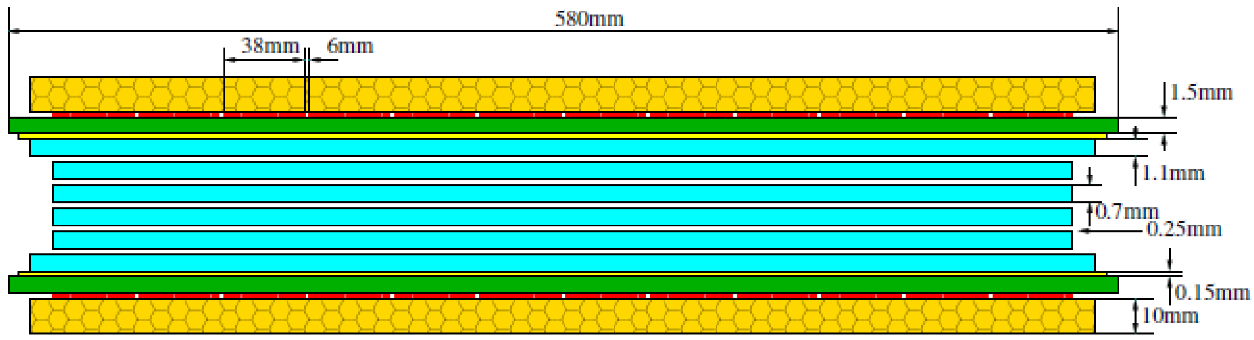
# STAR-MTD Physics Motivation

A large area of muon telescope detector (MTD) at mid-rapidity, **allows for the detection of**

- **di-muon pairs** from QGP thermal radiation, quarkonia, light vector mesons, resonances in QGP, and Drell-Yan production
- **single muons** from the semi- leptonic decays of heavy flavor hadrons
- **advantages over electrons:** no $\gamma$ conversion, much less Dalitz decay contribution, less affected by radiative losses in the detector materials, trigger capability in Au+Au
- **trigger capability for low to high $p_T$ J/$\psi$ in central Au+Au collsions excellent mass resolution, separate different upsilon states e-muon correlation to distinguish heavy flavor production from initial lepton pair production**

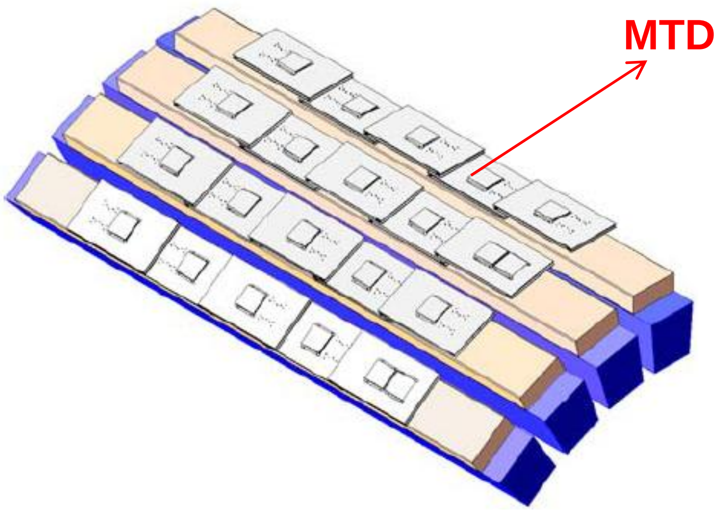
# Concept of Design of the STAR-MTD






**Multi-gap Resistive Plate Chamber (MRPC): gas detector, avalanche mode**

MTD

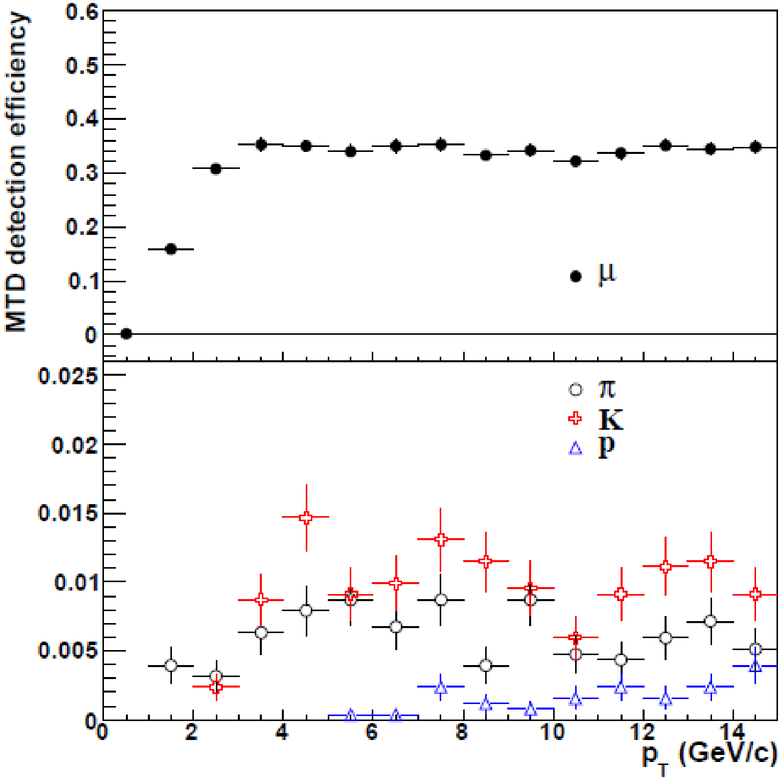


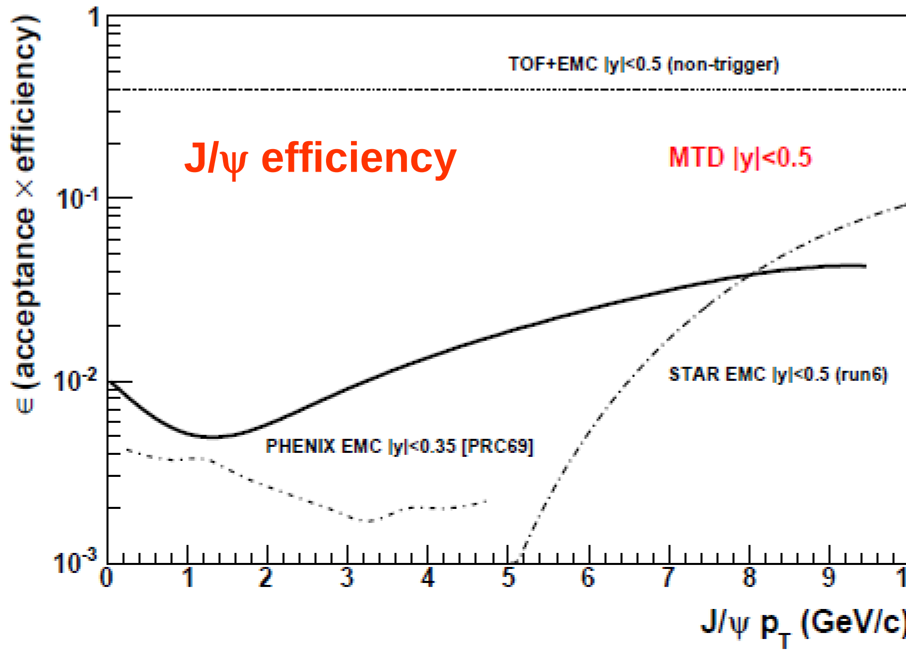
**A detector with long-MRPCs covers the whole iron bars and leave the gaps in-between uncovered. Acceptance: 45% at |η|<0.5**

**118 modules, 1416 readout strips, 2832 readout channels**

**Long-MRPC detector technology, electronics same as used in STAR-TOF**

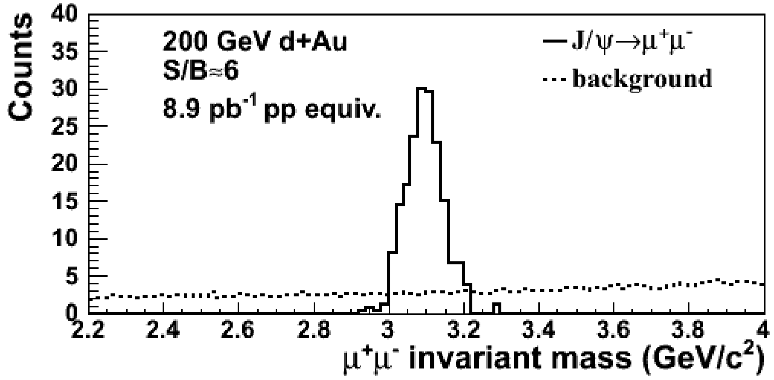
# Single Muon and J/ψ Efficiency

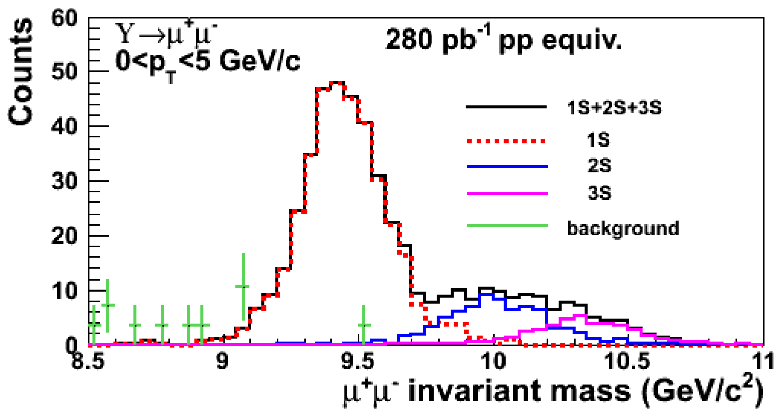



1. **muon efficiency at |η|<0.5: 36%, pion efficiency: 0.5-1% at $p_T$>2 GeV/c**
2. **muon-to-pion enhancement factor: 50-100**
3. **muon-to-hadron enhancement factor: 100-1000 including track matching, tof and dE/dx**
4. **dimuon trigger enhancement factor from online trigger: 40-200 in central Au+Au collisions**

# High Mass Di-muon Capabilities




1. J/ψ: S/B=6 in d+Au and S/B=2 in central Au+Au
2. With HFT, study B→J/ψ X; J/ψ→μμ using displaced vertices
3. Excellent mass resolution: separate different upsilon states

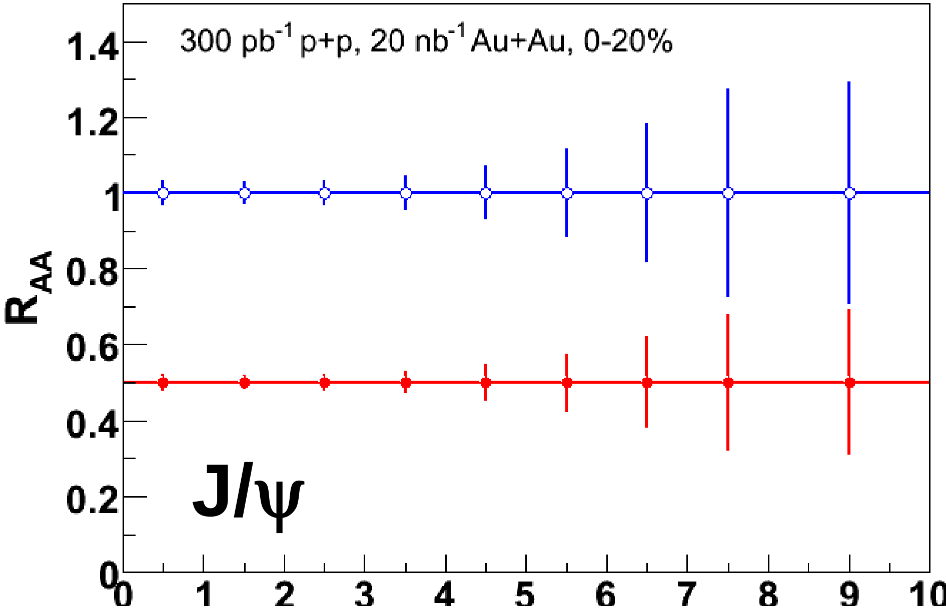
Heavy flavor collectivity and color screening, quarkonia production mechanisms:
J/ψ $R_{AA}$ and $v_2$; upsilon $R_{AA}$ …

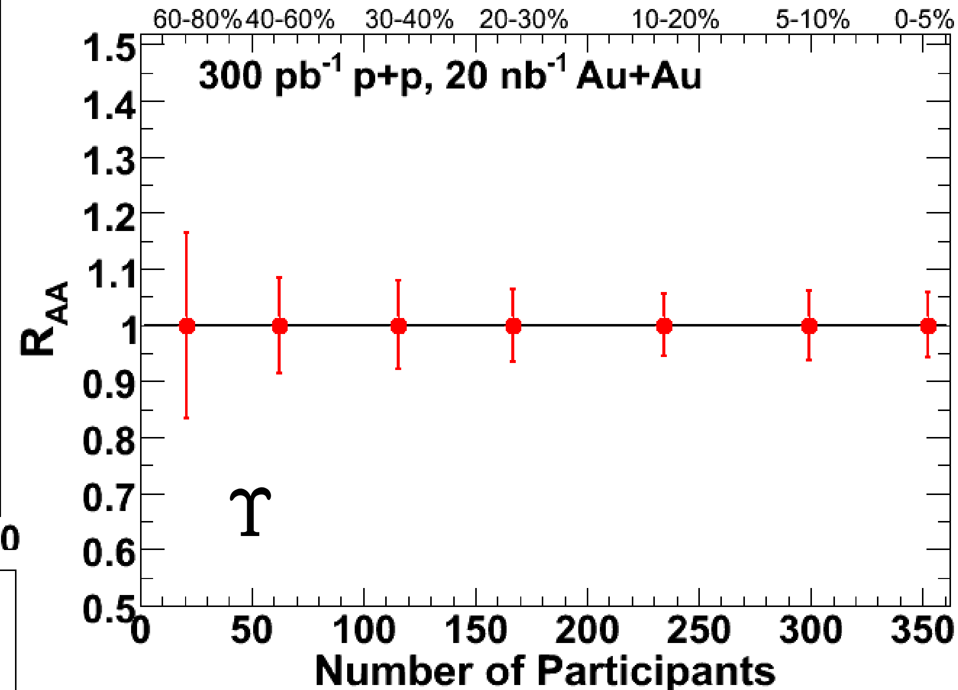
Z. Xu, BNL LDRD 07-007; L. Ruan et al., Journal of Physics G: Nucl. Part. Phys. 36 (2009) 095001

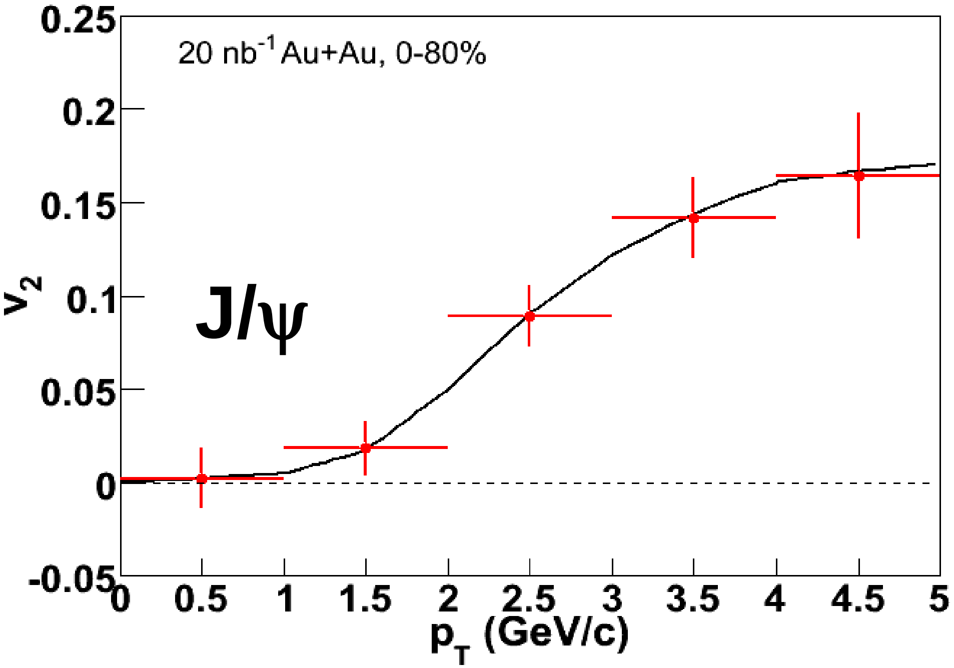
Quarkonium dissociation temperatures – Digal, Karsch, Satz

| state | $J/\psi(1S)$ | $\chi_c(1P)$ | $\psi'(2S)$ | $\Upsilon(1S)$ | $\chi_b(1P)$ | $\Upsilon(2S)$ | $\chi_b(2P)$ | $\Upsilon(3S)$ |
|---|---|---|---|---|---|---|---|---|
| $T_d/T_c$ | 2.10 | 1.16 | 1.12 | $>4.0$ | 1.76 | 1.60 | 1.19 | 1.17 |

# Future Measurement Projection



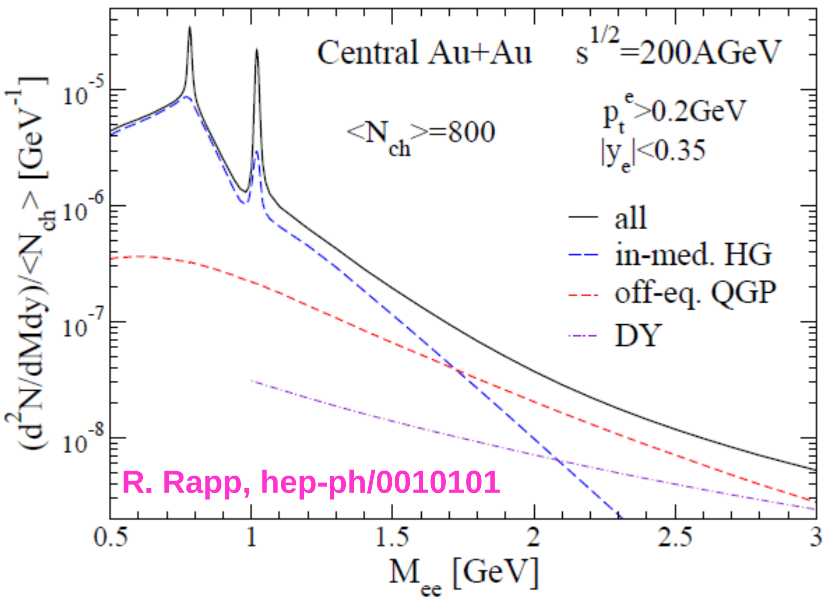



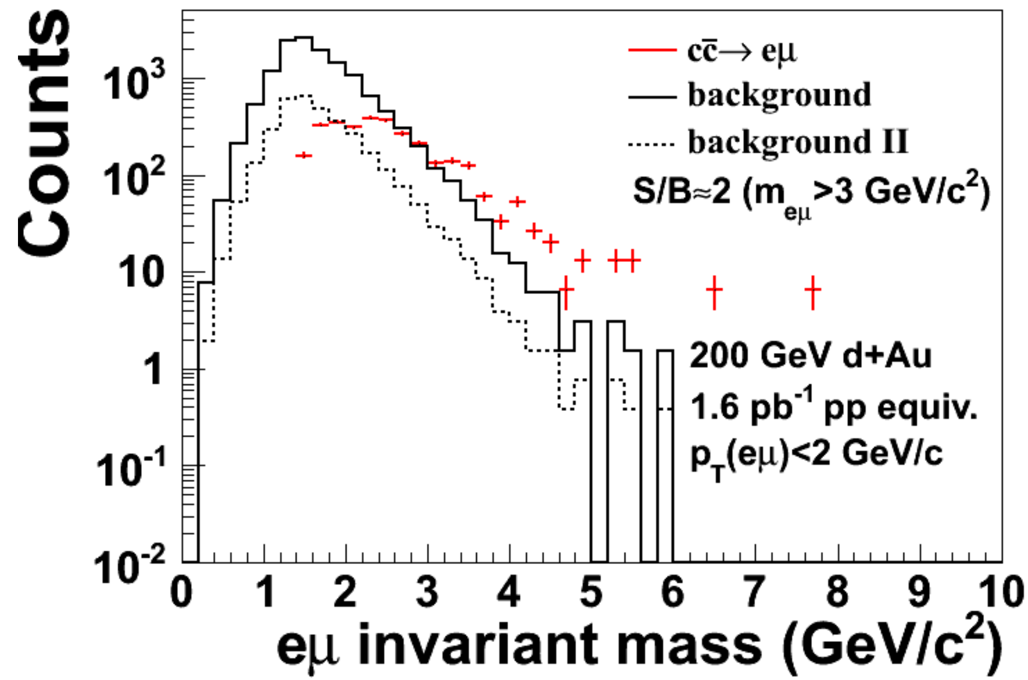

J/ψ $R_{AA}$ and $v_2$;
ϒ (1S+2S+3S) $R_{AA}$ versus $N_{part}$…

300 $pb^{-1}$ 200 GeV p+p (~24 weeks RHIC run)
20 $nb^{-1}$ 200 GeV Au+Au (~12 weeks)

Different Upsilon states in 500 GeV p+p collisions can be measured with good precision from 12 weeks run.

# Distinguish Heavy Flavor and Initial Lepton Pair Production: e-muon Correlation

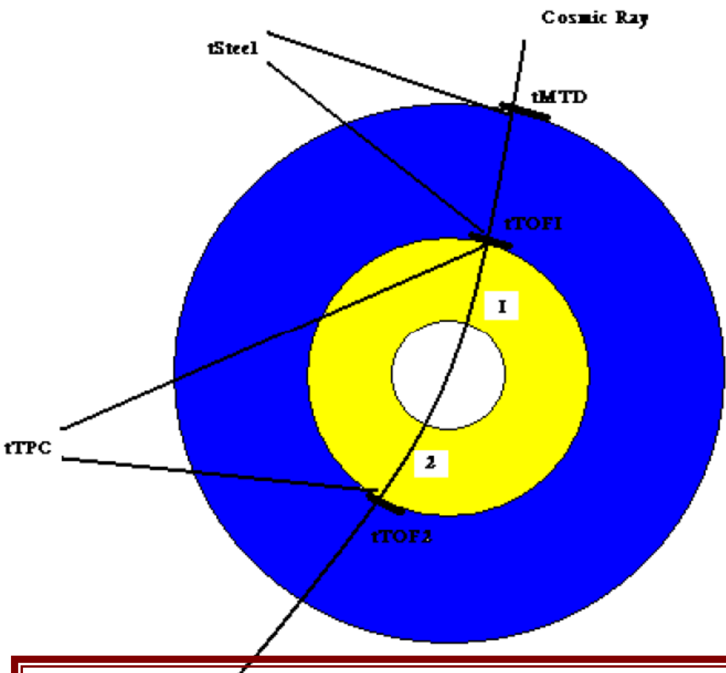


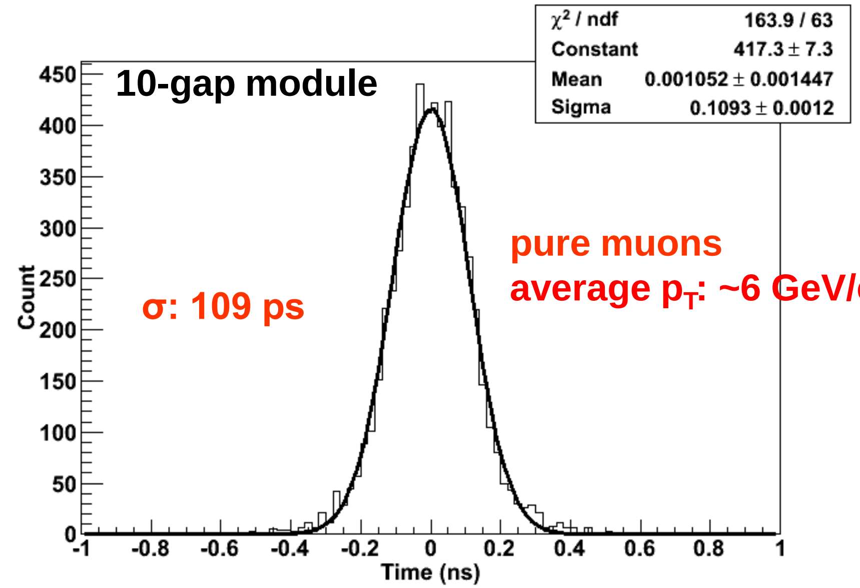



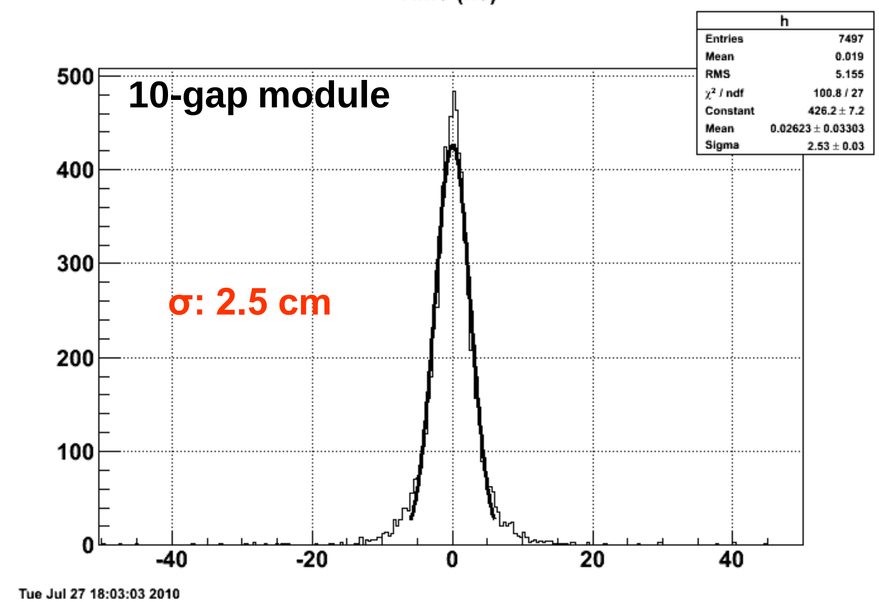

eμ correlation simulation with Muon Telescope Detector at STAR from ccbar:

- S/B=2 ($M_{eu}$>3 GeV/$c^2$ and $p_T(e\mu)$<2 GeV/c)
- S/B=8 with electron pairing and tof association

# Run 10 Performance: Time and Spatial Resolution




**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**

# Summary

- MTD will advance our knowledge of Quark Gluon Plasma:

  **trigger capability for low to high $p_T$ J/$\psi$ in central Au+Au collsions**

  **excellent mass resolution, separate different upsilon states**

  **e-muon correlation to distinguish heavy flavor production from initial lepton pair production**

  **rare decay and exotics …**

  **different background contribution provides complementary measurements for dileptons**

- The prototype of MTD works at STAR from Run 7 to Run 11. Results published at L. Ruan et al., Journal of Physics G: Nucl. Part. Phys. **36** (2009) 095001; 0904.3774; Y. Sun et al., NIMA 593 (2008) 430; Y. Wang et al., NIMA 640 (2011) 85.

- The MTD project is funded: the construction has started and will end in Mar. 2014:10% installation for Run 12, 43% for Run 13, 80% for Run 14.

# Backup

# Upsilon Statistics Using MTD at |y|<0.5

**Delivered luminosity: 2013 projected;**
**Sampled luminosity: from STAR operation performance**

| Collision system | Delivered lumi. 12 weeks | Sampled lumi. 12 weeks (70%) | ϒ counts | Min. lumi. precision on ϒ (3s) (10%) | Min. lumi. precision on ϒ (2s+3s) (10%) |
|---|---|---|---|---|---|
| 200 GeV p+p | 200 $pb^{-1}$ | 140 $pb^{-1}$ | 390 | 420 $pb^{-1}$ | 140 $pb^{-1}$ |
| 500 GeV p+p | 1200 $pb^{-1}$ | 840 $pb^{-1}$ | 6970 | 140 $pb^{-1}$ | 50 $pb^{-1}$ |
| 200 GeV Au+Au | 22 $nb^{-1}$ | 16 $nb^{-1}$ | 1770 | 10 $nb^{-1}$ | 3.8 $nb^{-1}$ |

**Upsilon in 500 GeV p+p collisions can also be measured with good precision.**

# The Details for the R&D Modules

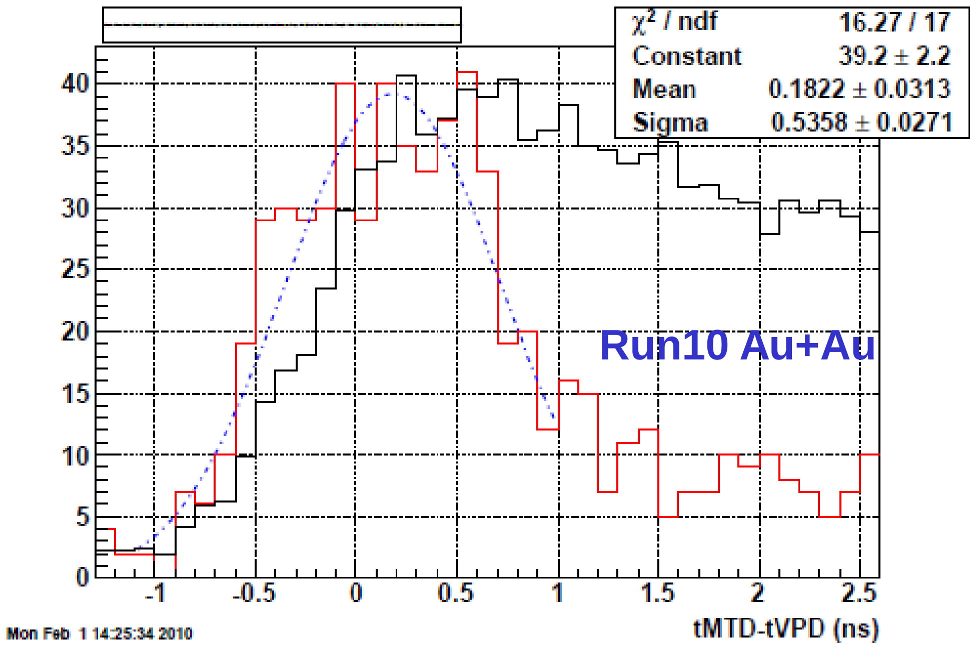
| Conditions | Modules and readout |
| --- | --- |
| **Cosmic ray and Fermi-lab T963 beam tests** | **double stacks,**<br>**module size:** 87(z)$\times$17($\phi$) cm$^2$,<br>Performance: 60 ps, ~0.6 cm at HV $\pm$ 6.3 kV |
| **Run 7: Au+Au**<br>**Run 8: p+p, d+Au** | **double stacks, 2 modules in a tray, module size:** 87(z)$\times$17($\phi$) cm$^2$,<br>Readout: trigger electronics,<br>Time resolution: 300 ps |
| **Run 9: p+p**<br>**Run 10: Au+Au, cosmic ray** | **double stacks, 3 modules in a tray, module size:** 87(z)$\times$17($\phi$) cm$^2$,<br>Readout: TOF electronics; trigger electronics for trigger purpose. |
| **Run 11** | **single stack, 1 module in a tray, module size:** 87(z)$\times$52($\phi$) cm$^2$,<br>Readout: TOF electronics; trigger electronics for trigger purpose,<br>Cosmic ray test performance: <100 ps |

R&D from 2007 to 2011 led to a final design.

# Trigger Capability with MTD Acceptance

**RHIC II lumonisity in terms of collision rate: 40 k Hz;**
**Au+Au projection: based on Run 10 prototype performance.**

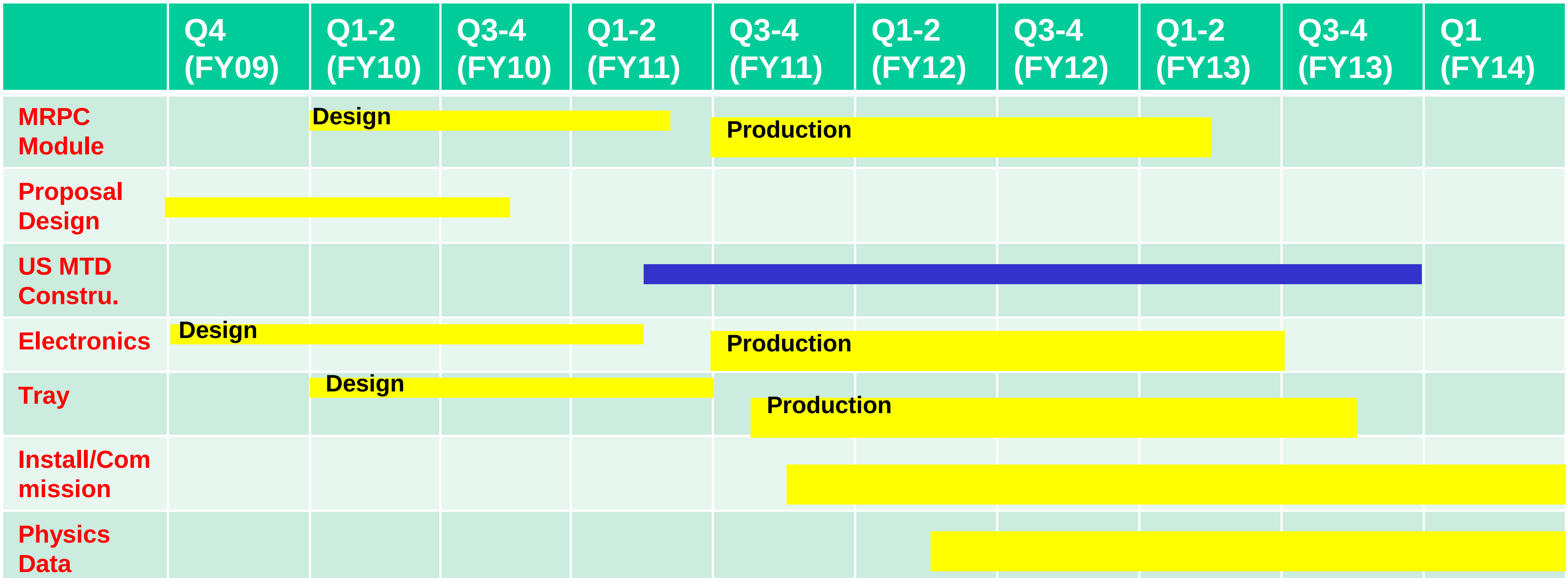
| trigger time window | double-hit rejection factor | dimuon L0 trigger rate |
|---|---|---|
| 2 ns | 50 | 800 Hz |
| 1.5 ns | 116 | 185 Hz |
| 1 ns | 509 | 80 Hz |




**1 ns trigger window: 80 Hz for dimuon trigger**

| L0 trigger timing resolution (assumed) | di-muon trigger efficiency of the timing cut |
|---|---|
| 140 ps | ±3.6σ (100%) |
| 200 ps | ±2.5σ (98%) |
| 300 ps | ±1.7σ (80%) |

# MTD Schedule




**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