Bunch Merging

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Bunch Merging Introduction

Collider luminosity is proportional to N_μ^2 of the number of muons per bunch; so its best to use few bunches, ideally one. Capturing the initial pion/muon phase space directly into a single bunch requires low frequency ($\lesssim$ 30 MHz) rf, and thus low gradients $\equiv$ more decays. It is more advantageous to capture into multiple bunches at 201 MHz and allow them, after cooling, to be recombined into a single bunch (still at low energy).

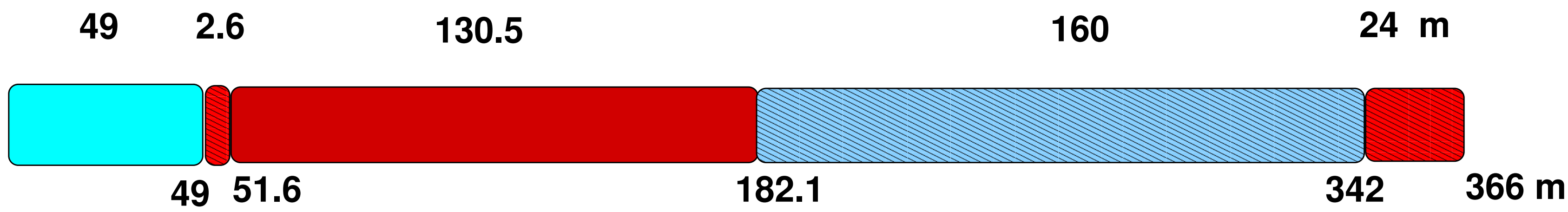
Introduction II

This recombination is done in two stages:

- Drift followed by
- 201 MHz rf, with harmonics, the individual bunches are phase rotated to fill the spaces between bunches and lower their energy spread;
- 5 MHz rf, plus harmonics, interspersed (or not) along a long drift (or wiggler) to phase rotate the train into a single bunch that can be captured using 201 MHz.

Bunch Merging Beamline

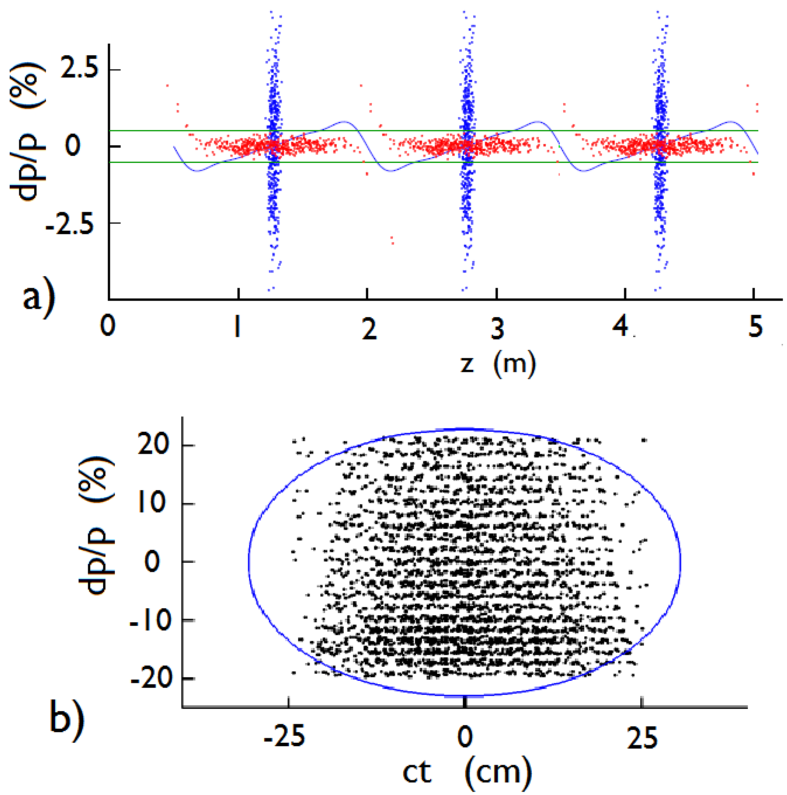
SCHEMATICS: BUNCH MERGER BEAMLINE



- **Initial drift**
- **High Frequency rf (201.25, 402.5, 603.75, 804 MHz)**
- **Low Frequency rf (5,10,15, 20 MHz)**
- **Linear wiggler (B= 0.775T; period = 2 m). Klystron**
- **Capture (201.25 MHz)**

There is an overall solenoidal field B= 1 T, except on the wiggler.

Bunch Merging 1-D Simulation (Palmer)



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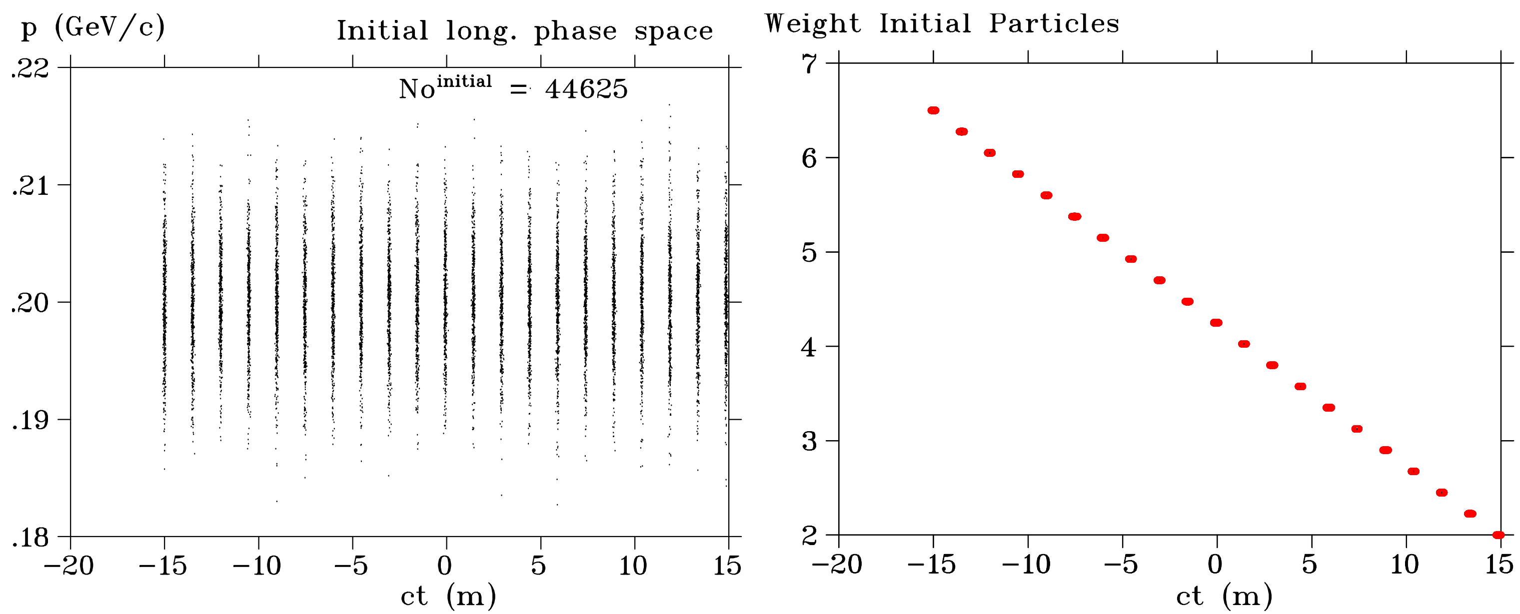
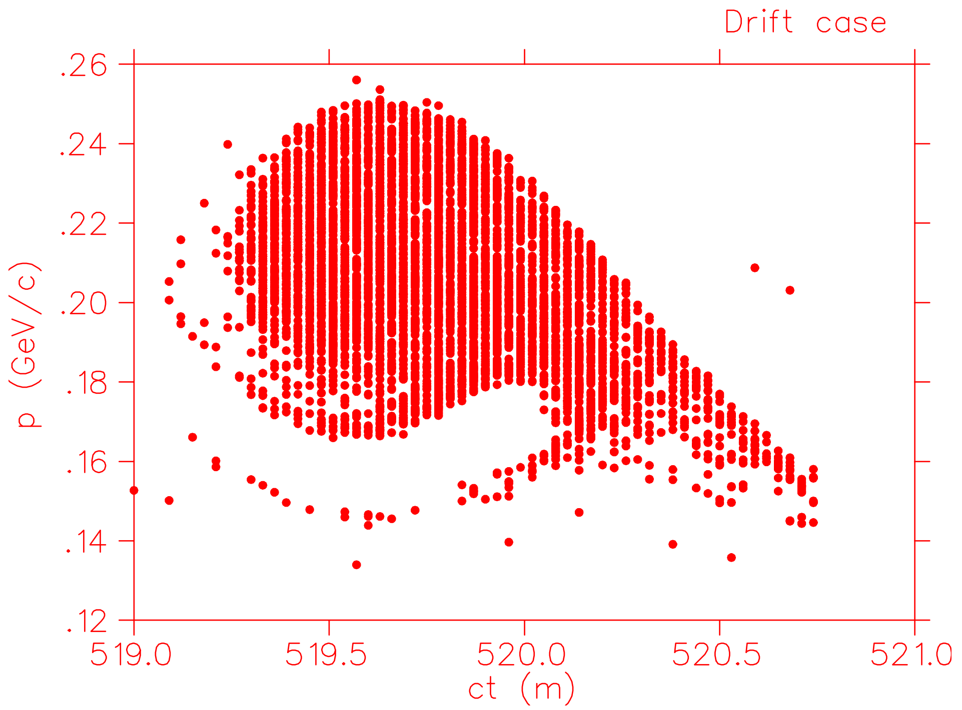
1-D Simulation: a) before (blue) and after 1^{st} rotation (red); b) after 2^{nd} rotation.

Icool simulation: Initial Beam



Initial longitudinal phase space, showing 21 bunches(LEFT); weight distribution (RIGHT).
$\epsilon_T = 1.45\ mm - rad$, $\epsilon_L = 1.6\ mm$ (all bunches $\epsilon_L = 331\ mm$); $< p_z >= 0.2\ GeV/c$.

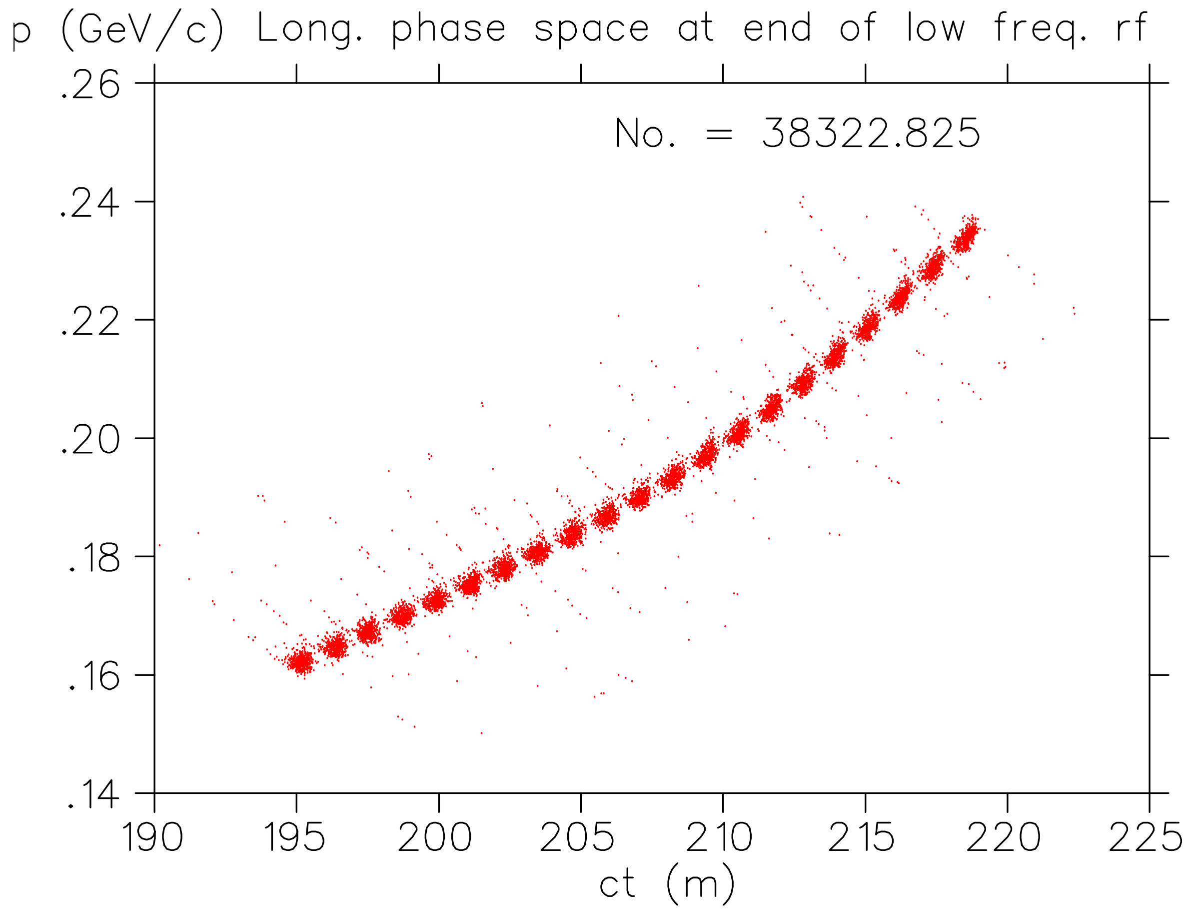
Icool simulation: Drift (Fernow)



$$\epsilon_T \approx 2.1\ mm - rad, \quad \epsilon_L \approx 95\ mm,$$
$$\sigma_E \approx 30\ MeV$$

Length channel =455.3 m Efficiency$\approx 50\%$.

Long phase space at entrance of wiggler



Notice that the lower energy particles are ahead in the bunch train; $L_{train} \approx 30\ m.$

Planar Wiggler

- $B_0 = 0.775\,T, \quad \lambda_s = 2\,m$ and $\quad k_y = 2.75$
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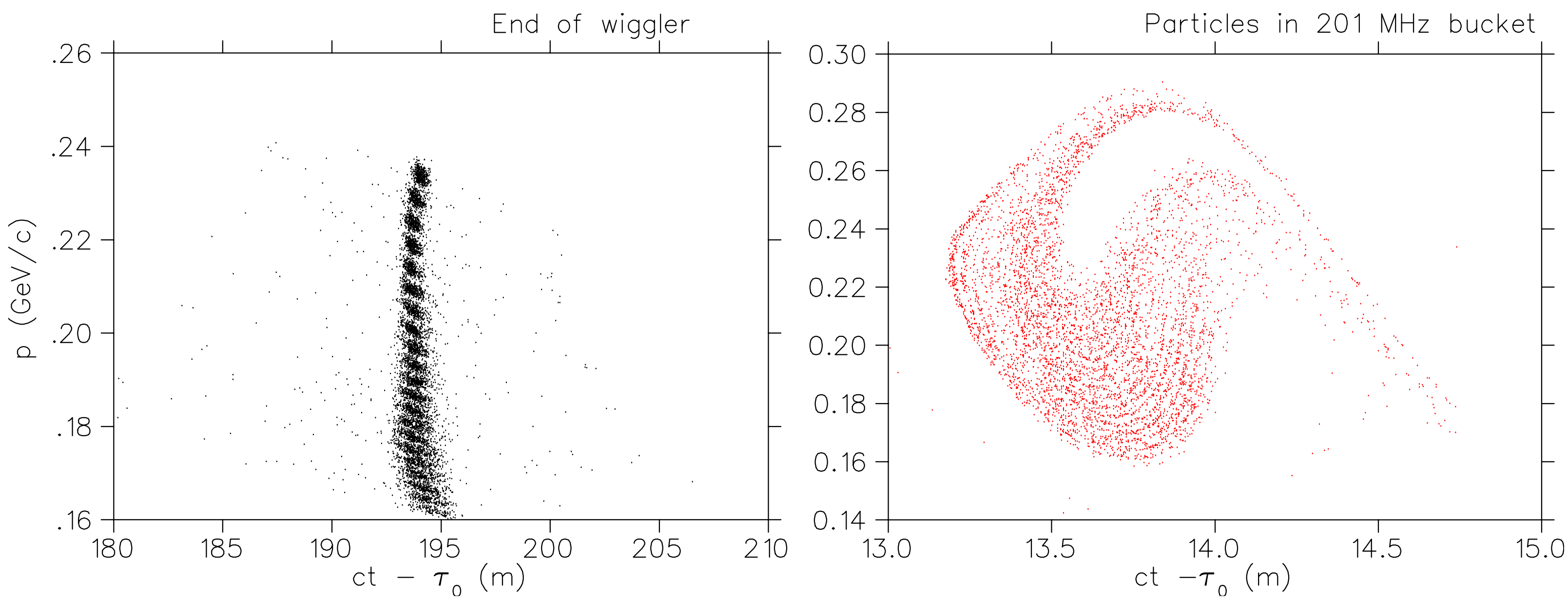
  - $B_x(s) \approx -B_0 k_x^2 xy \cos\left(k_s s + \phi_0\right)$
  - $B_y(s) \approx B_0 \cos\left(k_s s + \phi_0\right)$
  - $B_s(s) \approx -B_0 k_s y \sin\left(k_s s + \phi_0\right)$ with $k_x^2 = k_s^2 - k_y^2$
- Wiggler parameter $K_\mu = \frac{qB_0}{m_\mu c k_s} \approx 93.44 B_0[T]\lambda_W[m] \times \frac{m_e}{m_\mu} = 0.452 B_0[T]\lambda_W[m]$

Planar Wiggler II

- *back of the envelope calculation*
  - $< \beta_s > \approx 1 - \frac{1+K_\mu^2/2}{2\gamma^2}$
  - *Momentum compaction factor*
    $\alpha_c = \frac{\Delta L}{L\delta} \approx (\gamma^2 - 1)\frac{(1+K_\mu^2/2)}{\gamma^4}$
  - *Distance for the tail of the train to catch up with the front* $s = L_{train}\frac{m_\mu^2}{p\Delta p}\frac{\gamma^3}{(1+K_\mu^2/2)} \approx 163\ m$

Results: Planar Wiggler



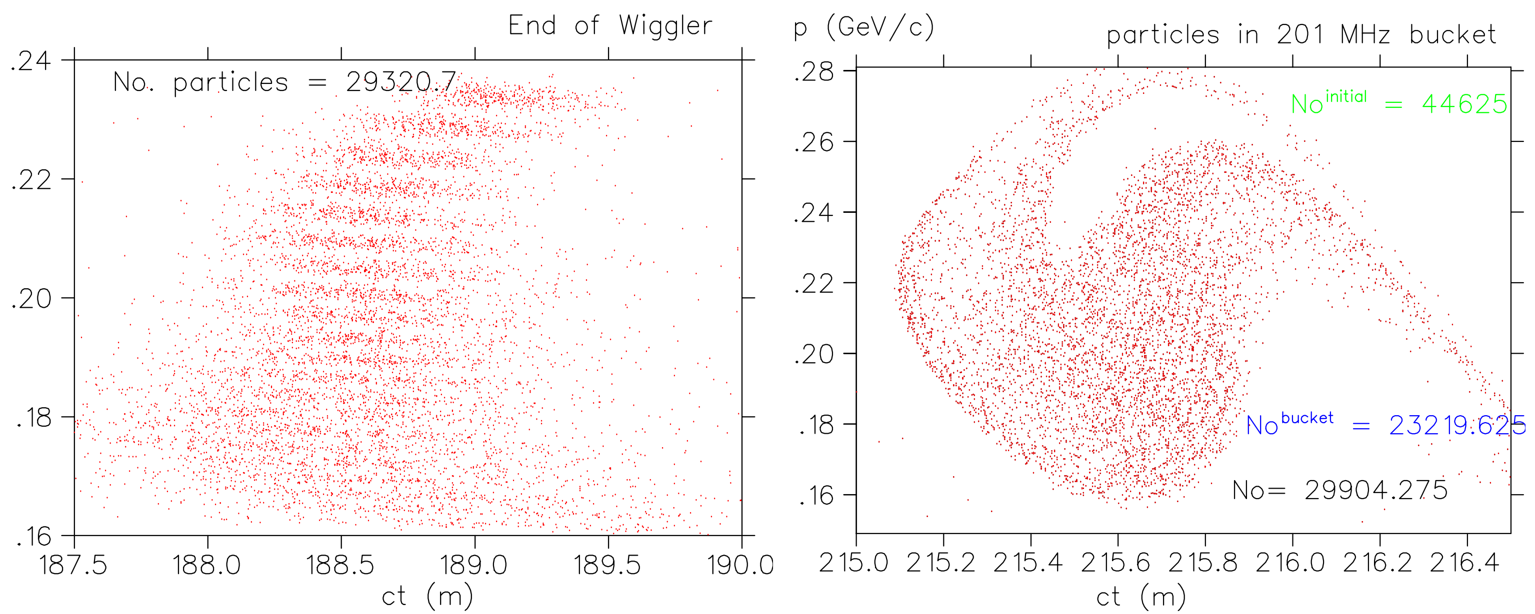
Long phase space at the end of the wiggler (LEFT); at the end of the bucket formation section (RIGHT).

Decay $\approx 25\ \%$ $\quad \epsilon_T \approx 1.8\ mm \quad \epsilon_L \approx 109\ mm$

Efficiency$\approx 47\%$ $\quad \sigma_E \approx 38\ MeV$

Length channel=366 m

Results: Klystron



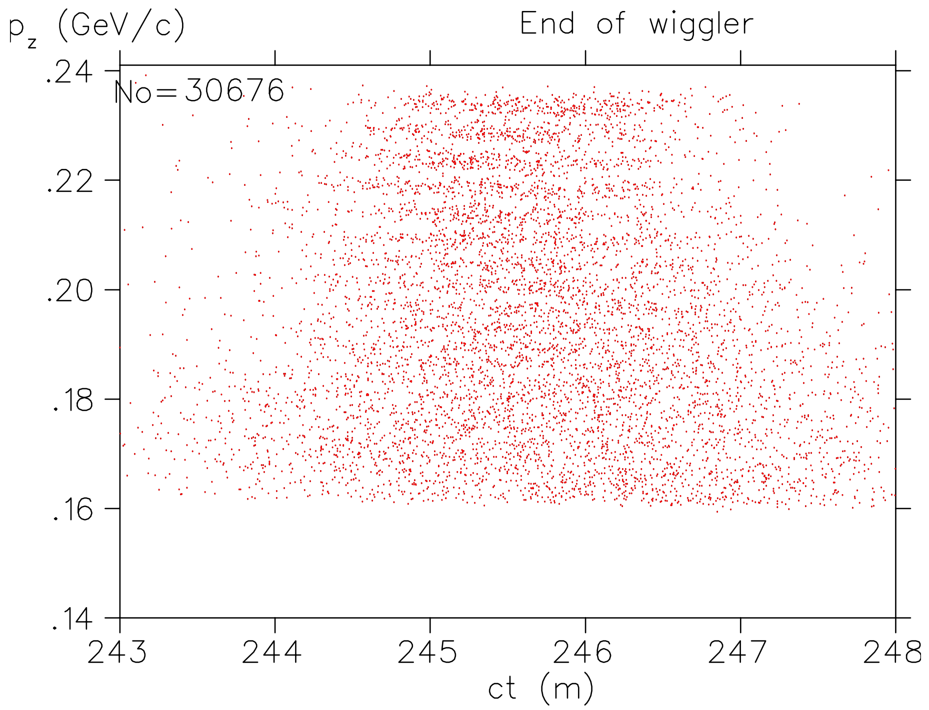
Long phase space at the end of the wiggler (LEFT); at the end of the bucket formation section (RIGHT).

Decay $\approx 25\ \%$ $\quad \epsilon_T \approx 2.3\ mm \quad \epsilon_L \approx 87\ mm$

Efficiency$\approx 52\%.$ $\quad \sigma_E \approx 39\ MeV$

Length channel=408 m

Circular wiggler



Conclusions

- Wiggler to hasten the bunch merging is promising; but efficiency need to be significantly improved
- MUCH MORE WORK IS NEEDED

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