Experimental overview on EM observables

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EM probes

**Dilepton**
- New results from PHENIX for $\sqrt{s_{NN}} = 200$ GeV (PHENIX)
- Collision energy/system size dependence (STAR)

**Photon**
- $v_2$ and $v_3$ of thermal photons (PHENIX)
- Thermal photon yield (ALICE)

**EW boson**
- Centrality dependence in Pb+Pb (ATLAS/CMS)
- Centrality dependence in p+Pb (ATLAS)
- nPDF in p+Pb (ATLAS/CMS/ALICE)
Dilepton
Au+Au $\sqrt{s_{NN}} = 200$ GeV

**Au+Au PHENIX**

**Au+Au STAR**

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**min. bias Au+Au $\sqrt{s_{NN}} = 200$ GeV**

- DATA
- $\pi^0 \rightarrow \gamma e e$
- $J/\psi \rightarrow e e$
- $\eta \rightarrow \gamma e e$
- $\eta' \rightarrow e e$
- $c\bar{c} \rightarrow e e$ (PYTHIA)
- $\rho \rightarrow e e$
- $\sum$
- $\omega \rightarrow e e$ & $\rho^0 e e$
- $\phi \rightarrow e e$ & $\eta e e$
- $b\bar{b} \rightarrow e e$ (PYTHIA)
- $c\bar{c} \rightarrow e e$ (random correlation)

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**Au + Au $\sqrt{s_{NN}} = 200$ GeV (MinBias)**

- $p_T > 0.2$ GeV/c, $|\eta^0| < 1, |y_{ee}| < 1$

- **Data/Cocktail**
- $\pi^0, \eta, \eta', \omega, \phi$
- $J/\psi, \psi', b\bar{b}, DY$
- $c\bar{c}$ PYTHIA

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**Data/Cocktail**

PRC 81 (2010) 034911

PRC 92 (2015) 024912
**New PHENIX results**

- **Au+Au PHENIX (2010 data)**

  ![Graph](image)

- **HBD upgrade**
  - Better hadron rejection: 30% → 5%
- **Better signal sensitivity**
- **Analysis improvements**
  - Neural Network
  - Flow modulation incorporated in the mixed events by an exact analytical method
  - Absolutely normalized correlated BG

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**Minimum bias data/cocktail**

**PHENIX and STAR results are now consistent**
New PHENIX results

Au+Au PHENIX (2010 data)

- HBD upgrade
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Minimum bias data/cocktail

arxiv: 1509.04667
Cross sections are derived using IMR in d+Au collisions

Uncertainty in extrapolation to m≈0

Lack of understanding in \( c\bar{c} \) cross section/correlation

Hadronic decays of D mesons (STAR, \( \text{PRL 113 (2014) 022301} \))

\[ \frac{d\sigma^{pp}}{dy} = 171 \pm 26 \text{ } \mu\text{b} \text{ (PYTHIA)} \]
LMR (0.3 – 0.76 GeV/c²)

Au+Au PHENIX

\( p_T \) dependence

- Enhancement over all \( p_T \) range

centrality dependence

- Increase with centrality

arxiv: 1509.04667
- Two extreme scenarios:
  - $c\bar{c}$ correlation remains the same in Au+Au as in p+p/p+A
  - $c\bar{c}$ totally decorrelated
    - There is room for QGP radiation
- Newly installed detectors in PHENIX/STAR
  - VTX(PHENIX)/HFT(STAR): Rejection of off-vertex electrons
  - MTD(STAR): e-\mu (no contribution from QGP radiation)
Broadening of $\rho$ meson explains the LMR excess in the energy region $\sqrt{s_{NN}} = 20$–200 GeV including $p_T$ and centrality dependence.

Talk by M. Makek
Broadening of $\rho$ meson describes LMR excess also in the heavier system

**STAR preliminary**

Talk by S. Yang
- Link to chiral restoration?
- Measurement of the $a_1$ meson is experimentally difficult
- According to PLB 731(2014)103, the medium-modified $\rho$ and $a_1$ meson degenerate with each other at high $T$. 

![Graph showing the broadening of $\rho$ meson at different temperatures](image-url)
Acceptance corrected excess in STAR is consistent with that in NA60 within large experimental uncertainties.

- BESII: x10 statistics
- Dielectron excess $\propto T_{\text{fireball}}$
- Size/Energy dependence

PLB 750 (2015) 64
System size and energy dependence

Au+Au STAR
In+In NA60

Talk by S. Yang
- Fireball lifetime is longer in central collisions than in peripheral collisions
**System size and energy dependence**

- Fireball lifetime is longer in central collisions than in peripheral collisions
- Fireball lifetime is longer in central 200 GeV than in low energies

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**Talk by S. Yang**

PLB 750 (2015) 64
EPJC 59 (2009) 607
- Ar+KCl: The spectrum is well described by a model
  - LVM broadening + system evolution with UrQMD
- pp: excess from cocktail
  - Insufficient description of Resonance → pee
Future Low energy experiments

- RHIC BES II (2018-)
- FAIR SIS100 HADES/CBM (2022-)
- FAIR SIS300 CBM (???)
- NICA MPD (2019-)
- J-PARC HI (???)
- SPS NA60+ (???)

Talk by V. Kekelidze
Talk by H. Sako

$\sqrt{s_{NN}}$ (GeV)
In-medium modification of $\phi$ meson in cold nuclear matter
J-PARC pA: E16 experiment (2017-)

Poster by K. Ozawa

x100 stat, x2 mass resolution of E325
LHC-ALICE (2020-)

- Midrapidity
  - Inner Tracking System (ITS): Rejection of $c\bar{c}$ contribution, Less material budget
  - Time Projection Chamber (TPC): Continuous readout using GEM
- Forward rapidity (-4 < $\eta$ < -2.5)
  - Muon Forward Tracker (MFT): Improve mass resolution

Talk by P. S. Reichelt

**Midrapidity**

**Forward**

![Graphs showing data analysis](image-url)
Photon
- Excess from pQCD component is visible
  - PHENIX: $T_{\text{slope}} \sim 240 \pm 20$ MeV independent of centrality
  - ALICE: $T_{\text{slope}} \sim 304 \pm 11^{\text{stat}} \pm 40^{\text{syst}}$ MeV (0-20%)
- PHENIX: $dN/dy \propto N_{\text{part}}^\alpha$ ($\alpha = 1.38 \pm 0.03^{\text{stat}} \pm 0.07^{\text{syst}}$)
- Similar to dielectron excess ($\alpha = 1.44 \pm 0.1$, STAR)
- Difficult to explain both “large yield” and “large $v_2$ and $v_3$”
- Many new theoretical ideas: more hadron-hadron interaction in HG, enhanced photon around $T_c$, semi-QGP, viscous correction, initial magnetic field etc
- Models tend to underestimate yield and $v_2$
- Similar trend as PHENIX? Theory lines are lower than data points both in yields and $v_2$
EW boson in Pb+Pb

- Understanding of collision geometry
- Baseline for the study of quenching via EW-jet
- No deviation from $N_{\text{coll}}$ scaling is seen
  - Similar observation in Z (ATLAS) and W (CMS)
- Assuming EW boson production should scale with $N_{\text{coll}}$, data favors the standard Glauber as valid description of collision geometry in p+Pb collisions.
The shapes of rapidity distributions are better described by CT10+EPS09.
Summary

Dilepton

- PHENIX and STAR results at $\sqrt{s_{NN}} = 200 \text{ GeV}$ are now consistent.
- Uncertainty in the modeling of $c\bar{c}$ contribution affects both LMR and IMR.
- Acceptance corrected excess is studied as a function of system size/collision energy.

Photon

- Large yield, $v_2$ and $v_3$ of thermal photons keeps being a source of new theoretical ideas.
  - Later time emission seems significant.

EW bosons

- Scale with $N_{\text{coll}}$ in PbPb collisions.
- nPDF effects are visible in pPb collisions.
\( \rho \) broadening

**In+In NA60**

\[
\frac{dN_{ch}}{d\eta} = 140
\]

all \( p_T \)

**Au+Au STAR**

**Data - Cocktail**

- Rapp: vacuum \( \rho \) + QGP
- Rapp: broadened \( \rho \) + QGP
- PHSD: broadened \( \rho \) + QGP

\[ M_{ee} (\text{GeV}/c^2) \]

**References**

- EPJC 61 (2009) 711
- PRC 92 (2015) 024912
Glauber and GGCF

$p+\text{Pb ATLAS}$

$\text{ATLAS}$

$p+\text{Pb, 1 \mu b}^{-1}$

$\sqrt{s_{NN}} = 5.02 \text{ TeV}$

$y_{\text{cm}} = 0.465$

$-2.7 < \eta < 2.7$

$2 < \eta < 2.7$

$0 < \eta < 1$

$-1 < \eta < 0$

$-2.7 < \eta < -2$

Glauber

GGCF $\omega_{g}=0.11$

GGCF $\omega_{g}=0.2$

arxiv:1508.00848