Two-particle correlation via bremsstrahlung

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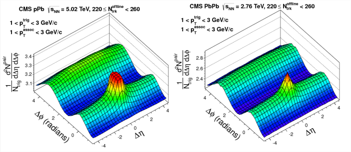
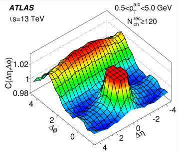
Ridge structure





Specific structure in two-particle angular correlations

This structure is understood through elliptic and higher-order flows for Pb-Pb collisions.

However, flows in small systems?

We try to describe this structure via kinematic interaction between jets and medium

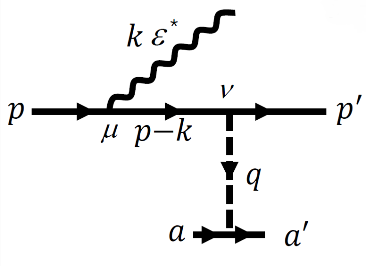
CMS collaboration, Physical Letters B **724**, 213240 (2013)

ATLAS collaboration, Physical Review Letters **116**, 172301 (2016)

Interaction between jet & medium

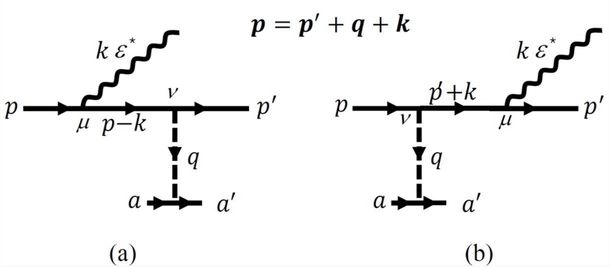
Energetic jet particles lose their energy while traversing the QGP via...

- Collision
- Radiation
  - Gluon radiation
  - **Photon radiation (Bremsstrahlung)**



* 1st order diagram for Bremsstrahlung

Bremsstrahlung processes



Two diagrams of γ emission and medium parton scattering might *inerfere constructively*.

$$d\sigma \sim |M_{(a)} + M_{(b)}|^2 = |M_{(a)}|^2 + |M_{(b)}|^2 + (\textbf{interference}) \qquad (1)$$

$\Rightarrow$ Medium parton aligned along the jet particle

$\Rightarrow$ Collective motion

$\Rightarrow$ **Can explain the ridge behavior**

Results

Correlation between

- p' & k

: final jet and emitted photon

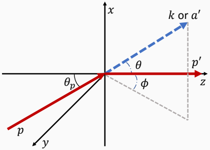
- p' & a'

: final jet and final medium parton

Set the coordinates

- z-axis along p'
- p on x-z plane

$\longrightarrow$ **Reaction plane**



Momentum distribution of initial medium partons

- Assume **Maxwell-Boltzmann distribution**
- **Fermi-Dirac distribution** gives same result

Initial condition

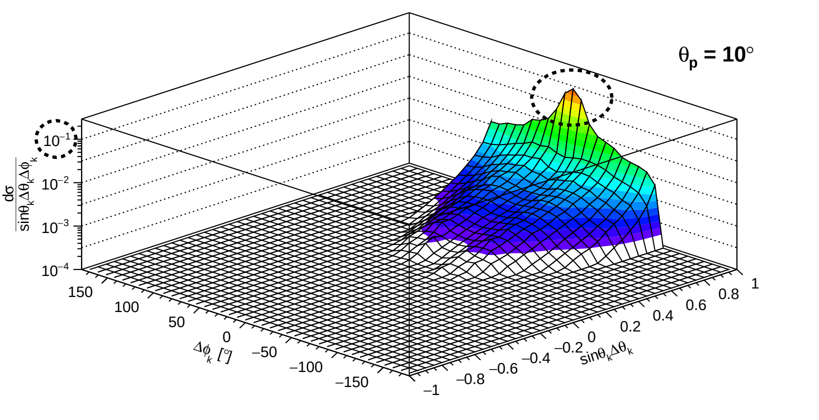
- $E = 10\,\mathrm{GeV}$
- $E = 9\,\mathrm{GeV}$

Correlation between p' and k

- Dependency check : $\theta_\mathbf{p} = \mathbf{10} \sim \mathbf{50}^\circ$

$\theta_\mathbf{p} = \mathbf{10}^\circ \qquad E_k = 500\,\mathrm{MeV} \qquad k_B T = 200\,\mathrm{MeV}$

*** The scale is reduced**



Correlation between p' and k

- Dependency check : $\theta_p = 10 \sim 50^\circ$

$\theta_p = 30^\circ$ $\quad E_k = 500\,\mathrm{MeV}$ $\quad k_B T = 200\,\mathrm{MeV}$

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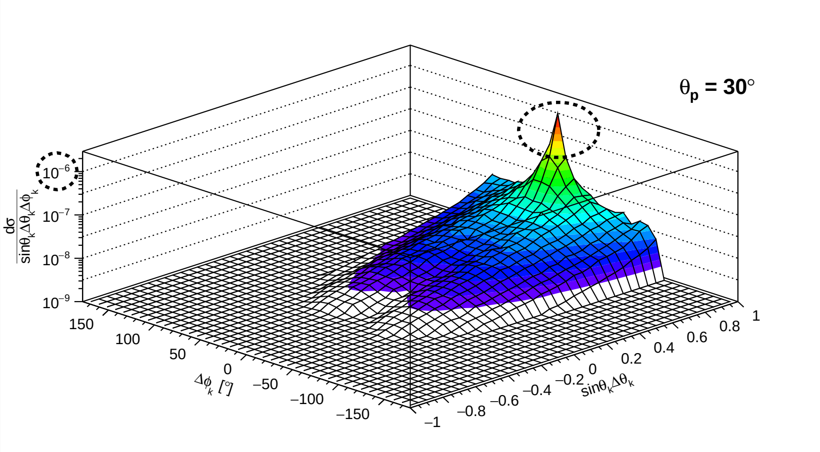

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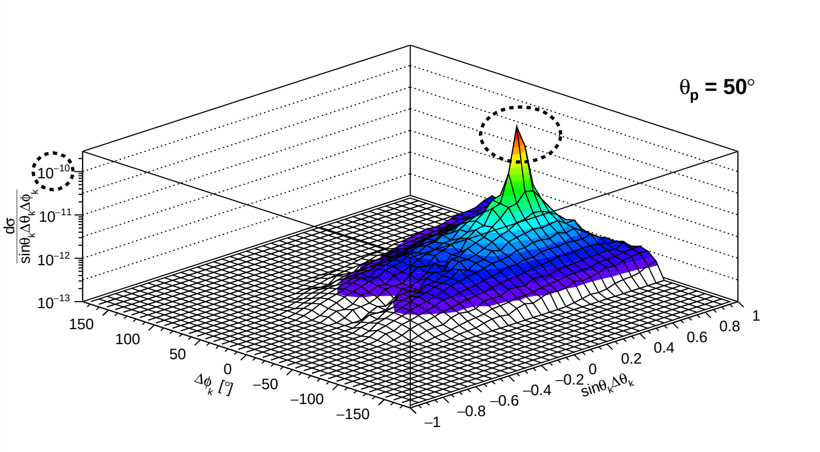


Correlation between p' and k

- Dependency check : $\theta_\mathrm{p} = 10 \sim 50^\circ$

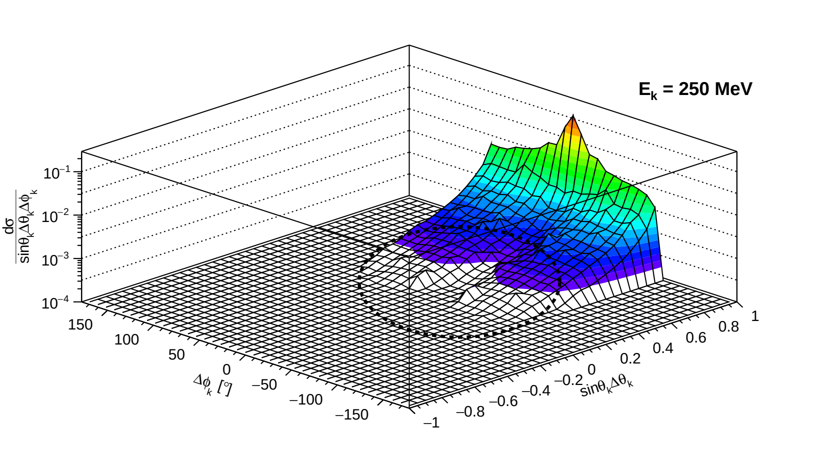
As θ_p increases...

- Peak position is shifted along p rather than p'
  - **Peak aligns to the initial jet particle**
- Peak amplitude reduces by ~ 0.0001 times
  - **High energy jet is hard to change its direction**
- Peak becomes sharper

Correlation between p' and k

- Dependency check : $\mathbf{E_k = 250 \sim 750}\,\mathrm{MeV}$

$$\theta_p = 10^\circ \qquad \mathbf{E_k = 250}\,\mathrm{MeV} \qquad k_B T = 200\,\mathrm{MeV}$$



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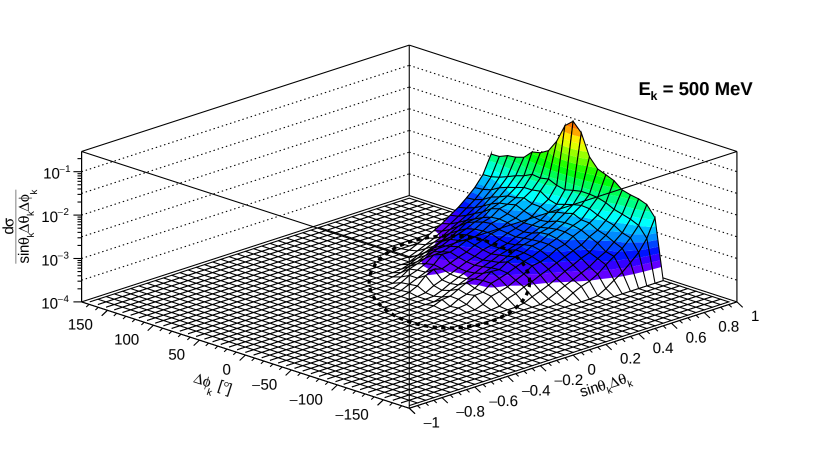

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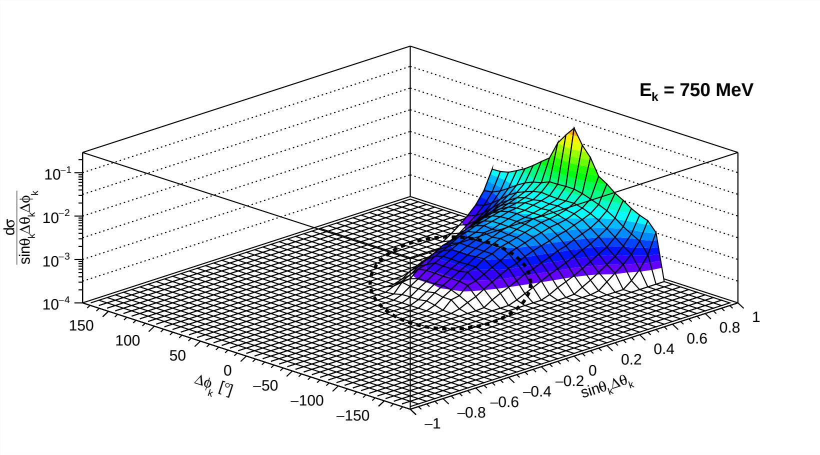


Correlation between p' and k

- Dependency check : $\mathbf{E_k = 250 \sim 750}\,\mathrm{MeV}$

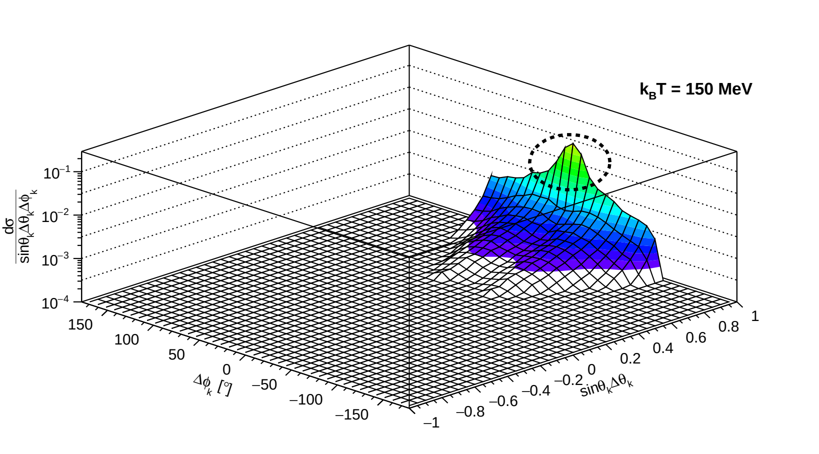
As E_k increases...

- Peak decreses by ~ 0.1
- Tails are combined at $\phi_k \approx 0$
- $d\sigma \sim 0$ for $\theta_k > 90^\circ$
- Possible region of $d\sigma \neq 0$ is getting shrinked
  - **Higher energy photon emits more in forward direction**

Correlation between p' and k

- Dependency check : $\mathbf{k_B T = 150 \sim 250}\,\mathrm{MeV}$

$\theta_p = 10\,^\circ \qquad E_k = 500\,\mathrm{MeV} \qquad \mathbf{k_B T = 150}\,\mathrm{MeV}$



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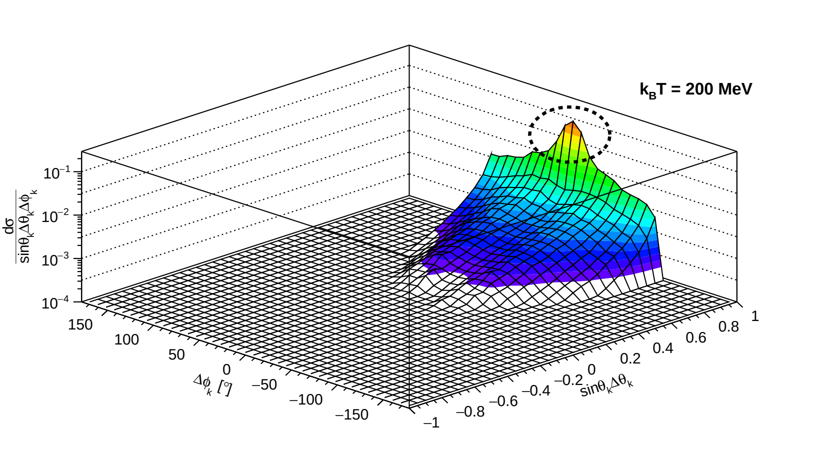

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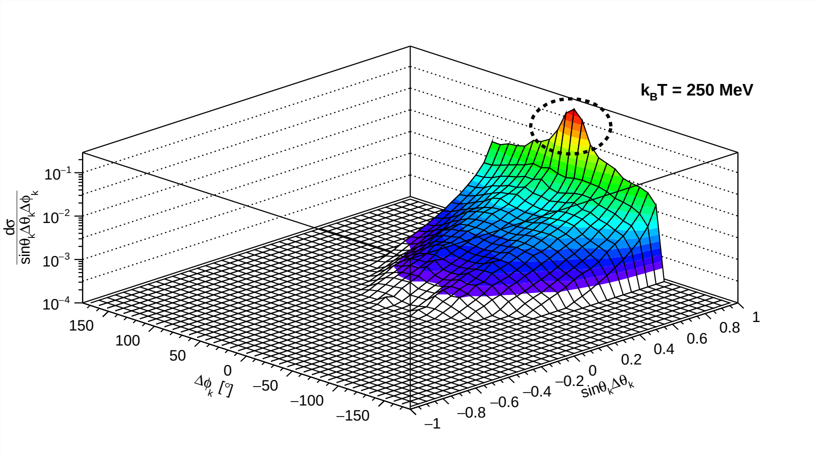


Correlation between p' and k

- Dependency check : $\mathbf{k_B T = 150 \sim 250}\,\mathrm{MeV}$

As T increases...

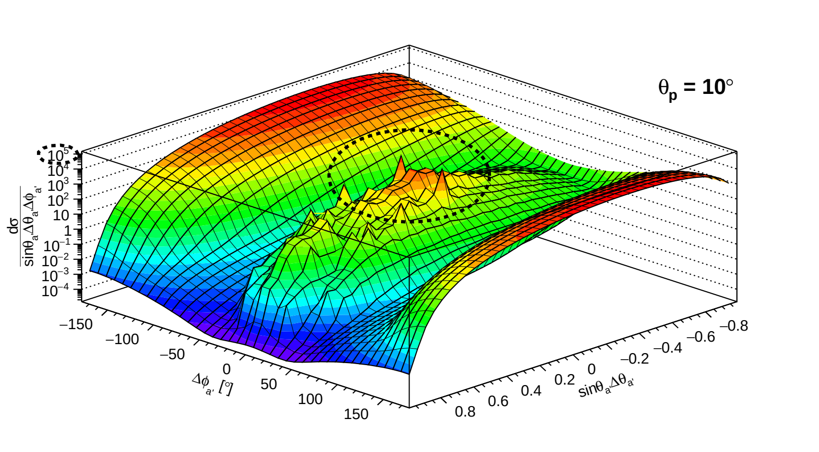
- Peak increases by ~ 5
- $\#$ of collison between jet and medium parton increases
    - **Due to the thermal motion of medium partons**

Correlation between p' and a'

- Dependency check : $\theta_\mathbf{p} = \mathbf{10} \sim \mathbf{50}^\circ$

$\theta_\mathbf{p} = \mathbf{10}^\circ \qquad k_B T = 200\,\mathrm{MeV}$

* The scale is reduced



Correlation between p' and a'

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$$\theta_p = 30^\circ \qquad k_B T = 200\,\mathrm{MeV}$$

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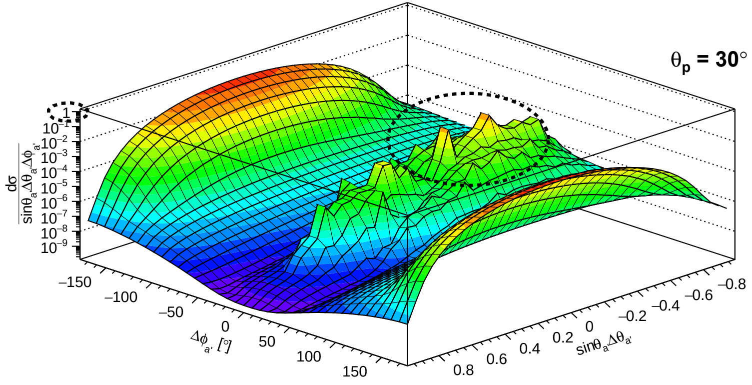

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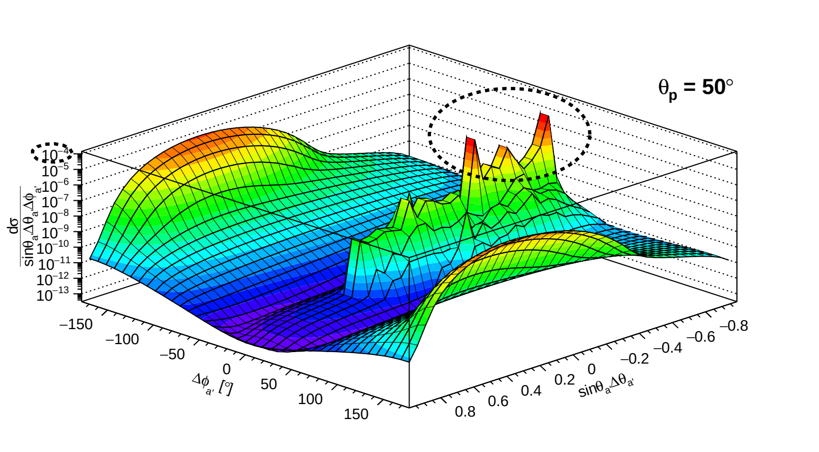


Correlation between p' and a'

- Dependency check : $\theta_\mathbf{p} = \mathbf{10} \sim \mathbf{50}^\circ$

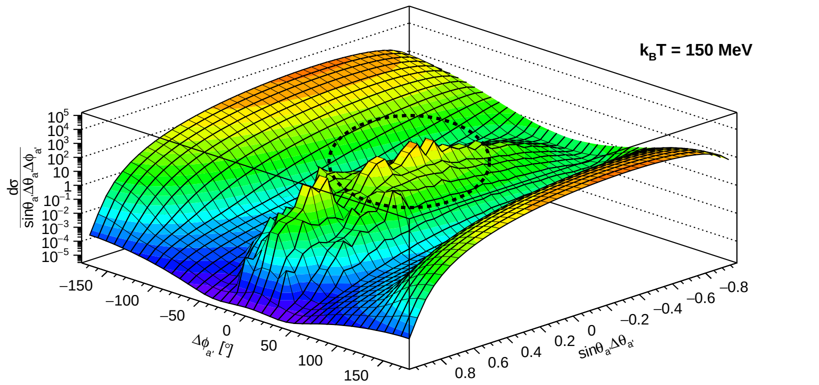
As θ_p increases...

- Peak-side & away-side Ridge move opposite direction each other
- $\Delta\theta_{ka'} \sim 90^\circ$
  - **Because of 4-momemtum conservation on the reaction plane**
- Peak amplitude reduces by $\sim$ 0.0001 times
- Peak and Rigde shrink

Correlation between p' and a'

- Dependency check : $\mathbf{k_B T} = \mathbf{150} \sim \mathbf{250}\,\mathrm{MeV}$

$\theta_p = 10^\circ \qquad \mathbf{k_B T} = \mathbf{150}\,\mathrm{MeV}$



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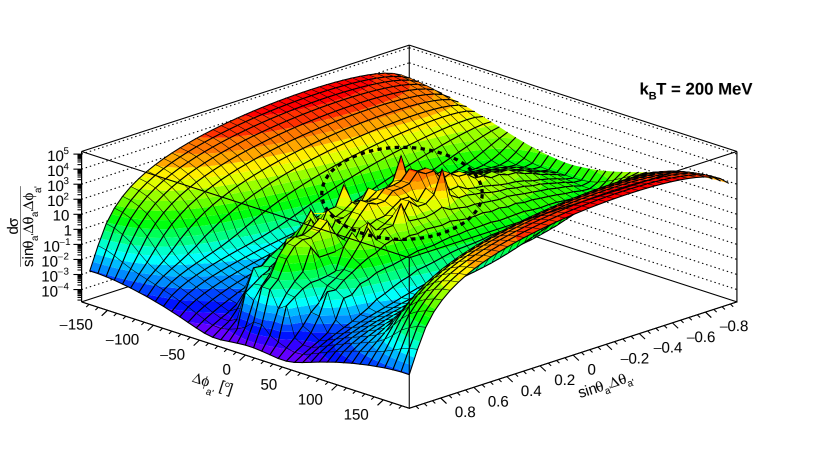

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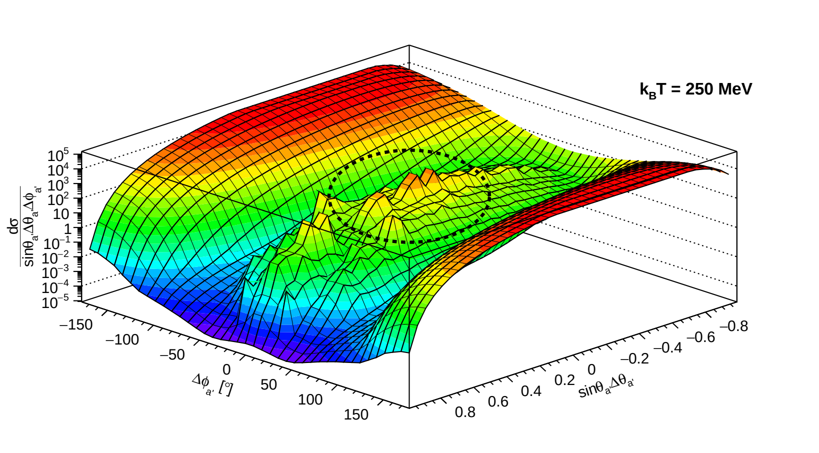
$\theta_p = 10\,^\circ$ $\quad$ $\mathbf{k_B T} = \mathbf{250}\,\mathrm{MeV}$



Correlation between p' and a'

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As T increases...

- Peak increases by ~ 5
- $\#$ of collison between jet and medium parton increases
  - **Due to the thermal motion of medium partons**

Conclusion & Outlooks

- We can describe ridge structure through kinematic interpretation
  - Correlation between p' and k
    - $\rightarrow$ Peak aligns to initial jet particle
    - $\rightarrow$ Photon is emitted in forward direction
  - Correlation between p' and a'
    - $\rightarrow$ Ridge sturucture appears
    - $\rightarrow$ Position of peak is determined by 4-momemtum conservation on x-z plane
- We have to study further effects
  - Apply *boost and flow effects* on initial parton distribution
  - Expand to *multiple scttering*
  - Eventually included **Gluon Bremsstrahlung**

Thanks for your attention!