Search for a visible Z' dark boson in μμττ final state with Belle II

Luigi Corona[1], Giacomo De Pietro[2] and Enrico Graziani[2] for the Belle II collaboration

[1]INFN and University of Pisa, [2]INFN of Roma Tre

■ Introduction and Motivations

- $L_\mu - L_\tau$ model introduces a light Z' boson with coupling only to the 2nd and 3rd lepton generations
- Search for the Z' produced in association with a μ pair and decaying to a τ pair, in e^+e^- collisions at 10.58 GeV/c²
- Dataset expected for this analysis ~100/fb
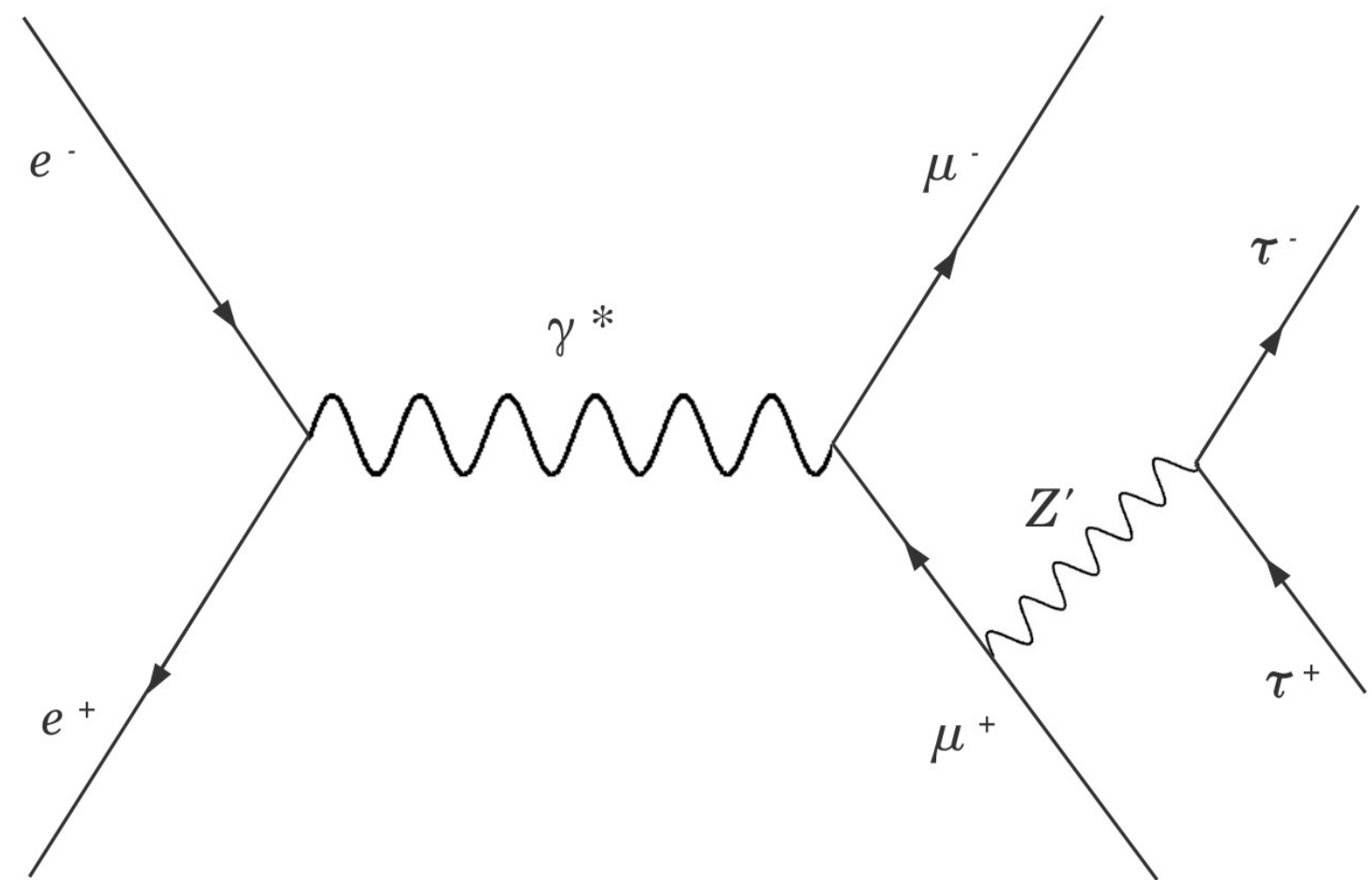
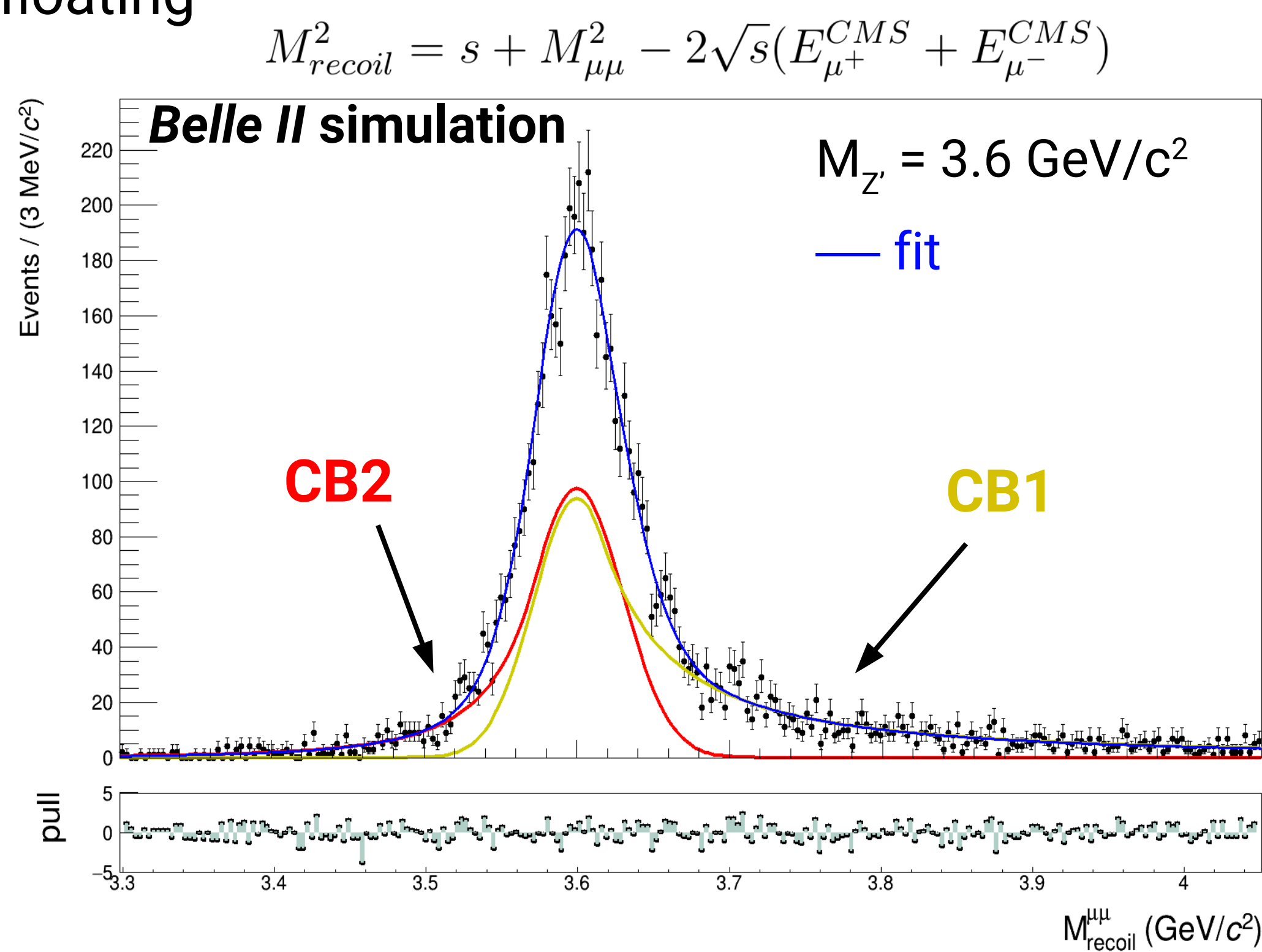- $L_\mu - L_\tau$ model anomaly free by construction
  - ➜ assuming $M_{Z'} \sim O(MeV - GeV)$ and $g' \sim O(10^{-6} - 10^{-2})$, it may solve
    - dark matter puzzle
    - $(g-2)_\mu$ anomaly
    - flavour anomalies like $B \to K^*\mu^+\mu^-$, R_K, R_{K^*}
- No experimental results for a ττ resonance in μμττ final states
  - ➜ the results can be reinterpreted in alternative models with resonances decaying to ττ

Shuve et al. Phys. Rev. D 89, 113004, Altmannshofer et al. 10.1007/JHEP12(2016)106
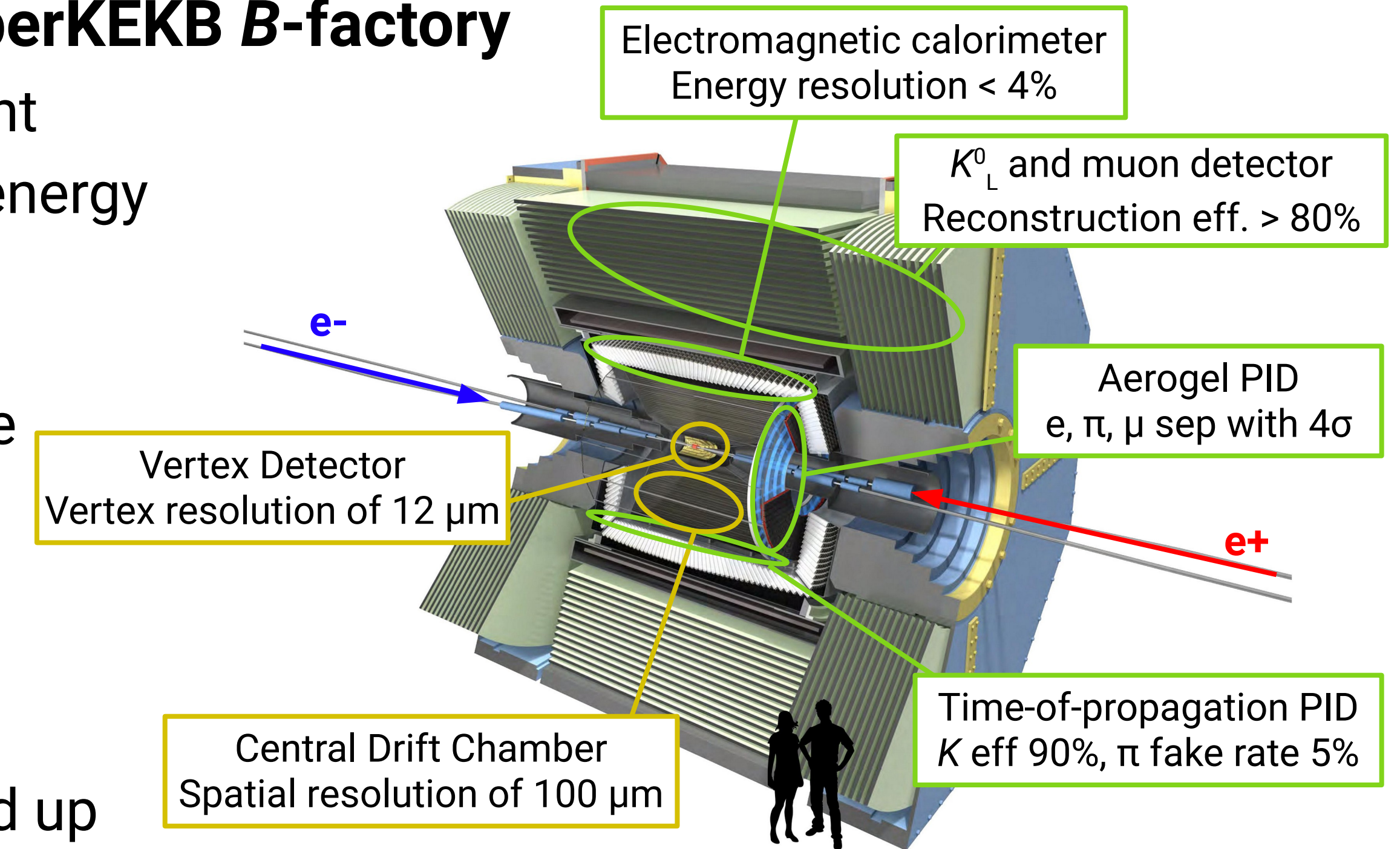
■ Signal shaping

- Signal peak expected in the recoil mass with respect to μμ
- Fit with the sum of two crystal ball distributions (CB1 + CB2)
  - ➜ fixed CB means at the Z' mass, all the other parameters floating

$$M_{recoil}^2 = s + M_{\mu\mu}^2 - 2\sqrt{s}(E_{\mu^+}^{CMS} + E_{\mu^-}^{CMS})$$

Belle II simulation, $M_{Z'} = 3.6$ GeV/c²

- Resolution: $\sigma = \sqrt{f \cdot \sigma_{CB1}^2 + (1-f) \cdot \sigma_{CB2}^2}$ *f: fraction of CB1*
  - ➜ from ~30 MeV/c² to ~1.5 MeV/c², as Z' mass increases

■ Belle II at SuperKEKB B-factory

- Clean environment
- Known collision energy
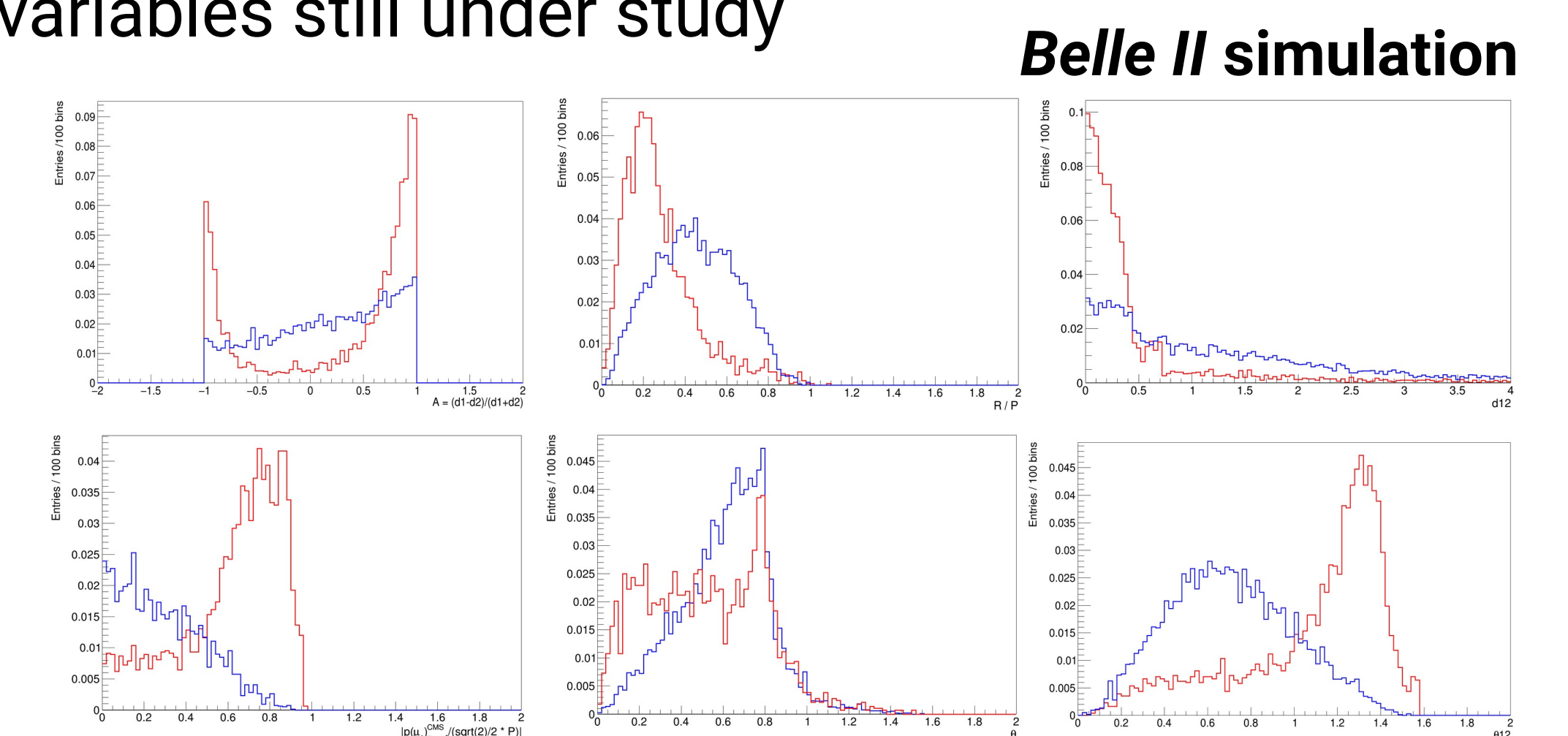- High hermeticity (> 90% of 4π)
- Capability to cope with high background

Electromagnetic calorimeter Energy resolution < 4%

K^0_L and muon detector Reconstruction eff. > 80%

Aerogel PID e, π, μ sep with 4σ

Time-of-propagation PID K eff 90%, π fake rate 5%

Central Drift Chamber Spatial resolution of 100 μm

Vertex Detector Vertex resolution of 12 μm

■ Goal
- Collect 50/ab
  - ➜ 165/fb collected up to now

## ■ Background suppression

- Main background components expected: $q\bar{q}$, ττ, μμ, eeμμ
- Background suppression: MLP (neural network) based
  - ➜ 15 discriminating variables from kinematic studies
  - ➜ some additional variables still under study

Belle II simulation

Examples:
Signal
Background

Background that survives MLPs (80/fb)

- ττ (16%)
- $q\bar{q}$ (43%)
- eeμμ (26%)
- μμ (15%)

Belle II simulation

- 3 different MLPs, one for each of the following Z' mass ranges:
  [3.6, 5.6] GeV/c²
  [5.6, 7.6] GeV/c²
  [7.6, 10] GeV/c²
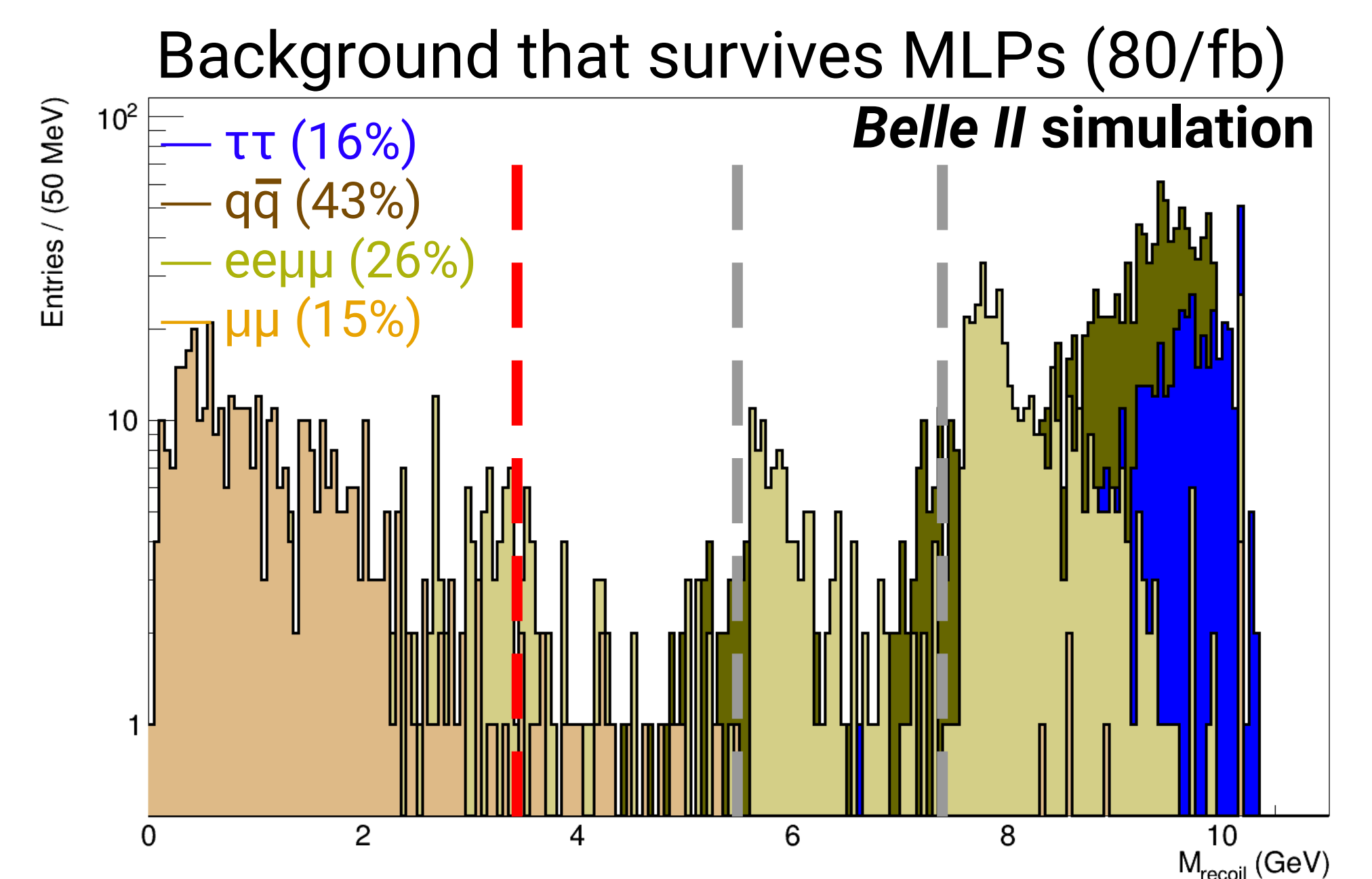
■ Control samples

CS-1 $\pi^+\pi\tau\tau$
  - ➜ signal does not peak
  - ➜ signal efficiency negligible
CS-2 $M_{recoil} < 3.3$ GeV/c² and M(4-tracks) < 9.5 GeV/c²
  - ➜ overall ratio data/MC ~1.08
- Use them for trigger efficiency and systematics studies (including MLPs)

CS-2 ~37/fb of data

ψ(2s)

- Data
- MC
- ττ
- $q\bar{q}$
- μμ
- eeμμ

■ Preliminary results

Sensitivity to g' ($L_\mu - L_\tau$)

(g-2) ±2σ

Belle II 2018
$\int Ldt = 276$ pb⁻¹

- L_μ-L_τ (obs.) 90% CL UL
- L_μ-L_τ, BF(Z'→ inv)=1 (obs.) 90% CL UL
- L_μ-L_τ expected UL
- L_μ-L_τ, BF(Z'→ inv)=1 expected UL

- 10/fb
- 100/fb
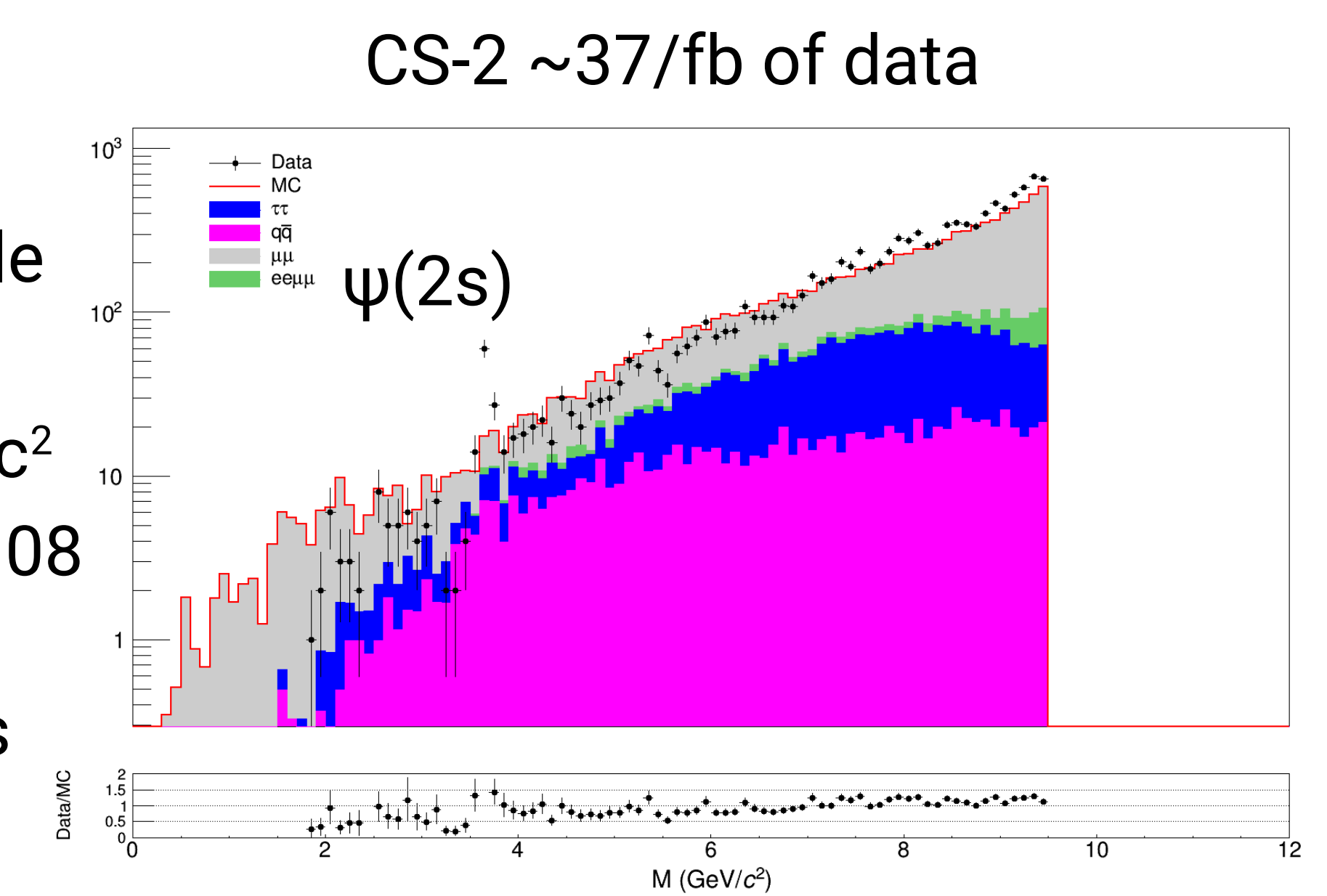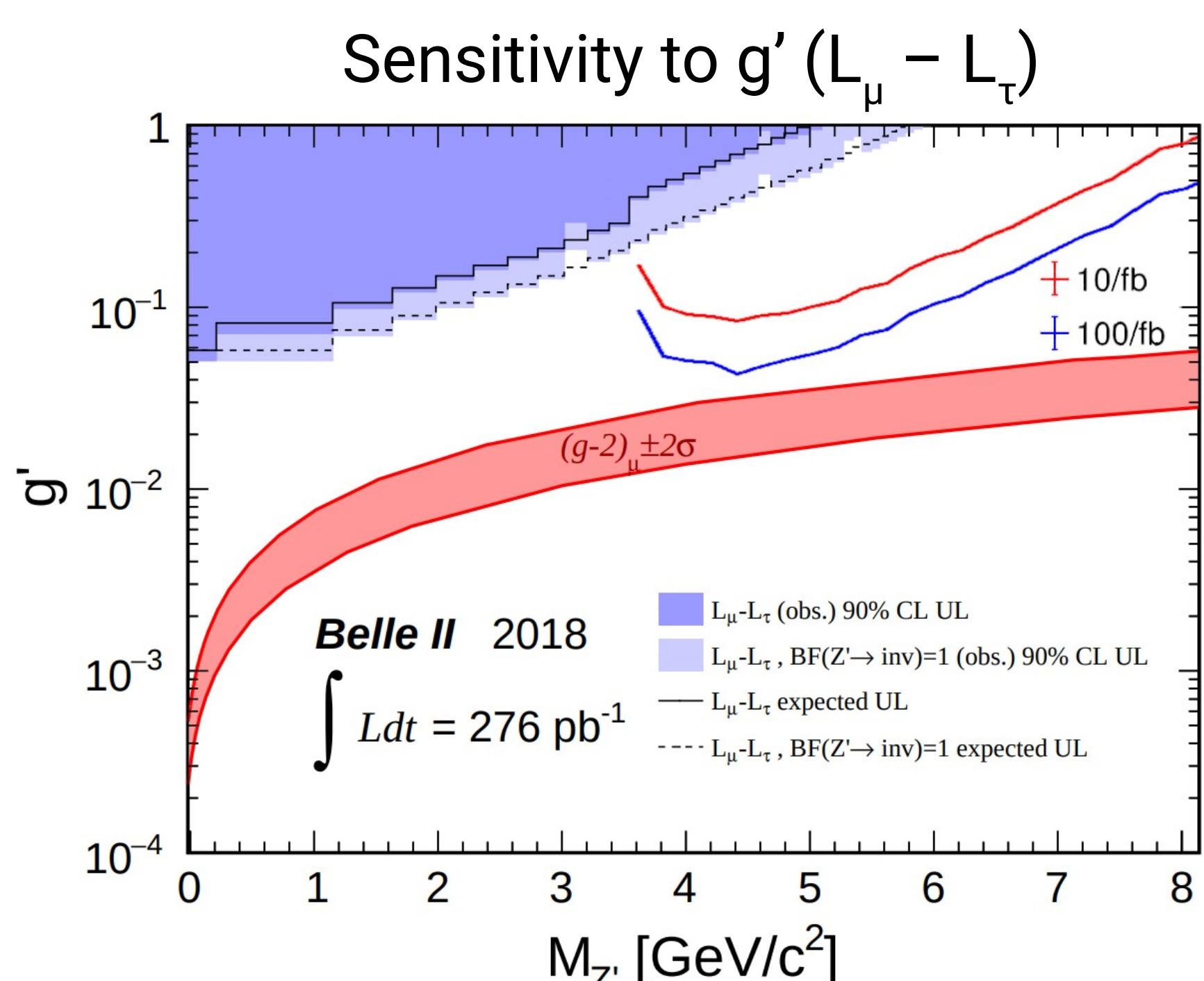
- 90% CL upper limits is calculated as a basic Poisson counting experiment
- No trigger efficiency and systematic uncertainties are included
- Obtained using only 6 discriminating variables

■ Conclusions and outlook

- Implement signal yield extraction through a sig+bkg fit
  - ➜ improve sensitivity
- Test MLP on control samples
- Study the trigger efficiency and the systematics

$N_{sig}(CB1 + CB2) + N_{bkg}$Chebyshev0

Belle II simulation

$\chi^2 = 1.19$
$N_{sig} = 20.81 \pm 6.52$
$N_{bkg} = 54.17 \pm 8.71$
$N_{sig}^{exp.} = 20.0$
$N_{bkg}^{exp.} = 55.0$