Two-particle correlations using THERMINATOR model for BES program

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XII Workshop on Particle Correlations and Femtoscopy
Amsterdam, 14.06.2017

Outline

Phenomenological models

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Phenomenological models

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Microscopic

- Dynamic simulation of the collision process inspired by QCD
- Tracking of individual objects
- Propagation of individual particles through a cascade of collisions and decays

Phenomenological models

Phenomenological models

Microscopic | Macroscopic

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Macroscopic

- No consideration of the dynamics of individual objects in detail
- Statistical description of multiparticulate system

Phenomenological models

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→ Microscopic → Macroscopic

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What about generators?

THERMINATOR generator

THERMal heavy-**I**o**N** Gener**ATOR**

- Generates collisions of relativistic ions
- Uses Monte Carlo methods
- Implements thermal models of particle production with single freeze-out

THERMINATOR: THERMal heavy-IoN generATOR
A. Kisiel,T. Tałuć, W. Broniowski, W. Florkowski.
Comput.Phys.Commun. 174 (2006) 669-687

THERMINATOR is a Monte Carlo event generator designed for studying of particle production in relativistic heavy-ion collisions performed at such experimental facilities as the SPS, RHIC, or LHC. The program implements thermal models of particle production with single freeze-out.

Input file

```
[Ranges]
# Rapidity range
RapPRange = 4.0

# Spatial rapidity range
RapSRange = 8.0

[Model_parameters]
# Proper time at freeze-out [fm]
Tau = 9.91

# Maximum transverse radius [fm]
RhoMax = 7.43

# Transverse velocity [c]
VelT = 0.407

# Parameter A
ParA = 0.5

# Delay of the particle emition [fm]
Delay = 0.0

# Freeze-Out Temperature [MeV]
Temperature = 165.6

# Chemical potentials for Barion, Isospin (I_3), Strangeness and Charm [MeV]
MuB = 28.5
MuI = -0.9
MuS =  6.9
MuC =  0.0

[Subdirectory]
# subdirectory to store events of this model
EventSubDir = bwap/
```

Input file

Input file takes following information:

- The number of events
- Parameters:
  - Temperature [MeV]
  - MuB, MuI, MuS [MeV]
  - VelT
  - Tau, RhoMax [fm]

Input parameters

- Temperature (T) and chemical potentials: barion (μ_B), strangeness (μ_S), third component of isospin (μ_I) — thermodynamic parameters
- VelT (Vt) — a parameter specific to the Blast-Wave model, denoting velocity
- Tau, RhoMax — geometric parameters

Vt, Tau and RhoMax affect the produced particles

The relation between RhoMax and Tau is:

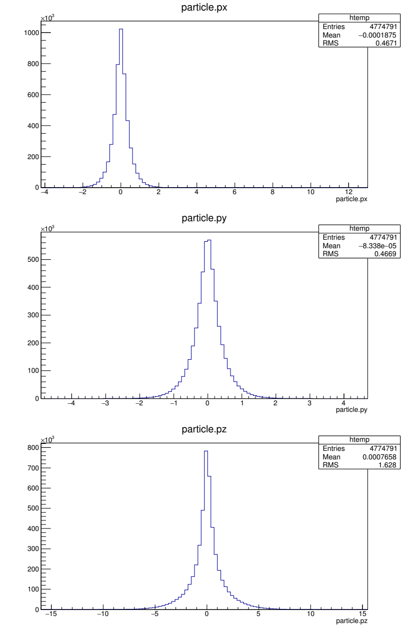
$$\rho_{max}^2 \cdot \tau \simeq V$$

V is the volume of the source

Output file

Events stored in root file.
Informations about particles:

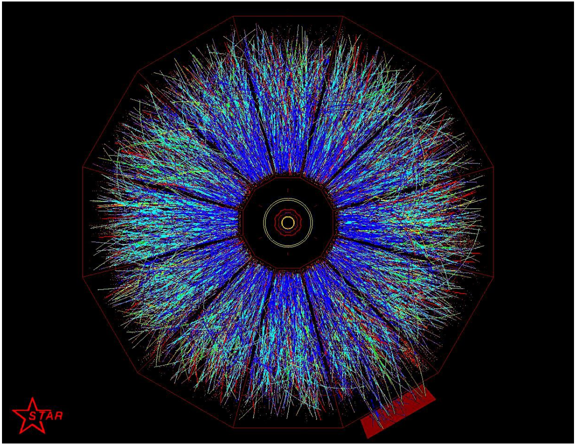
- eid – sequence number in the event
- fathereid – squence number of the parent
- pid – PDG identification number
- decay flag (1 - decayed, 0 - not)
- mass [GeV/c^2]
- components of four-momentum: e, px, py, pz [GeV/c]
- space-time coordinates of the creation point [fm/c]



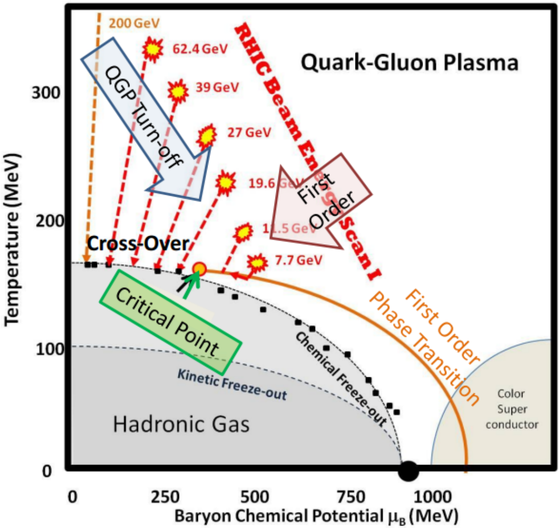
Relativistic Heavy Ion Collider (RHIC)

Goal of the RHIC Heavy Ion Program:

- search the QGP and measure its properties
- scan the QCD phase diagram



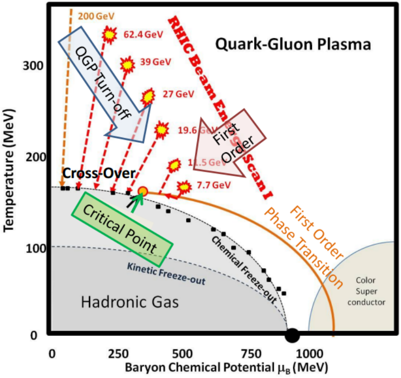
Beam Energy Scan at STAR

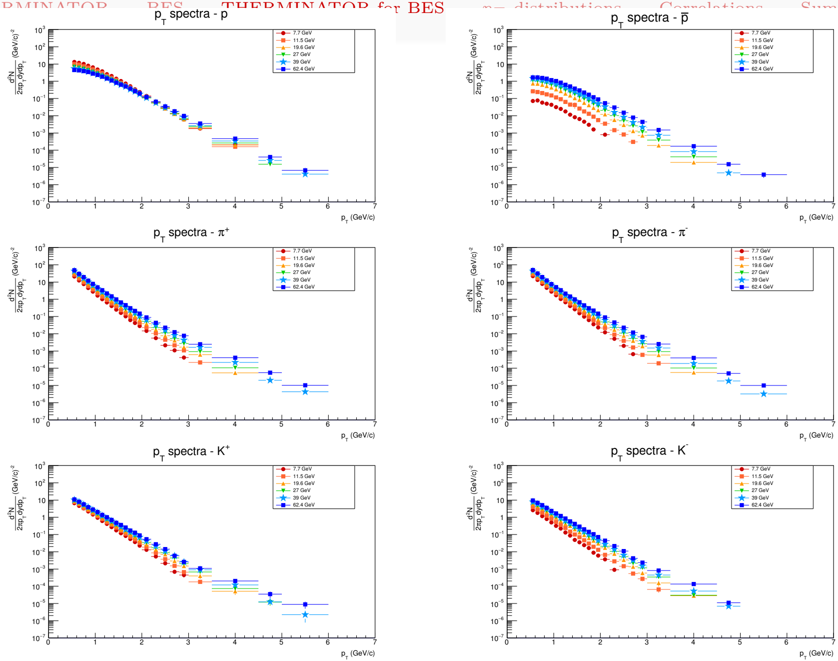


BES goals

Analyze all BES energies and find answers:

- Search for turn-off of QGP signatures
- Search for the QCD critical point
- Search for the signals of phase transition/phase boundary





S. Horvat

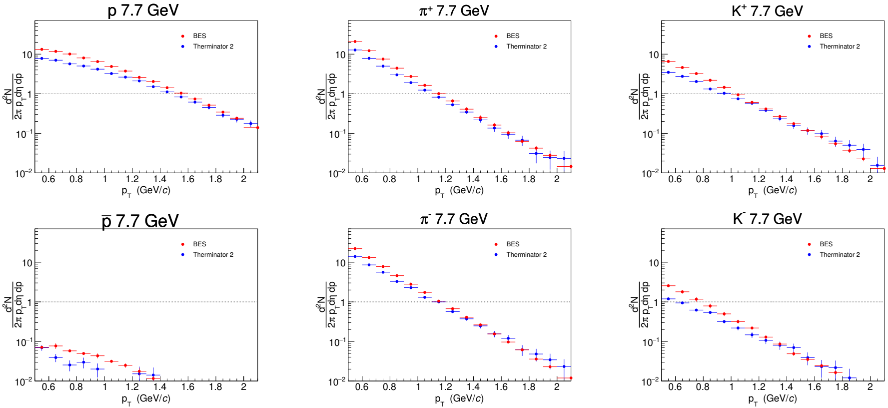
$p_T = \sqrt{p_x^2 + p_y^2}$ Au-Au, centrality: 0-5%, rapidity: $|y| < 0.25$

Thermodynamic parameters

$\sqrt{s_{NN}}$ [GeV]	T [MeV]	μ_B [MeV]	μ_{I_3} [MeV]	μ_S [MeV]
7.7	139.0	406.4	-10.5677	93.4685
11.5	150.1	303.2	-7.9697	69.9562
19.6	156.2	196.8	-5.2882	45.6875
27	157.6	149.0	-4.0845	34.7938
39	158.4	106.9	-3.0241	25.1974
62.4	158.8	68.9	-2.0676	16.5409

"Therminator generator adaptation to the conditions of RHIC and FAIR experimantal complexes", Engineer's Thesis, Monika Seniut

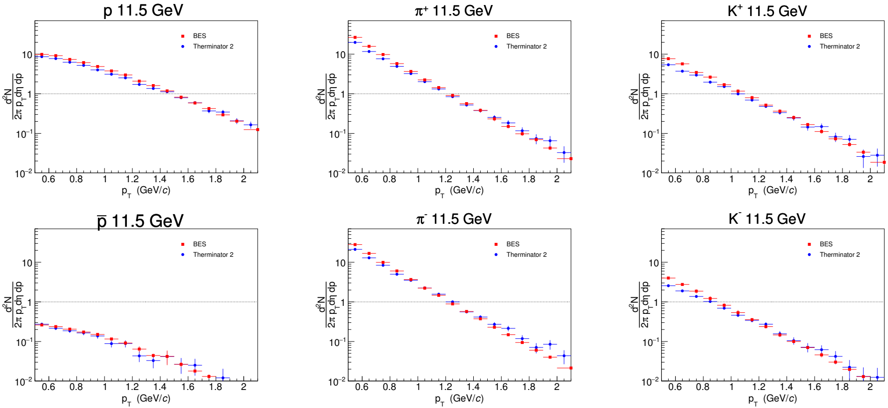
$\sqrt{s_{NN}} = 7.7$ GeV, 0-5%



$\sqrt{s_{NN}}$ [GeV]	Rho_max [fm]	Tau [fm]	Vt
7.7	7.63	7.00	0.65

$$\chi^2/NDF = 3.77$$

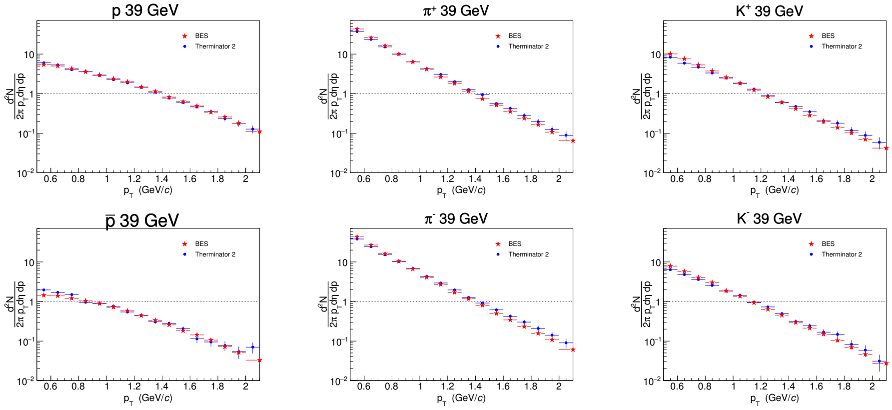
$\sqrt{s_{NN}} = 11.5$ GeV, 0-5%



$\sqrt{s_{NN}}$ [GeV]	Rho_max [fm]	Tau [fm]	Vt
11.5	8.00	7.15	0.75

$$\chi^2/NDF = 1.50$$

$\sqrt{s_{NN}} = 39$ GeV, 0-5%



$\sqrt{s_{NN}}$ [GeV]	Rho_max [fm]	Tau [fm]	Vt
39	9.45	7.75	0.70

$$\chi^2/NDF = 0.63$$

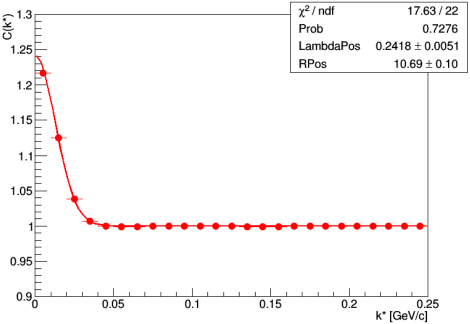
Two pions correlation - formulas

1D correlation

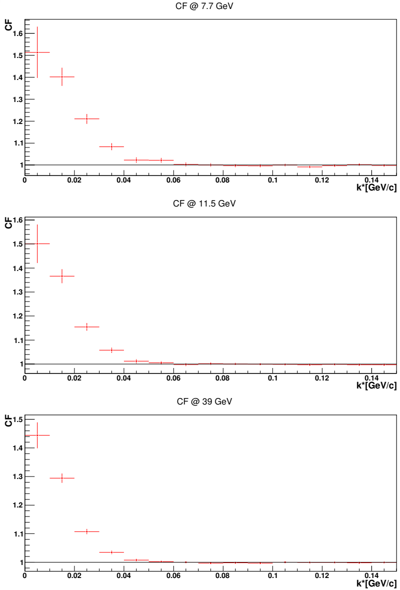
$$CF(q) = 1 + \lambda \cdot exp(-q^2 R^2)$$

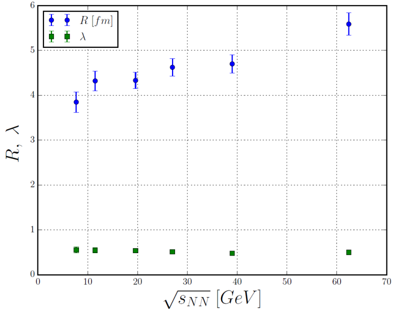
3D correlation

$$CF(q) = 1 + \lambda \cdot exp(-q_o^2 R_o^2 - q_s^2 R_s^2 - q_l^2 R_l^2)$$



One dimensional correlation function

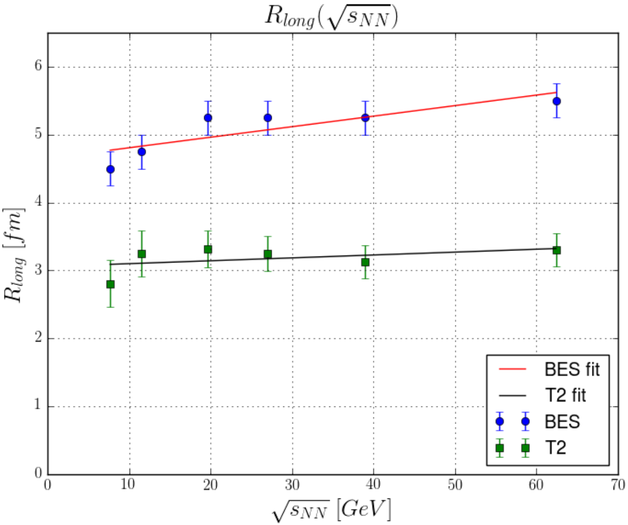




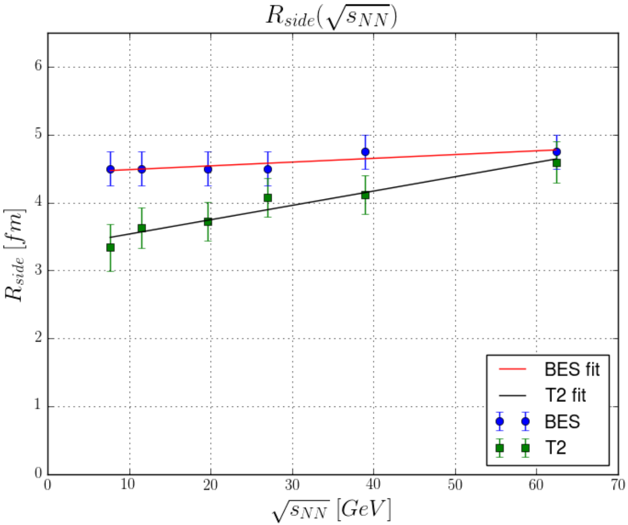
One dimensional correlation function - radii

$\sqrt{s_{NN}}$ [GeV]	R [fm]	λ
7.7	3.85 ± 0.23	0.55 ± 0.07
11.5	4.32 ± 0.22	0.55 ± 0.06
19.6	4.33 ± 0.18	0.54 ± 0.05
27	4.62 ± 0.19	0.51 ± 0.05
39	4.7 ± 0.2	0.48 ± 0.04
62.4	5.59 ± 0.25	0.50 ± 0.05

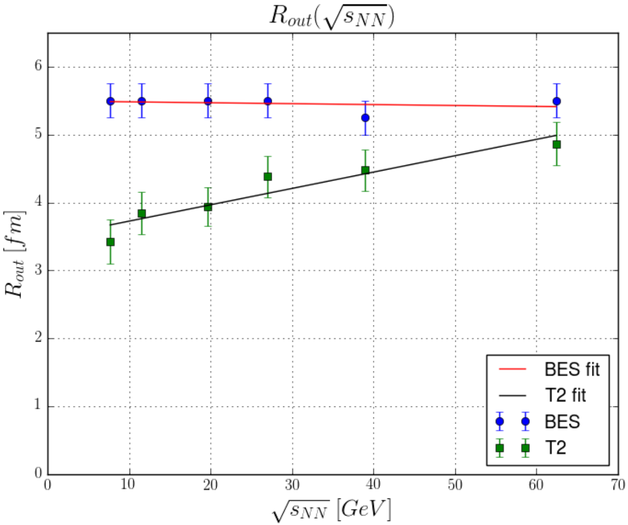
Three dimensional correlation function - R_{long}



Three dimensional correlation function - R_{side}



Three dimensional correlation function - R_{out}



Summary and conclusions

Summary:

- Good agreement between model and experimental data in p_T distribution
- Differences between radii for model and experimental data:
  - R_{out} & R_{long} are smaller for Therminator 2 data
  - R_{side} - close to experimental data (for energies from $\sqrt{s_{NN}} = 19.6$ GeV)
  - R_{out} & R_{side} - bigger dependencies on energy

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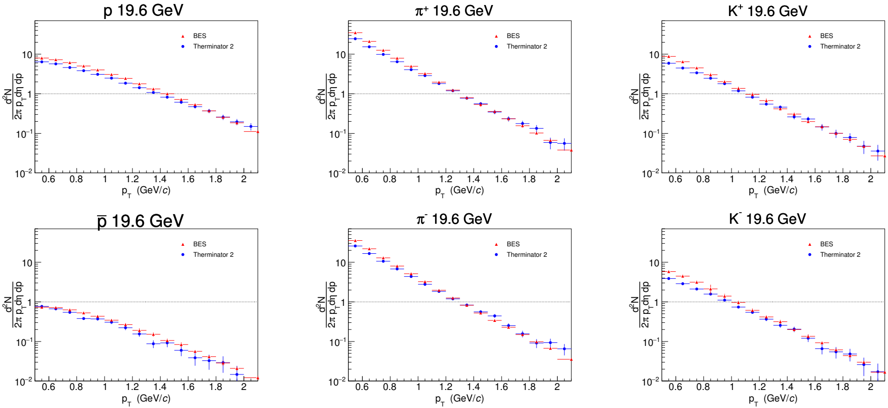
Thank you for your attention!!!

BACKUP

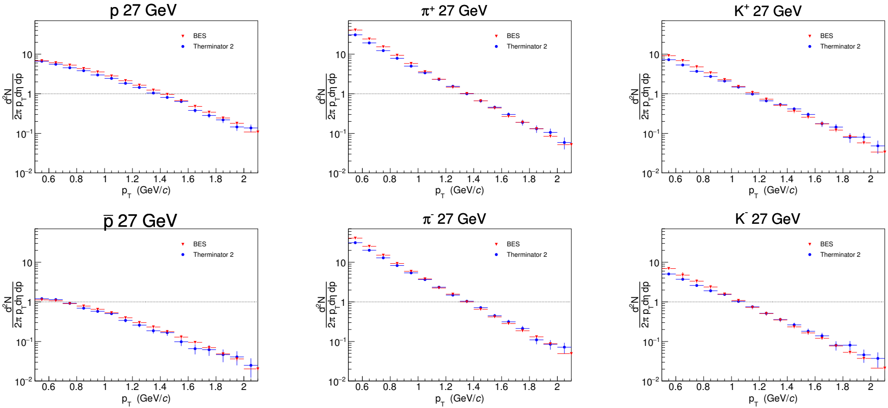
$\sqrt{s_{NN}} = 19.6$ GeV, 0-5%



$\sqrt{s_{NN}}$ [GeV]	Rho_max [fm]	Tau [fm]	Vt
19.6	8.10	7.25	0.75

$$\chi^2/NDF = 2.35$$

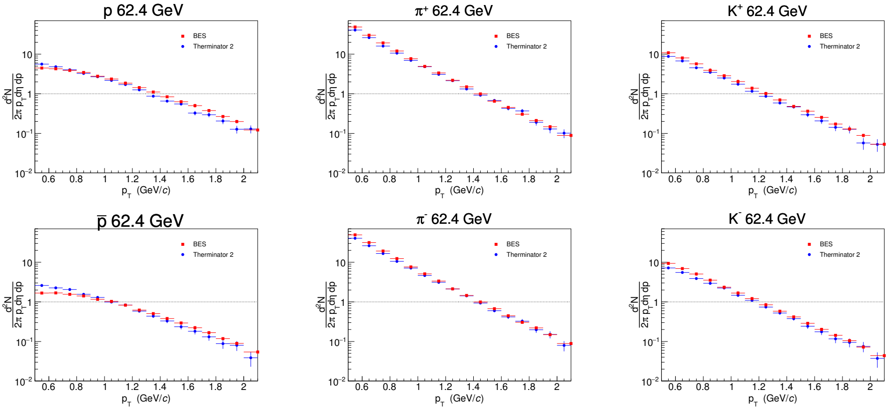
$\sqrt{s_{NN}} = 27$ GeV, 0-5%



$\sqrt{s_{NN}}$ [GeV]	Rho_max [fm]	Tau [fm]	Vt
27	8.80	7.50	0.75

$$\chi^2/NDF = 1.56$$

$\sqrt{s_{NN}} = 62.4$ GeV, 0-5%



$\sqrt{s_{NN}}$ [GeV]	Rho_max [fm]	Tau [fm]	Vt
62.4	9.82	8.00	0.75

$$\chi^2/NDF = 1.40$$

3D radii for BES program energies

$\sqrt{s_{NN}}$ [GeV]	λ	R_{out}	R_{side}	R_{long}
7.7	0.79 ± 0.13	3.43 ± 0.33	3.34 ± 0.34	2.81 ± 0.35
11.5	0.8 ± 0.1	3.84 ± 0.31	3.6 ± 0.3	3.25 ± 0.34
19.6	0.8 ± 0.1	3.94 ± 0.29	3.72 ± 0.28	3.32 ± 0.27
27	0.8 ± 0.1	4.4 ± 0.3	4.08 ± 0.28	3.25 ± 0.26
39	0.72 ± 0.08	4.48 ± 0.31	4.11 ± 0.28	3.13 ± 0.24
62.4	0.8 ± 0.1	4.87 ± 0.32	4.6 ± 0.3	3.3 ± 0.2