Luminosity Spectrum Reconstruction

Stéphane Poss, André Sailer (CERN), Sicheng Wang (HKUST)

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Spectrum Reconstruction in Two Slides

With the distribution $f(O_1, O_2, \ldots)$ of observables measurable in the Detector

$$f(O_1, O_2, \ldots) \approx \sigma(E_1, E_2; O_1, O_2, \ldots) \times \underline{\mathscr{L}\left(E_1, E_2\right)} \otimes \mathrm{ISR}\left(E_1, E_2\right) \otimes \mathrm{FSR}\left(O_1, O_2, \ldots\right) \otimes \mathrm{D}\left(O_1\right) \mathrm{D}\left(O_2\right) \ldots,$$

connected to the luminosity spectrum $\mathscr{L}\left(E_1, E_2\right)$ and measurable in the detector. One can then:

- Model (i.e., parameterise) the luminosity spectrum
- Let Bhabha generator take care of cross-section and initial state radiation
- Do GEANT4 simulation for detector resolutions
- Use a reweighting technique for *efficient* fitting and extract $\mathscr{L}$

Reweighting Fit in Words

Reweighting technique uses χ^2-fit of two histogram with a distribution like

$$f(O_1, O_2, \ldots) \approx \sigma(E_1, E_2; O_1, O_2, \ldots) \times \underline{\mathscr{L}\left(E_1, E_2\right)} \otimes \mathrm{ISR}\left(E_1, E_2\right) \otimes \mathrm{FSR}\left(O_1, O_2, \ldots\right) \otimes \mathrm{D}\left(O_1\right) \mathrm{D}\left(O_2\right) \ldots,$$

- Data histogram: measured in detector, spectrum simulated by GUINEAPIG, apply Bhabha-scattering and detector simulation
- MC histogram: Luminosity spectrum according to the MODEL, apply Bhabha-scattering and detector simulation
  - Apply Bhabha scattering/ISR/Detector resolutions on event-by-event basis via MC Generator and detector simulation
  - Remember initial probability based on luminosity spectrum of each event $\mathscr{L}\left(x_1^i, x_2^i; [p]_0\right)$
  - Vary all event probabilities (via MODEL parameters $[p]_N$) until minimum χ^2 is found

$$\text{event weight: } w^i = \frac{\mathscr{L}\left(x_1^i, x_2^i; [p]_N\right)}{\mathscr{L}\left(x_1^i, x_2^i; [p]_0\right)}$$

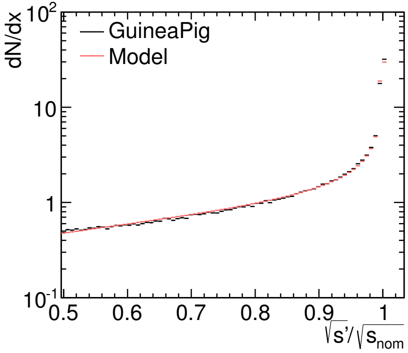
- Advantage
  - Only have to do (very time consuming) Bhabha-scattering and detector simulation once

Luminosity Spectrum Reconstruction at 3 TeV

- Released LCD-Note-2013-008 (updated number from LCD-Note-2011-040)
- Shortened Note and submitted to EPJC
- Conclusion: Luminosity spectrum reconstruction works well enough at 3 TeV

Luminosity Spectrum at 350 GeV and 3 TeV

- **Could well reconstruct the tail of the distribution at 3 TeV**
- Much longer tail at 3 TeV, compared to 350 GeV
- Some differences between reconstructed distribution near the peak
  - For threshold scans at 350 GeV, the peak might have to be known better
- Summer Student Sicheng Wang was retracing steps to see if reconstruction works as well at 350 GeV



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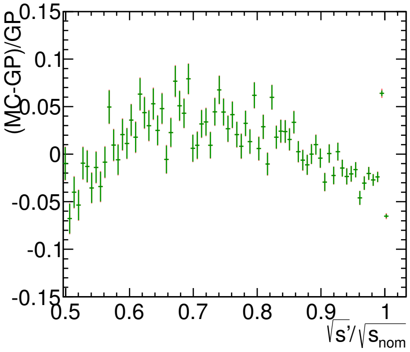

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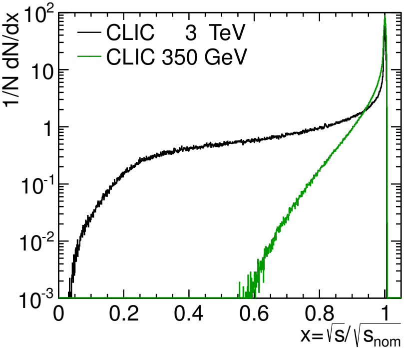

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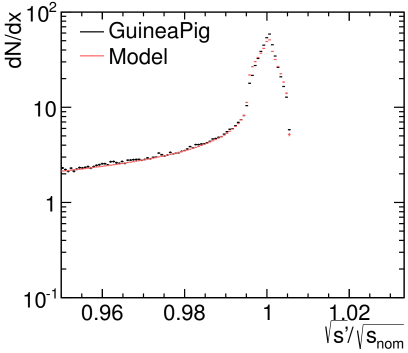

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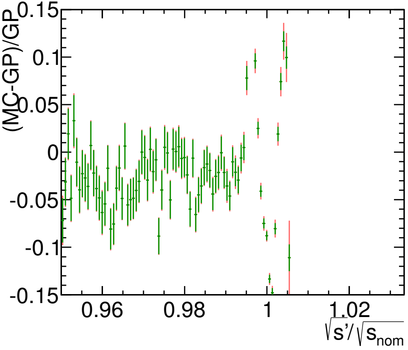

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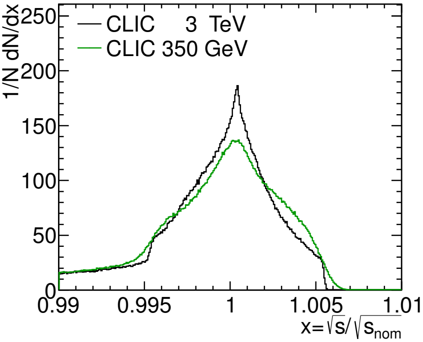
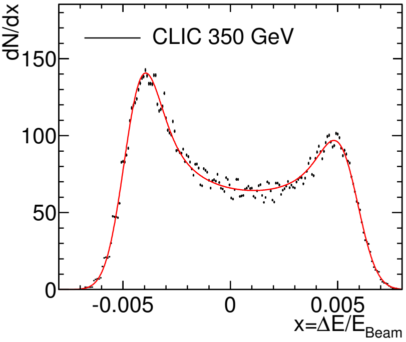


Beam-Energy Spread at 350 GeV

- The beam-energy function, a beta-distribution *b* convoluted with Gauss, well describes the distribution

$$\mathrm{BES}(x) = \int_{x_{\mathrm{min}}}^{x_{\mathrm{max}}} b(\tau)\mathrm{Gauss}(x-\tau)\mathrm{d}\tau$$

- **Side Remark: Some issue coming from the accelerator simulation causes steps in the distribution (not present in 3 TeV files)**
  - **Later: Smeared the energy and longitudinal position of the macro particles to remove the steps**



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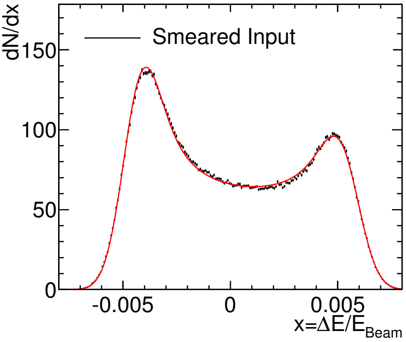

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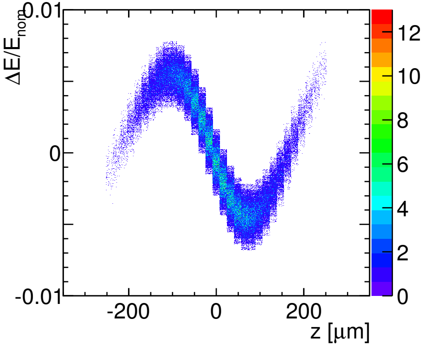

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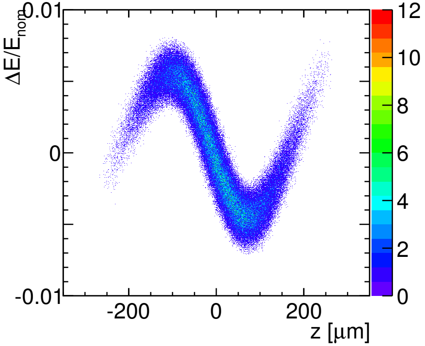
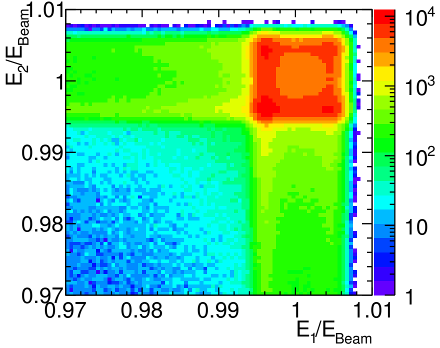


Luminosity Weighted Beam-Energy Spread

$$\mathrm{BES}(x) = \int_{x_{\mathrm{min}}}^{x_{\mathrm{max}}} b(\tau)\mathrm{Gauss}(x-\tau)\mathrm{d}\tau$$

- Can also use the function to fit the luminosity weighted beam-energy spreads
- However for these fits, it is better to not fix the parameters $x_{\mathrm{min}}, x_{\mathrm{max}}, \sigma$,
- Could just be, that we have to convolute with a distribution for the beamstrahlung, which pushes x_{min} to lower values and increases σ
- Needs a bit more investigation, and maybe have to include different or variable $x_{\mathrm{min}}, x_{\mathrm{max}}$ in the fit



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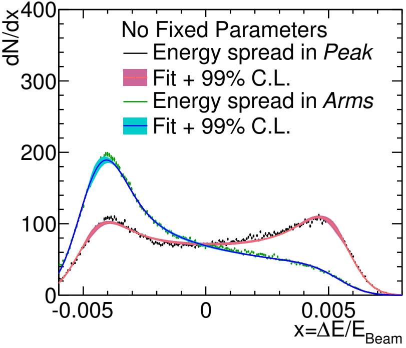

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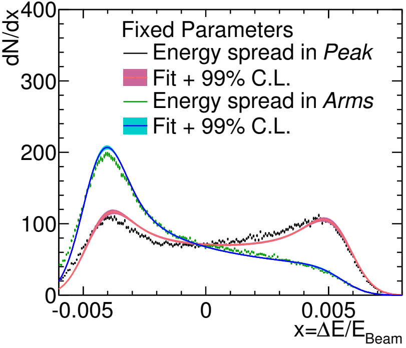
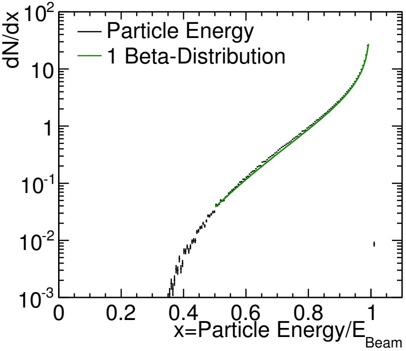


Luminosity Spectrum at 350 GeV CLIC

- **Beta Distribution fits the Energy distribution**
- The four-region approach from 3 TeV is still applicable



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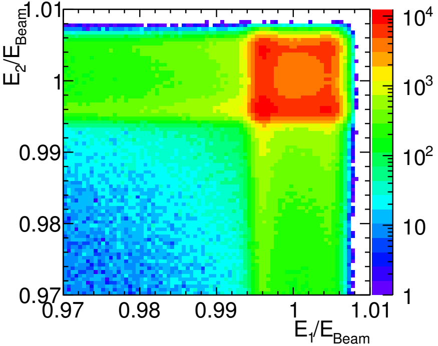
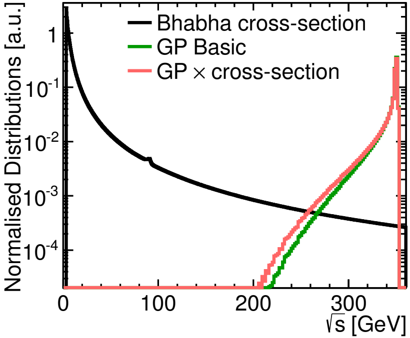


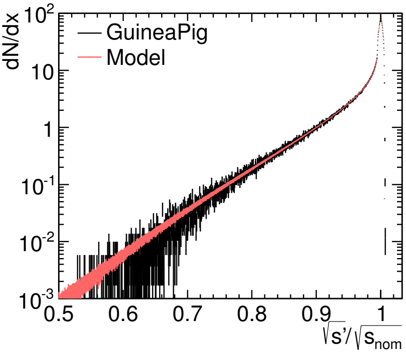
Expected Number of Events

- Bhabha cross-section at CLIC 350 GeV is about 620 pb (particles with $\theta > 7^\circ$)
  - Cross-section estimated with BHWide, without Beamstrahlung, with ISR
- 6.2 million events in 10 fb^{-1}(which is the luminosity used for $t\bar{t}$-threshold scan points)
- Sufficient number of events for reconstruction of the spectrum for each scan point



Reconstructed Spectrum

- Applied the re-weighting fit on the Bhabha event observables
- Selection cut for events with $0.7\sqrt{s}_{\mathrm{nom}}$ (based on reconstructed observables)
- Not yet applied detector resolutions
- Beamstrahlung tail is well reconstructed
- Peak shows large deviations for small energy steps



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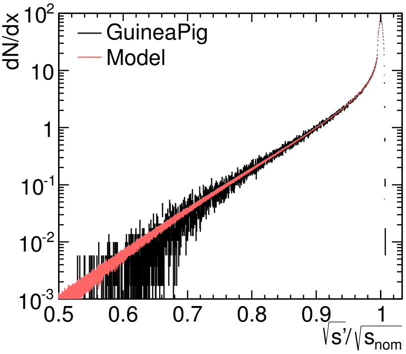

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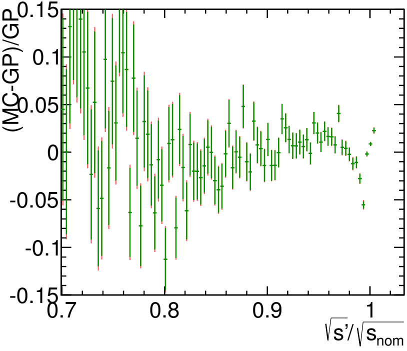

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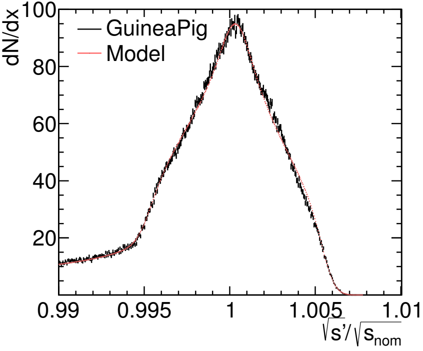

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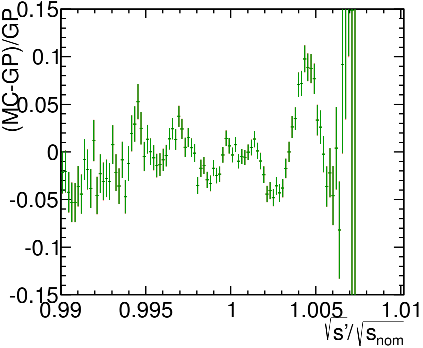

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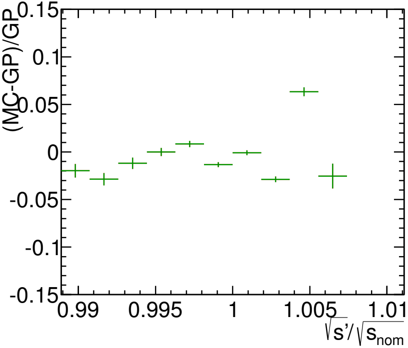

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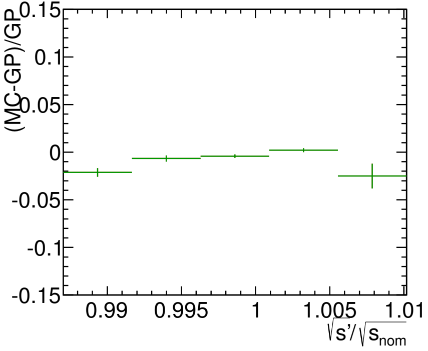

Reconstructed Width

- Important for the $t\bar{t}$-threshold scan is that the width is properly reconstructed
- Estimated the standard deviation – as there is no ‘width’ parameter – of the GUINEAPIG and reconstructed luminosity spectrum

GUINEAPIG:	0.003332 ± 0.000003	(uncertainty from 1 million events)
Reconstructed:	0.003334 ± 0.000002	(uncertainty from parameters)

  Difference between the widths is less than 0.1%, but larger than uncertainties from sample or parameters
- Frank Simon, Michal Tesař will estimate impact on top-mass measurement
  - Increasing uncertainty by factor 4 to account for their increase due to detector resolutions

Summary

- Reconstruction at 3 TeV is working, note submitted for publication
- Summer student looked at reconstruction at 350 GeV, showing promising results
- There is still some work possible for this reconstruction
- Cross-check underway for $t\bar{t}$ threshold scan
- It might be possible to use smearing/scaling to use 3 TeV beam files to create 1.4 TeV beam files, and create backgrounds

Backup Slides

The MODEL: Putting the Individual Parts Together

$$\mathscr{L}(x_1, x_2) =$$

$$p_{\text{Peak}}\,\delta(1-x_1) \otimes \text{BES}\left(x_1; [p]_1^{\text{Peak}}\right)$$
$$\delta(1-x_2) \otimes \text{BES}\left(x_2; [p]_2^{\text{Peak}}\right)$$

$$+\, p_{\text{Arm1}}\,\delta(1-x_1) \otimes \text{BES}\left(x_1; [p]_1^{\text{Arm}}\right)$$
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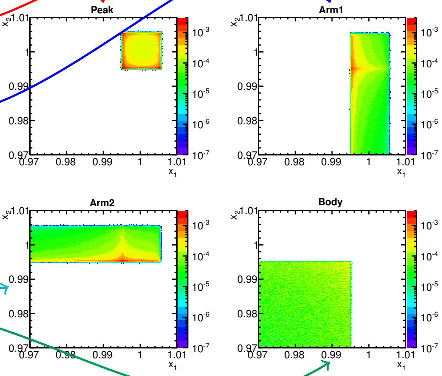

With

$$\text{BES}(x) = \int_{x_{\min}}^{x_{\max}} b(\tau)\text{Gauss}(x-\tau)\,\mathrm{d}\tau$$

$$\text{BB}(x) = (b \otimes \text{BES})(x)$$

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Model: 19 free parameters, here drawn with arbitrary parameter values

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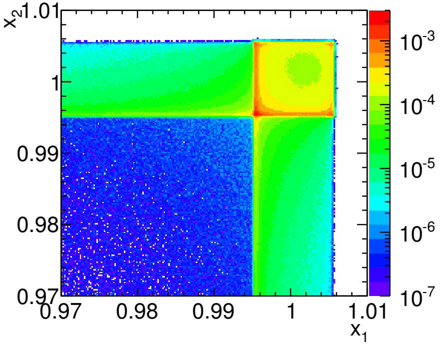

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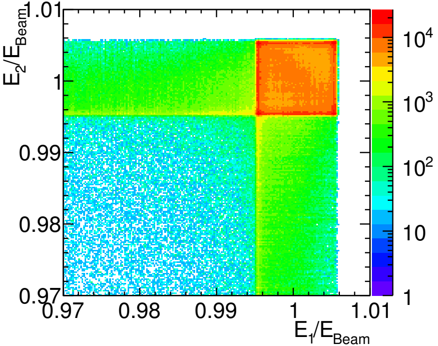

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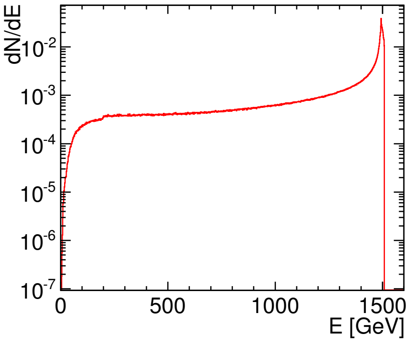
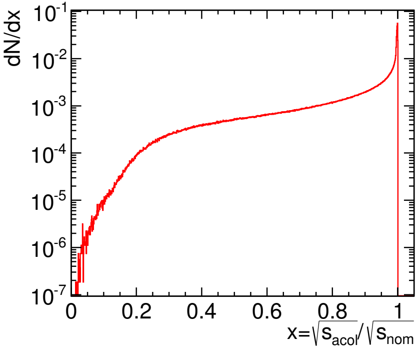
Observables (shown for 3 TeV)

Unsmeared

Energy of the electron/positron:



Relative centre-of-mass energy (c.m.e.):



Very large effect on energy, small on relative c.m.e. because of better angular resolution

$$\frac{\sqrt{s'_{acol}}}{\sqrt{s_{nom}}} = \sqrt{\frac{\sin(\theta_1)+\sin(\theta_2)+\sin(\theta_1+\theta_2)}{\sin(\theta_1)+\sin(\theta_2)-\sin(\theta_1+\theta_2)}},$$

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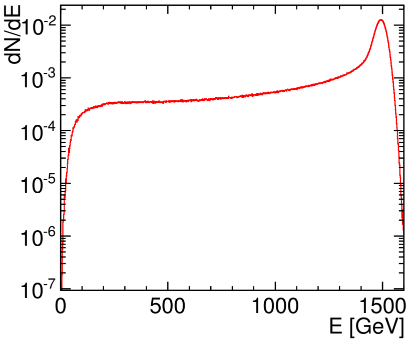

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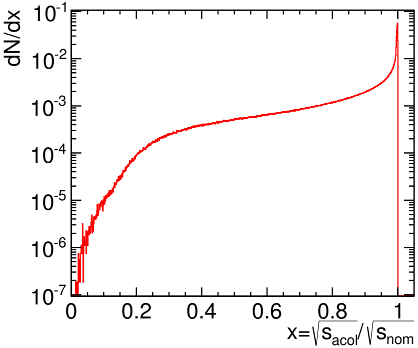

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