CLIC BDS tuning and luminosity signal

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Outline

- CLIC BDS tuning
  - Update since ILCW'10
- Consideration on luminosity signals

Summary of IWLC' 10

pre-alignment H&V [μm]	Success rate %	lattice	comments
10	80	L* = 3.5 m	nominal
10	84	L* = 3.5 m	Higher energy bandwidth
10	87	L* = 3.5 m	Lumi optimization + horizontal knobs

Design and sextupole knobs improve the FFS performances

Since the workshop…

- New improved knobs
- New tuning strategies

Tuning strategy (1/2)

inputs

- horizontal and vertical random mis-alignment: σ =10 μm
- bending magnets perfectly aligned
- 100 seeds
- identical electron and positron machine

Tuning steps

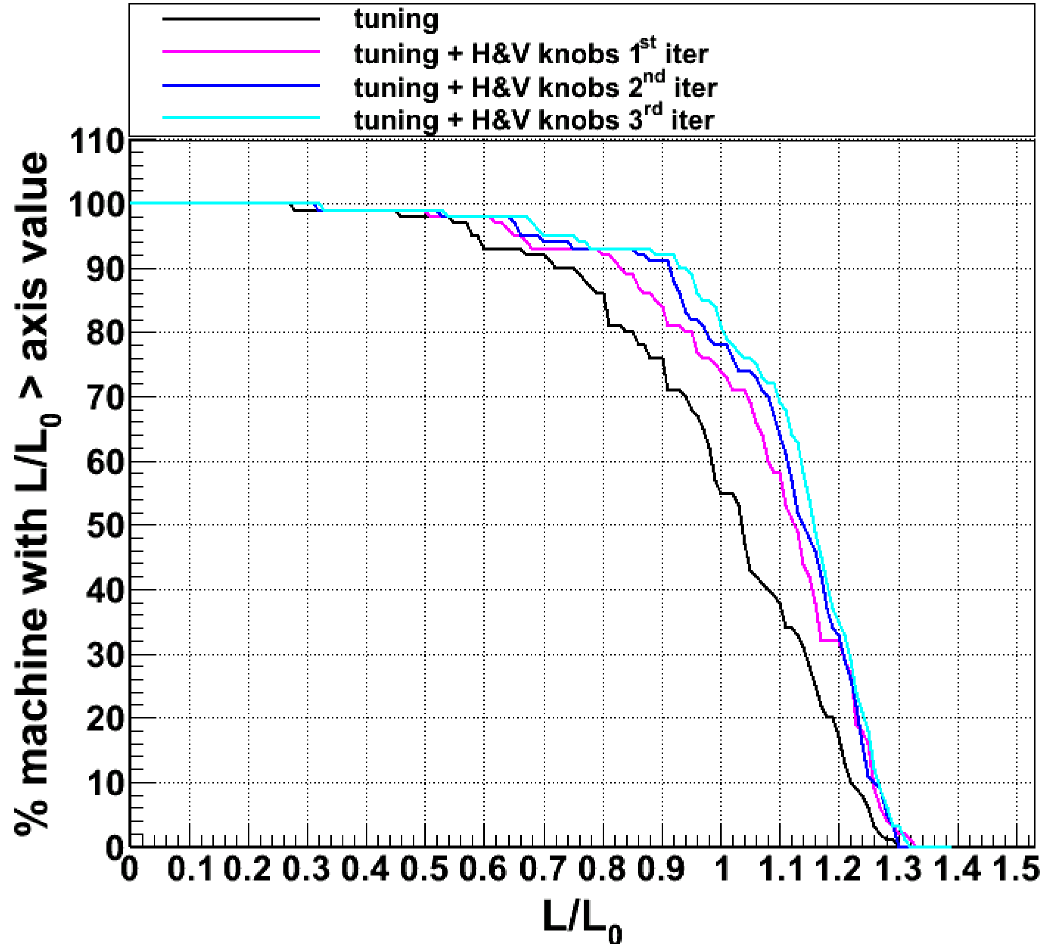
1. Luminosity optimization (Simplex-Nelder algorithm)
2. Horizontal and Vertical sextupole knobs

In both steps we need some fast luminosity measurements

- Luminosity optimization needs O(10000) measurements
- Knobs tuning L points $\times$ M knobs $\times$ N iter O(100) measurements

Luminosity results (1/2)

- luminosity optimization only: 55% of the seeds reach 100% of nominal luminosity.
- after 2 iterations of H and V knobs: 90% of the seed reach 90% of nominal luminosity



- luminosity optimization needs ~16000 luminosity measurements
- Knobs tuning

20 points × 8 knobs × 2 iter ~ 320 luminosity measurements

Tuning strategy (2/2)

inputs

- horizontal and vertical random mis-alignment: σ =10 μm
- bending magnets perfectly aligned
- 100 seeds
- identical electron and positron machine

tuning steps

1. (BDS) 1-to-1 correction x and y plane : 50 iteration (= 50 bunch)
2. (BDS) DFS y plane and target DFS x plane: 40 iteration (= 40 bunch)
3. (BDS) Multipole shunting: 20-30 bunch

   1. + 2. + 3. ~ 60 ns

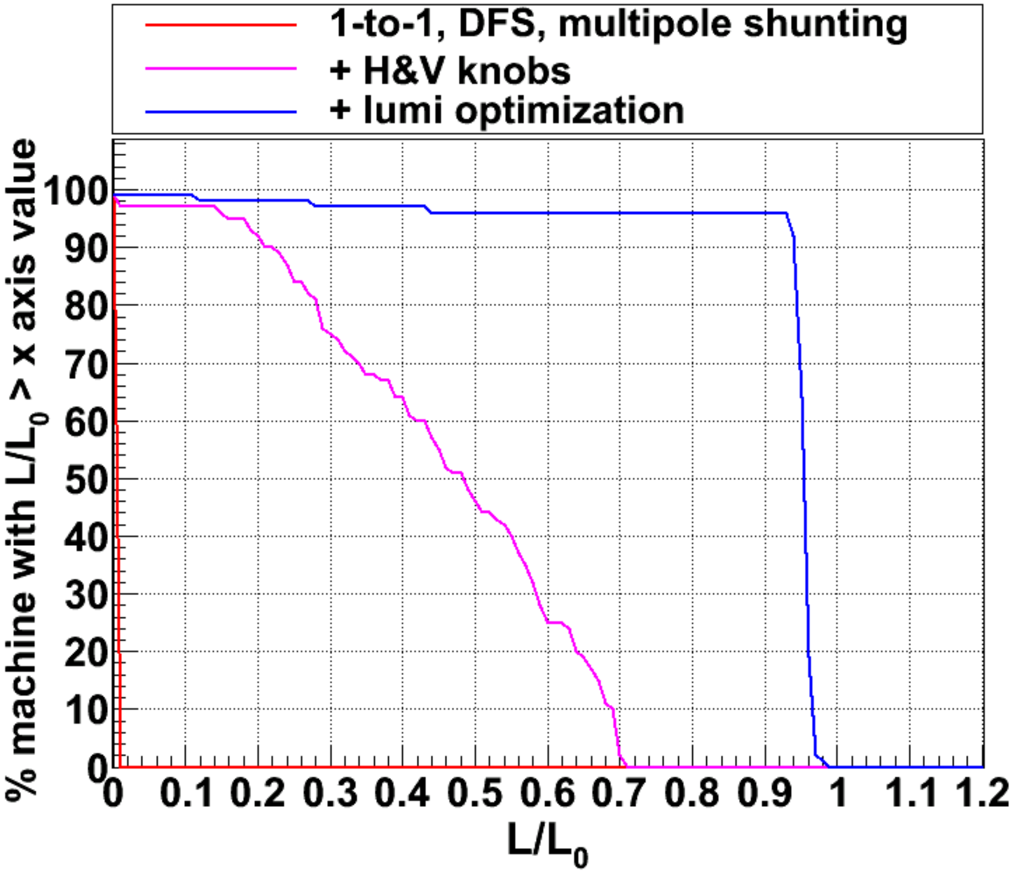
4. (FFS) sextupole knobs scan : O(100-1000) luminosity measurement
5. (FFS) luminosity optimization O(1000)

Luminosity results (2/2)

- 1-to-1, DFS and multipole shunting recover ~ 1% of lumi (bad systematic convergence of the algorithm in the horizontal plane)

- most of the luminosity is recovered by the sextupole knobs (10 H &V knobs)
20 points × 10 knobs × 4 iter
~ 800 luminosity measurement

- luminosity optimization ~4000 (iteration) luminosity measurement



95% of the machine reach 90% of nominal CLIC luminosity
Total number of luminosity measurements reduced from ~17000 to ~5000

Luminosity signal

Luminosity measurement signal

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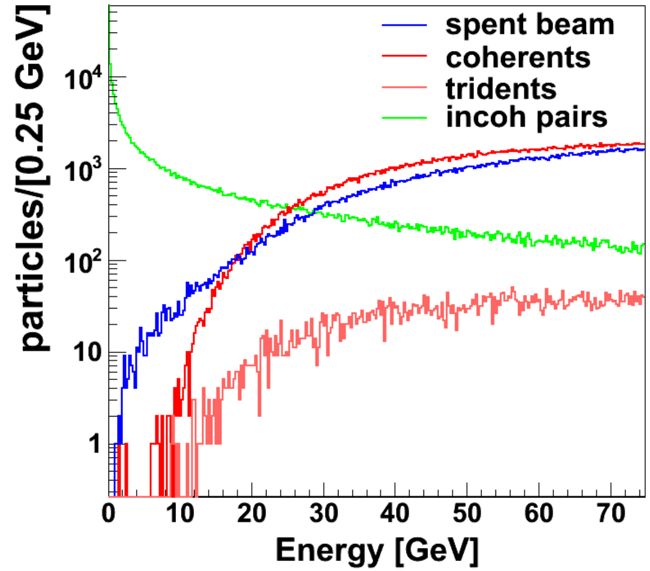
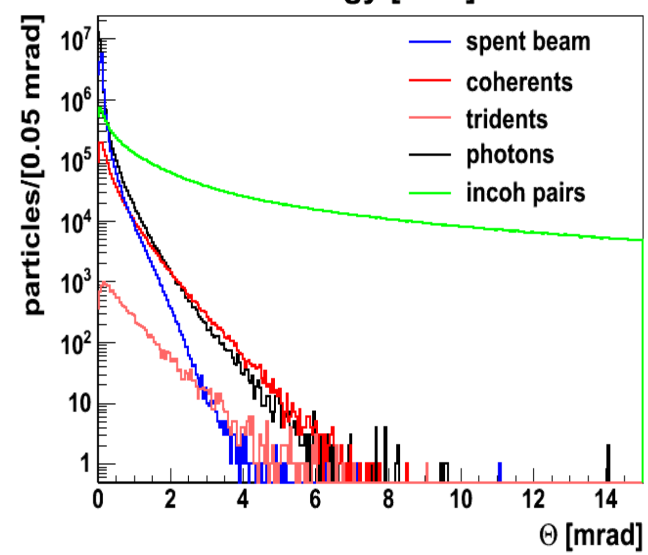
- radiative bhabha :
  high counting rate O(10^4 /bx) but not really visible in the spent beam spectrum

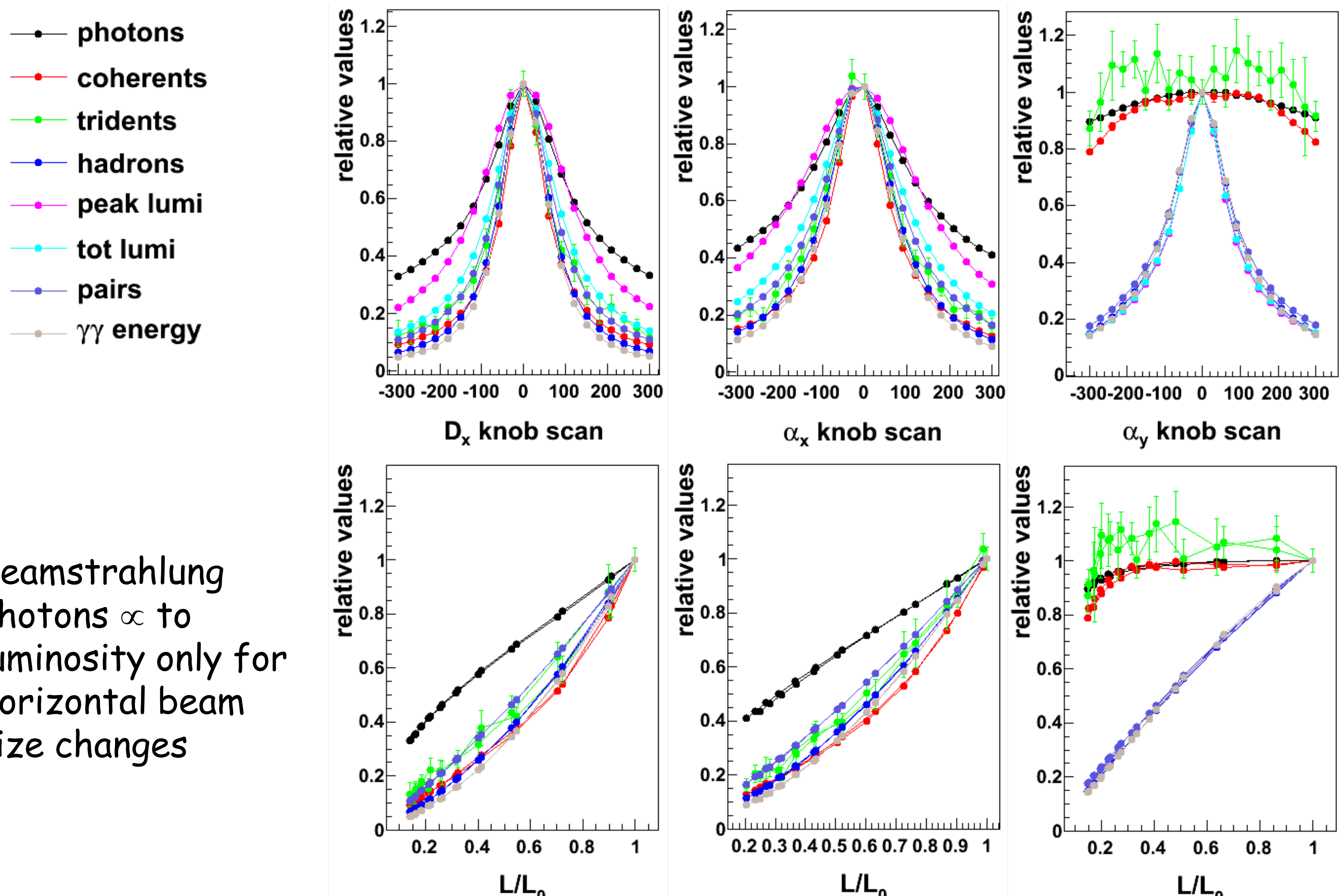
- low angle bhabha
  7-70 minutes for 1% luminosity measurement according to the Θ cut O(20 -2 Hz)

- long term luminosity stability due to dynamic imperfections in Main Linac + BDS ~ 10-30 minutes
  ⇒ we need to tune in O(min)



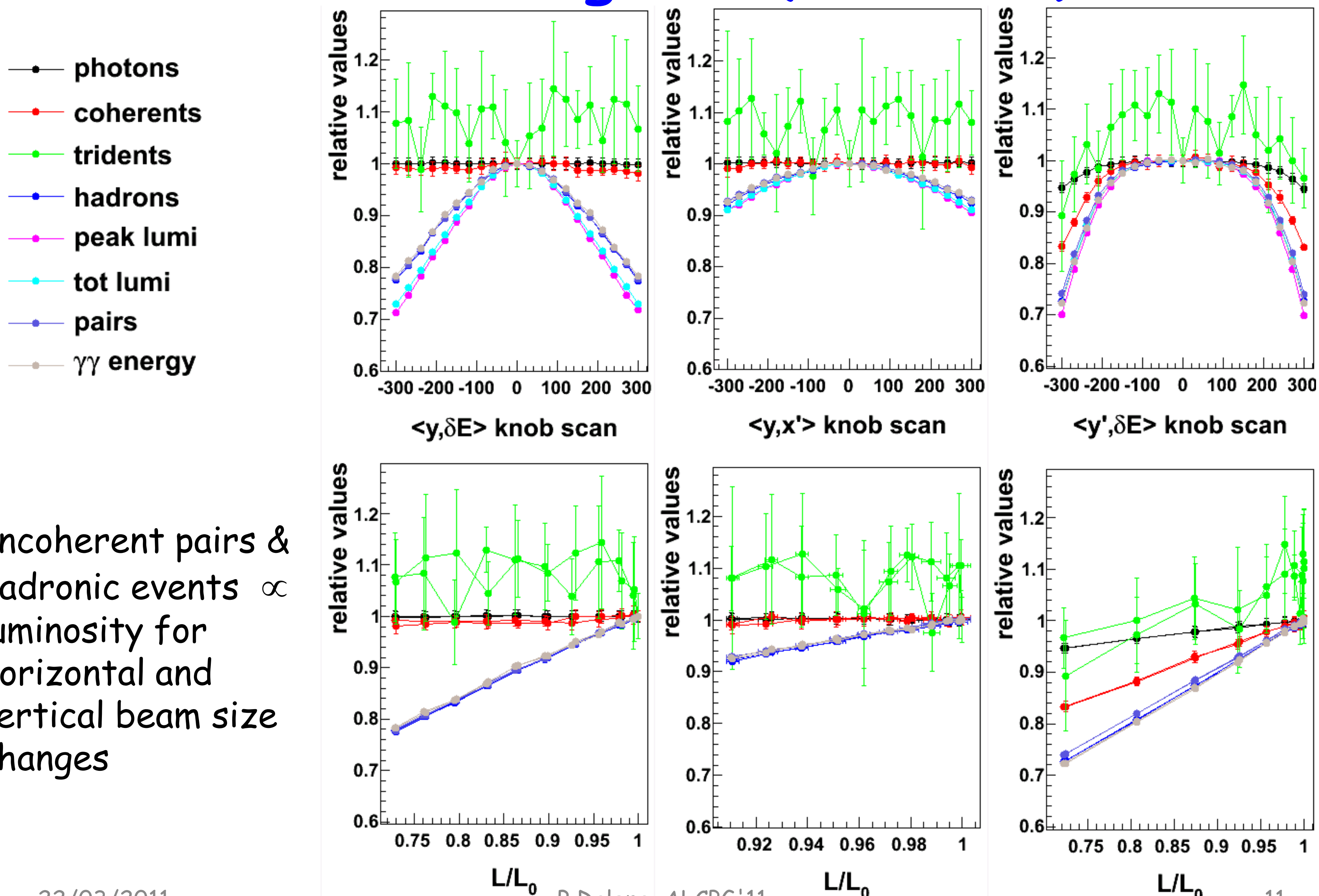


Possible signals (H knobs)



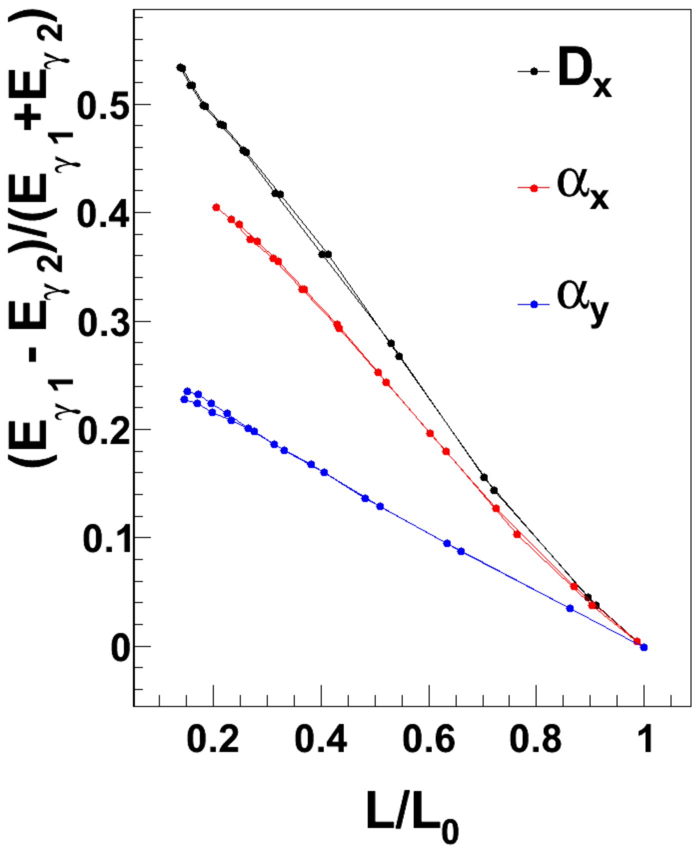
Beamstrahlung photons ∝ to luminosity only for horizontal beam size changes

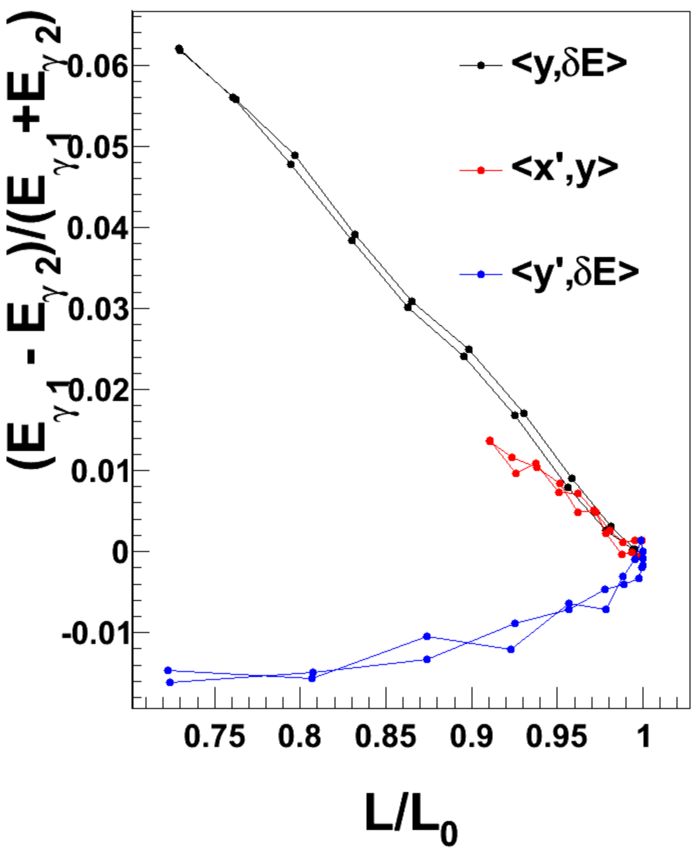
Possible signals (V knobs)



Incoherent pairs & hadronic events $\propto$ luminosity for horizontal and vertical beam size changes

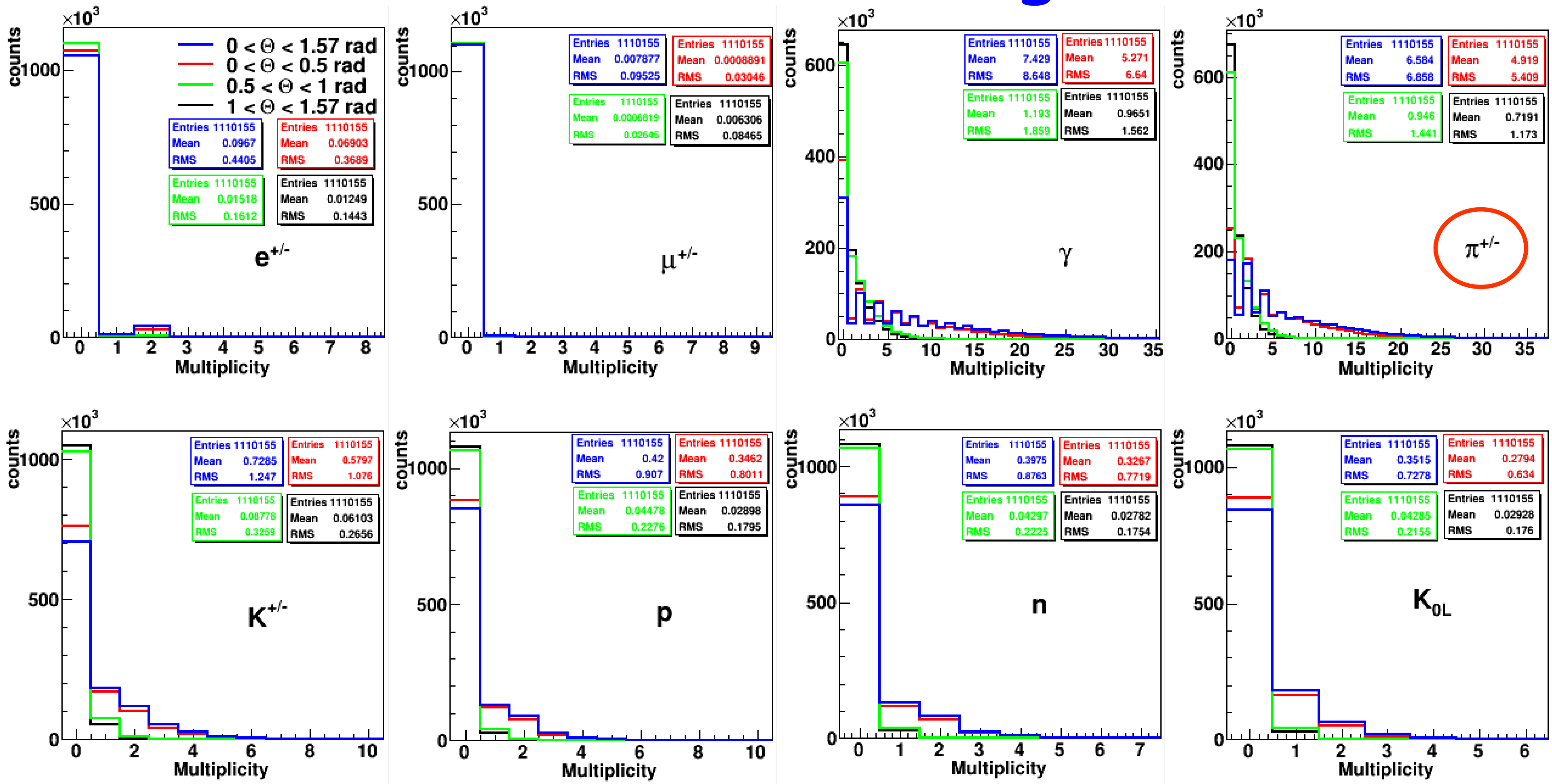
Combination of beamstrahlung signal





The correlation of beamstrahlung photons from the two beams are more $\propto$ luminosity than their number.

Hadronic events signals



- No Pt cut applied
- $N_{\gamma\gamma \rightarrow hadron}$ per bx are ~3
- Hadronization from Pythia (D. Schulte)

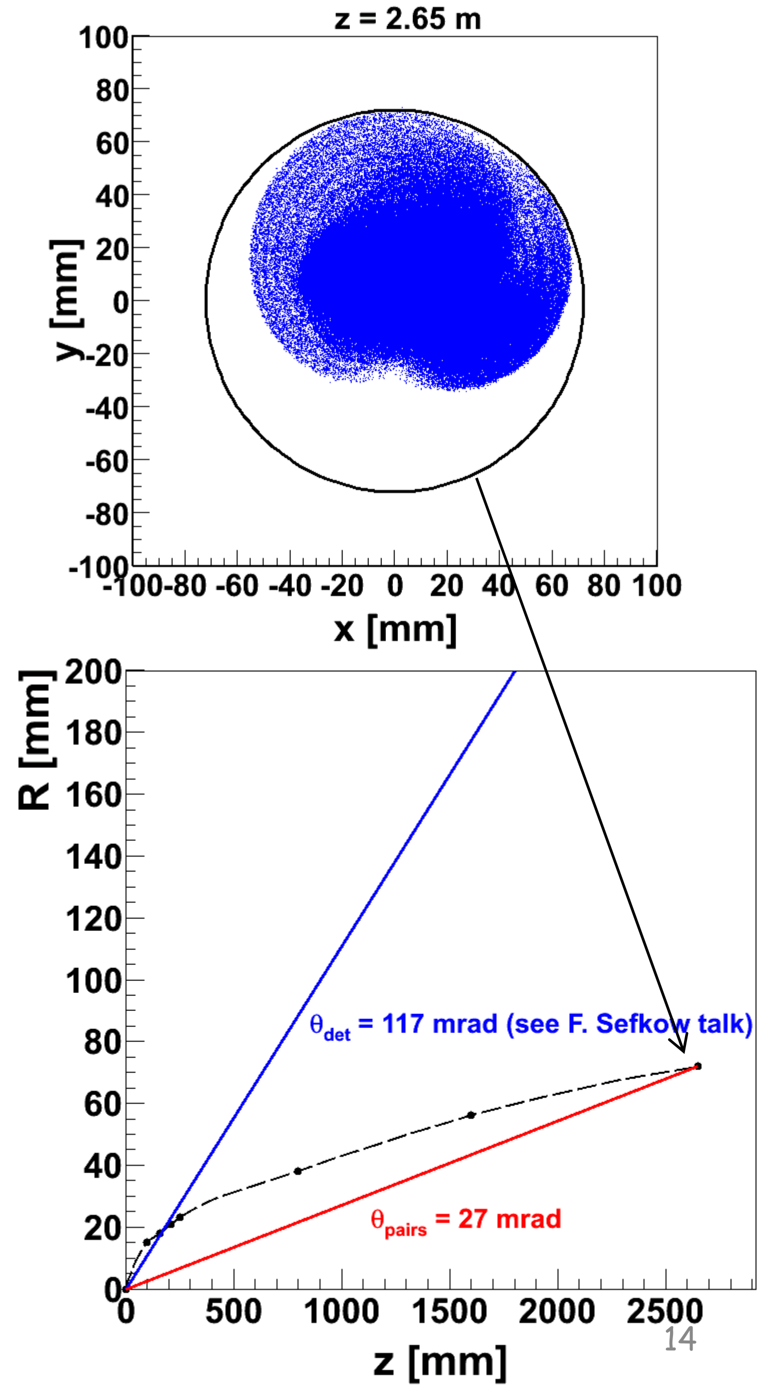
pions multiplicity is a good signal candidate

θ cuts

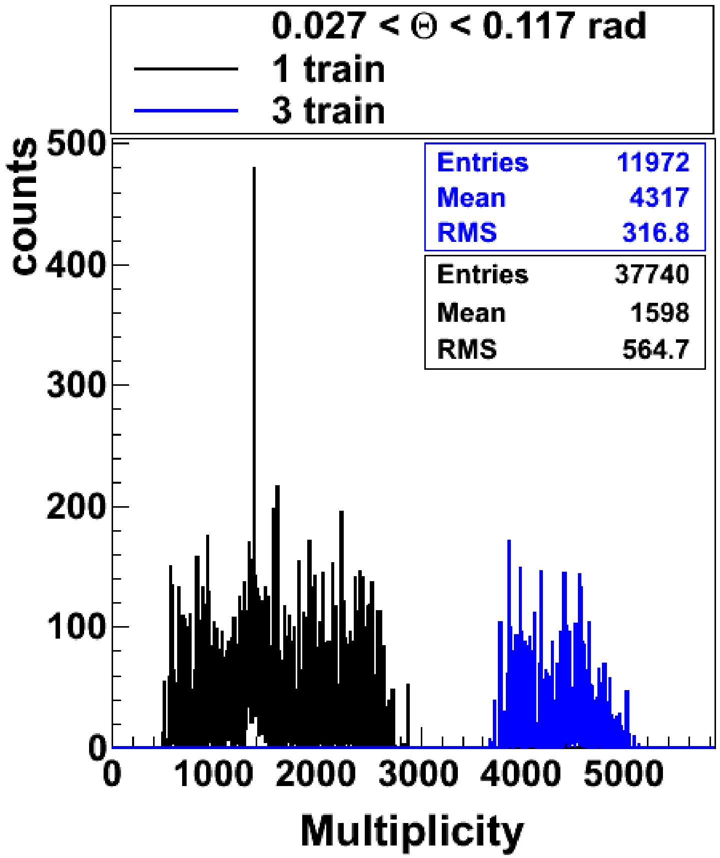
- Defined to reduce incoherent pairs background
- Lorentz boost in the lab frame + helix track in a uniform magnetic field (5 Tesla)

Two regions can be identified

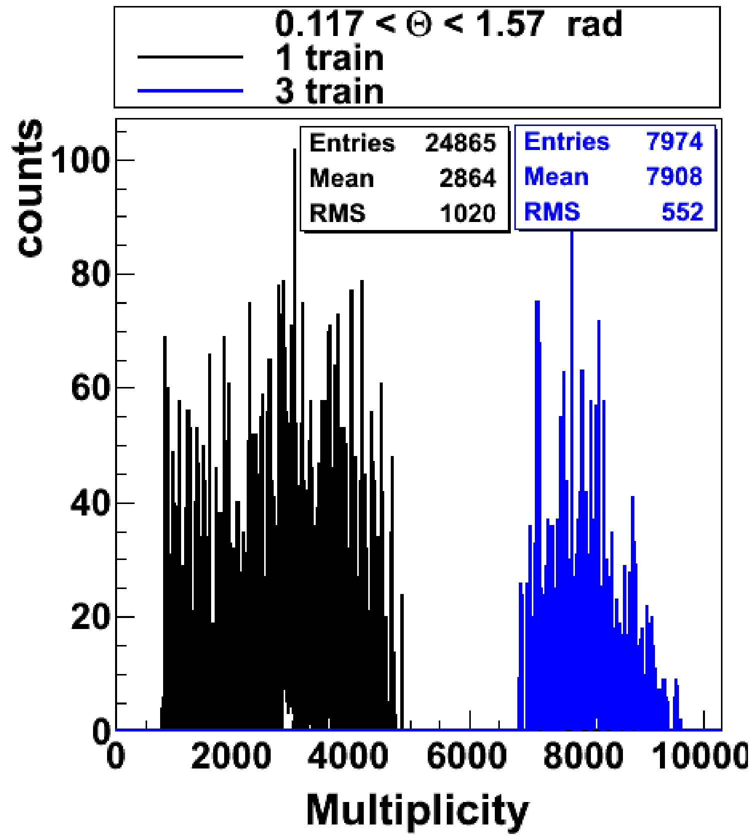
- $\theta_{pairs} < \theta < \theta_{det}$
- $\theta > \theta_{det}$



Multiplicity distributions



Pt cut 0.050 GeV/c



Pt cut 0.160 GeV/c

3 train : Mult rms ~ 7% ⇒ ~ 1% with 100 train

Conclusion

- Static tuning of CLIC BDS-FFS succeded with two techniques

- Minimum number of luminosity measurements needed so far ~ 5000 $\Rightarrow$ we need a fast luminosity measurement

- Possible luminosity signals are hadronic events
  - pions multiplicity with 1% rms with 100 train

  $\Rightarrow$ 2 s for one luminosity measurement (~3 hour to tune the system)

Outlook

- Improve the tuning algorithm to reduce the number of luminosity measurements
- Look at different luminosity signals correlations

Back-up

Tuning strategy (1/2)

inputs

- horizontal and vertical random mis-alignment: σ =10 μm
- bending magnets perfectly aligned
- 100 seeds
- identical electron and positron machine

Tuning steps

luminosity optimization (Simplex-Nelder algorithm)

↓

While (luminosity gain > iteration -1) apply knob of best lumi and iterate

- H
  - horizontal dispersion
  - αx
  - αy
- V
  - vertical dispersion
  - $\langle y, x' \rangle$
  - $\langle y', \delta \rangle$
  - $\langle y, y' \rangle$
  - $\langle x, y \rangle$

Luminosity Measurement Signal

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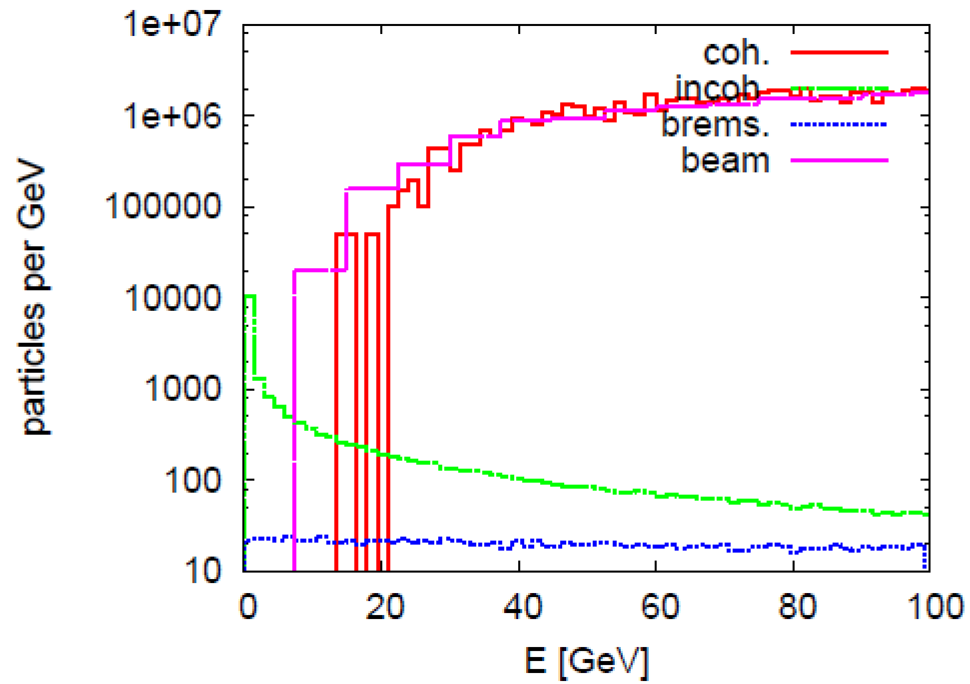
- Radiative Bhabhas
  - have high counting rate ($\mathcal{O}(10^4/bx)$)
  - but are not visible in spent beam spectrum
- Low angle Bhabhas
  - at agressive $\geq 10\,\mathrm{mradian}$ rate of $\mathcal{O}(20Hz)$
  - at safer $\geq 30\,\mathrm{mradian}$ rate of $\mathcal{O}(2Hz)$

  $\Rightarrow$ need 7–$70\,\mathrm{minutes}$ for 1% luminosity measurement
- Luminosity is precise to 1% in $2\,\mathrm{s}$

$\Rightarrow$ Need to find other signals



- Low angle Bhabha cross section

$$\frac{d\sigma}{dt} = \frac{2\pi m^2 r_e^2}{s^2}\left[\frac{s^2+u^2}{t^2} + \frac{2u^2}{ts} + \frac{u^2+t^2}{s^2}\right]$$

Integrare con prima