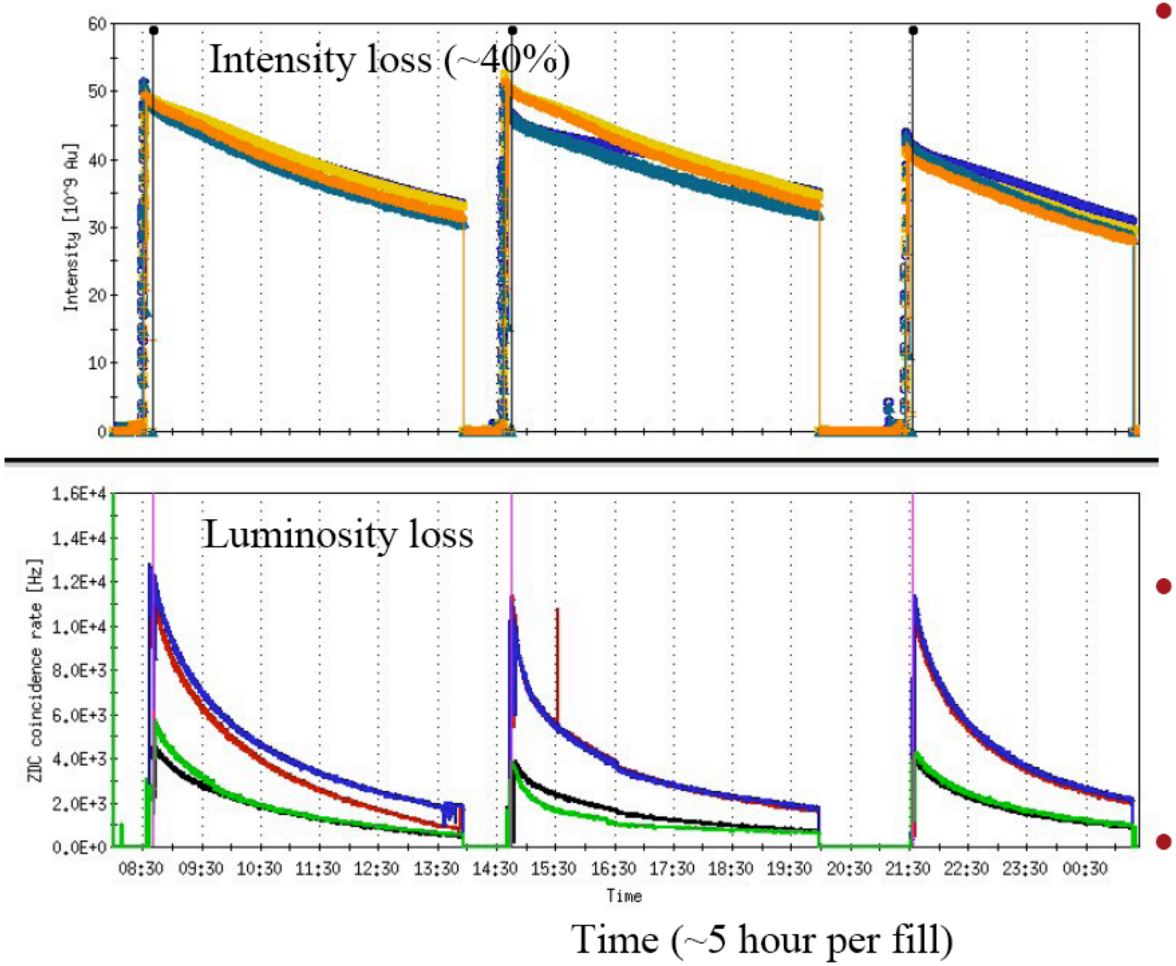
Beam Studies for e-Cooling

Vladimir Litvinenko

APEX Topics relevant for RHIC II and eRHIC e-Cooling

- Accurate understanding of IBS for ions *(need ions for the studies)*
- Other sources of emittance growth - both coherent and incoherent *(need protons for the studies)*
- IBS suppression lattice *(need ions for the studies)*
- RHIC lattice for electron cooling (β ~ 200 m, $/\alpha/ \ll 1$)
- Beam-beam and other effects with Bi-Gaussian beams

Au-Au luminosity limit: intra-beam scattering



- Luminosity loss – frequent refill
  - Transverse emittance growth
  - Longitudinal growth & beam loss due to RF voltage limitation
- De-bunching & physics background – beam gap cleaning
- IBS: Z^4/A^2 scaling

Accurate understanding of IBS for ions - talk by A. Fedotov

- Accurate understanding of IBS for ions
  - Affect luminosity evolution during the store
  - Determines the requirements for electron beam
  - Determines e-cooler complexity and cost

Other sources of emittance growth - both coherent and incoherent

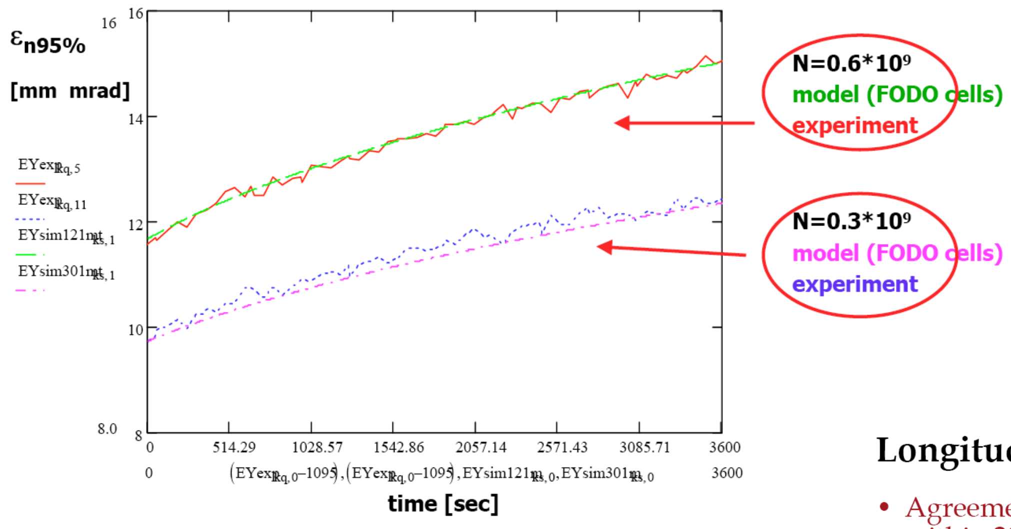
- e-Cooling needs to know enemy it has to fight
  - Distinguish coherent from incoherent growth mechanisms

- *Accurate understanding of emittance growth for ions*
  - *Affect luminosity evolution during the store*
  - *Determines the requirements for electron beam*
  - *Determines e-cooler complexity and cost*

Transverse emittance bench-marking

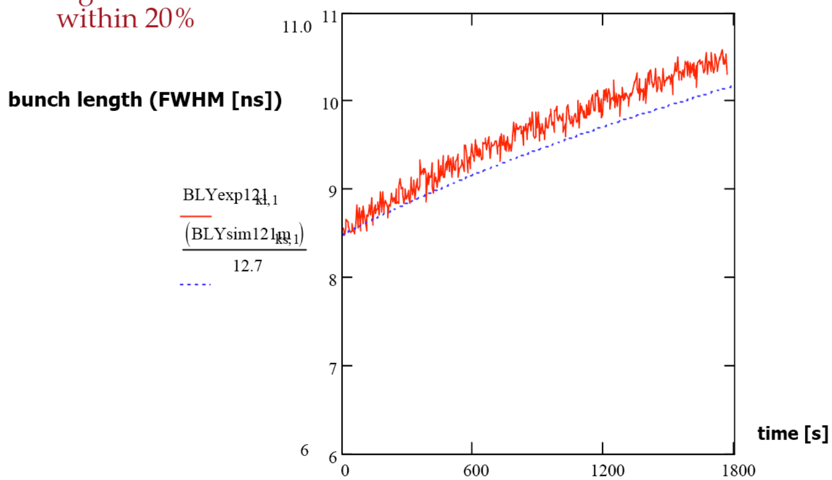
- Agreement satisfactory (dispersion uncertainty within 40%); uncertainty is in the coupling condition and actual machine dispersion

Vertical emittance



Longitudinal bench length bench-marking

- Agreement within 20%



IBS suppression lattice (talk by Steve Tepikian)

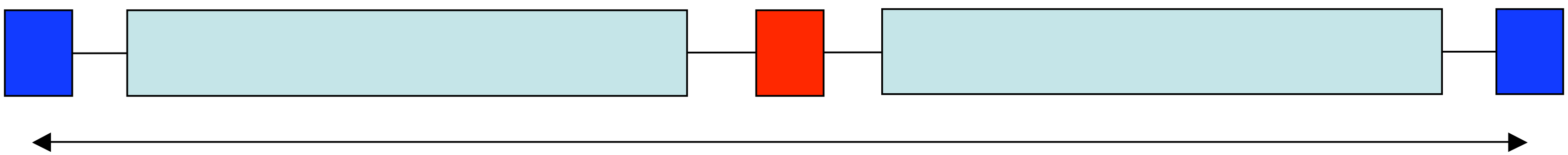
- Optimize the RHIC lattice in ion-ion collider mode for SIGNICANT reduction of the transverse IBS

- *Reduction of emittance growth for ions*
  - *Affect luminosity evolution during the store*
  - *Determines the requirements for electron beam*
  - *Determines e-cooler complexity and cost*

Transverse IBS in RHIC

The main contribution to the transverse IBS in RHIC come from the arcs, most of which comprised of FODO cells

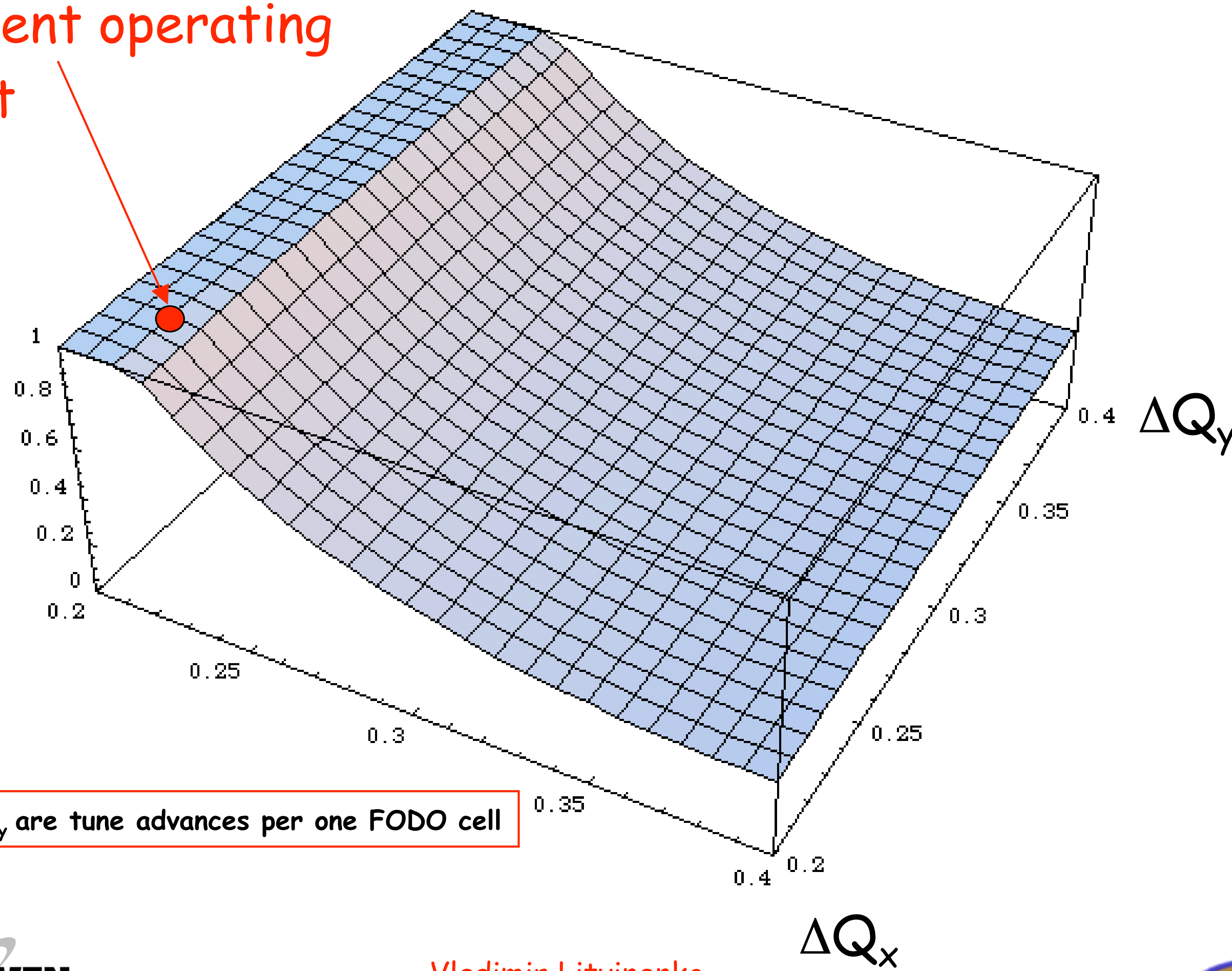
$$\frac{d\varepsilon_x}{ds} = H(s) \cdot \frac{d\delta_E^{\ 2}}{ds}; \qquad H(s) = \gamma_x D_x^2 + 2\alpha_x D_x D_x{}' + \beta_x D_x{}'^2$$



$$\frac{d\delta_E^{\ 2}}{ds} \propto \frac{N}{\sigma_s \sigma_r^{\ 2} \sigma_{r'}}; \qquad H_{\mathrm{mod}}(s) = \frac{H(s)}{\sqrt{\beta_y(1+\alpha_x^{\ 2}) + \beta_x(1+\alpha_y^{\ 2})}}$$

Transverse IBS rate in RHIC

Present operating point



NOTE: $\Delta Q_{x,y}$ are tune advances per one FODO cell

BROOKHAVEN NATIONAL LABORATORY

Vladimir Litvinenko
APEX Workshop Nov 8, 2005

RHIC

J.Wei

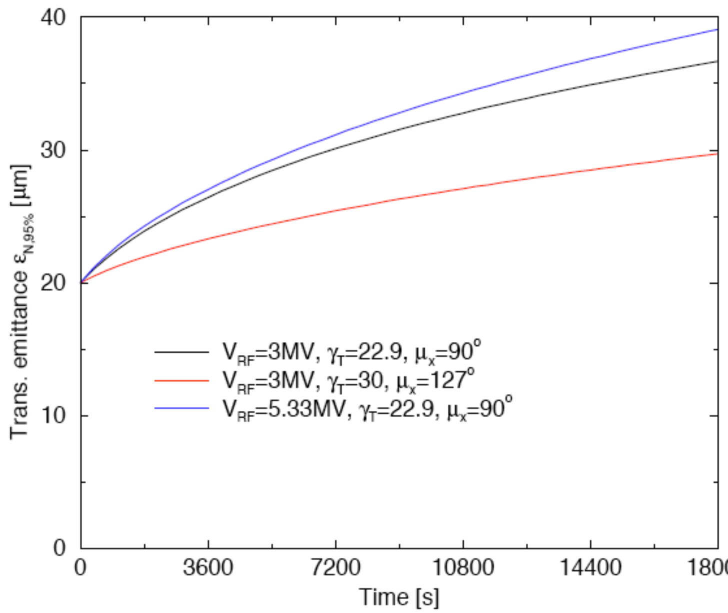


FIG. 2. Transverse emittance as a function of time for the design lattice (black), the low-dispersion lattice (red), and the design lattice with increased RF voltage (blue).

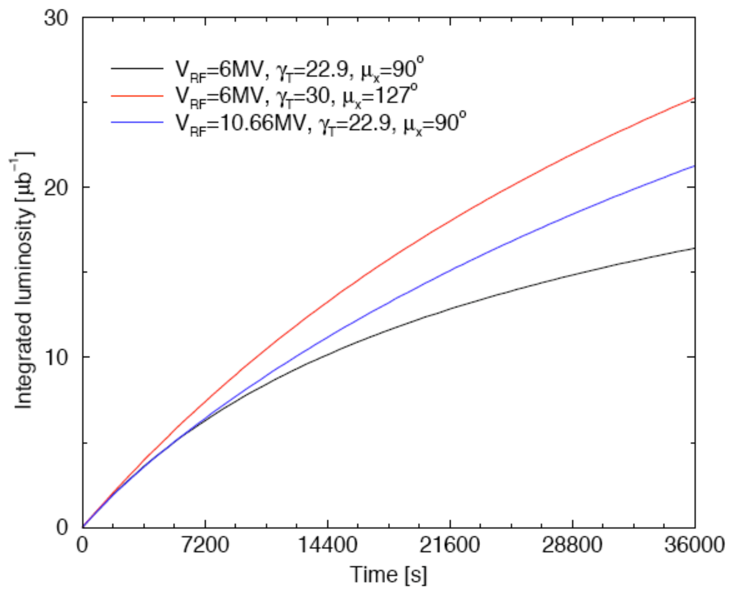


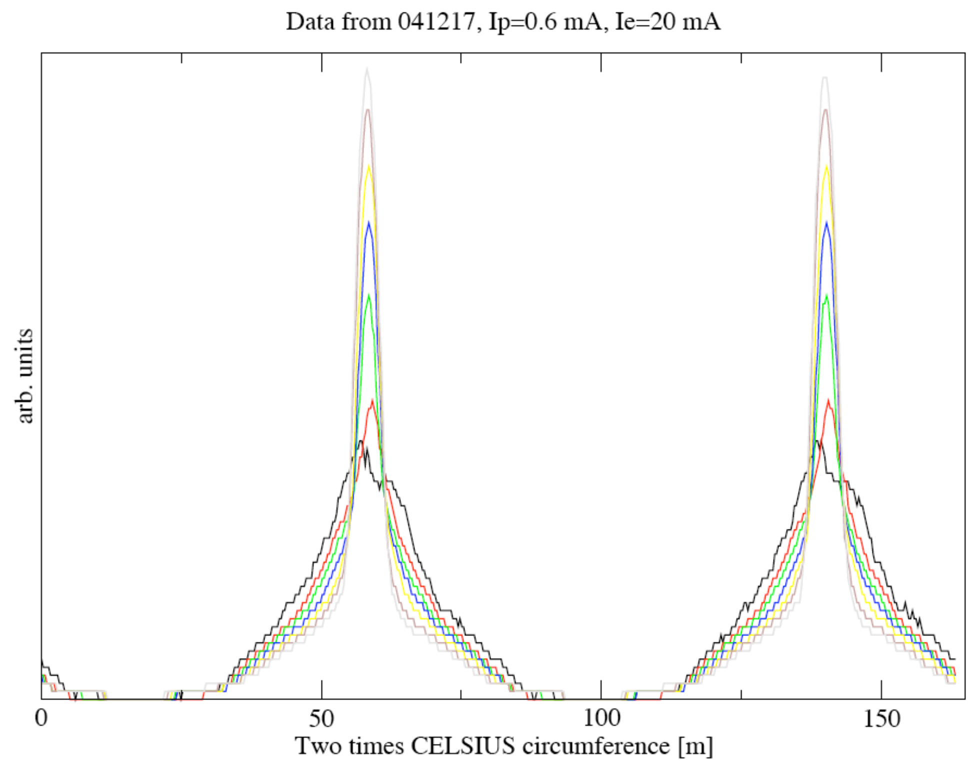
FIG. 5. Integrated luminosity as a function of time for the design lattice (black), the low-dispersion lattice (red), and the design lattice with increased RF voltage (blue).

RHIC lattice for electron cooling

- Present scheme of e-Cooler is on based the use of non-magnetized low emittance co-propagating and interacting with ions in two warm section around one of IPs - there is no solenoid any longer…
- Cooling improves with decrease of angular spread in ion beam, i.e. with increase of $\beta / (1+\alpha^2)$
- Present design requires β ~ 200 m, /α/ <<1
- There is RHIC lattice with β*~100m

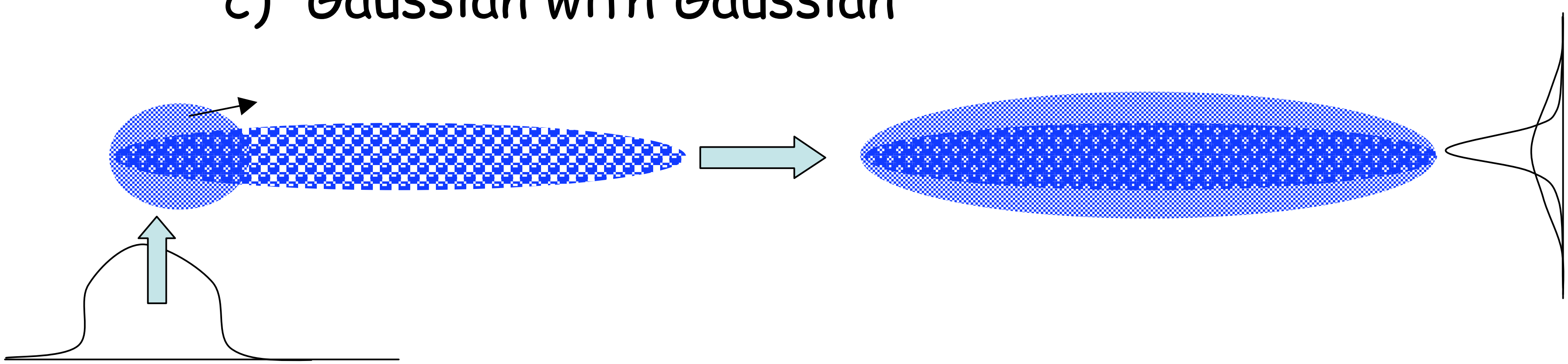
Effects of Bi-Gaussian beams

- e-Cooling naturally generates non-Gaussian ion beams with a dense core and weak "wings" - can be rather accurately represented by two Gaussians (bi-Gaussian)
- Simulations (C.Montag) indicate that beam-beam effects differ from Gaussian beam case
- IBS of bi-Gaussian is different from that of Gaussian
- Worth looking experimentally and compare with predictions



Data from 041217, Ip=0.6 mA, Ie=20 mA
arb. units
0
50
100
150
Two times CELSIUS circumference [m]

a) RHIC with injection RF -> long bunches
b) Kick transversely the tail of the beam
c) Generate one or two bi-Gaussian beams
d) Compare luminosity and beam-beam effects by colliding
   a) Bi-Gaussian with Bi-Gaussian
   b) Bi-Gaussian with Gaussian
   c) Gaussian with Gaussian



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