Measurement of the beam energy spread

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Motivations

- Necessary ingredient for the determination of Γ_{Φ} from the line shape fits

- Dominant contribution to the resolution on K_L momentum estimated from K_L tag

- To be plugged into the future MC production

- Does it vary along the data set? In particular, does it vary with the nominal value of the sqrt(s)?

Old method (1)

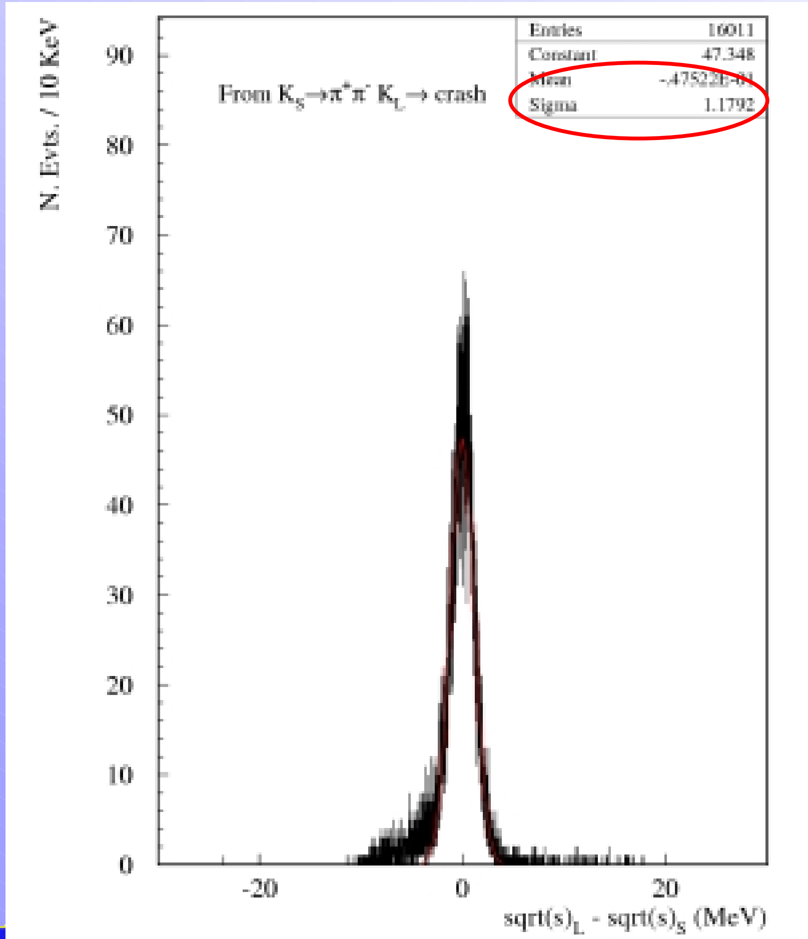
- $K_S \to \pi^+\pi^-$ + Kcrash: two independent estimates of the sqrt(s) are available in the same event:
  - 1) $\mathbf{P_S}$ from K_S, $\mathbf{P_L}$ using the ϕ momentum
  - 2) $\mathbf{P_L}$ from the time of the Klong cluster, $\mathbf{P_S}$ using the ϕ momentum
- In absence of correlation, one has:
  - 1) Sum = $\text{sqrt(s)}_L + \text{sqrt(s)}_S = x + y + 2b$
  - 2) Diff = $\text{sqrt(s)}_L - \text{sqrt(s)}_S = x - y$
  - 1) Var(Sum) = $\sigma_x^2 + \sigma_y^2 + 4\,\sigma_b^2$
  - 2) Var(Diff) = $\sigma_x^2 + \sigma_y^2$

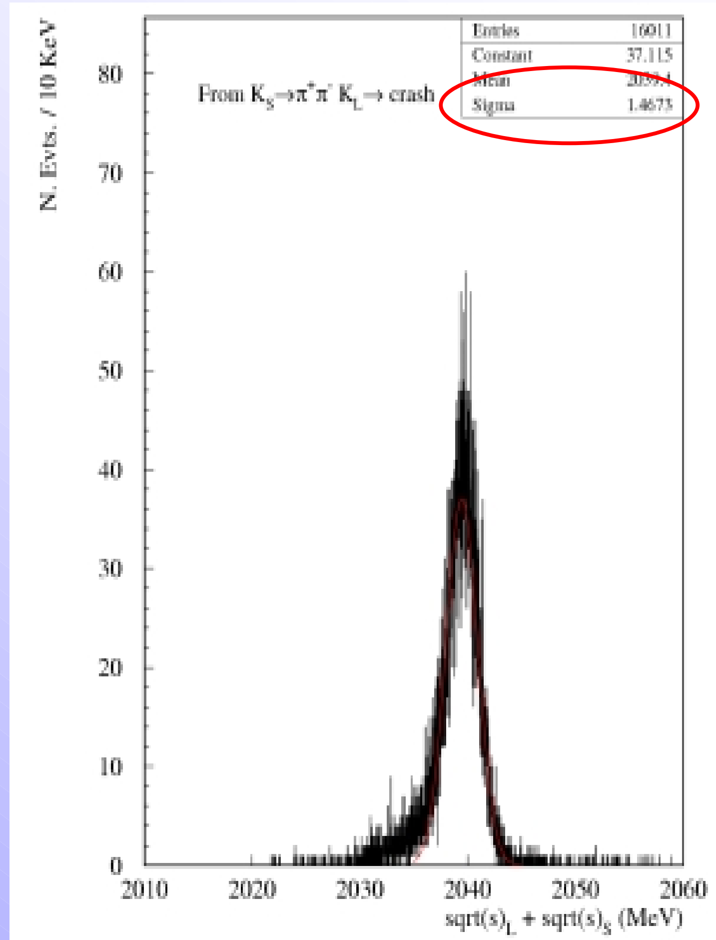
resolutions on the c.m. energy estimates from K_S and K_L

2 x c.m. energy spread

Old method (2)

- Fit Sum and Diff distributions as gaussians
  - c. m. e. spread = ½ $\sqrt{(\sigma^2_{Sum} - \sigma^2_{Diff})}$





Old method (3)

- Result lies around 450 KeV
- Drawbacks:
  - Bad gaussian fits, due to asymmetric tails in the resolution
  - Systematical variation of the result as the fit range changes
  - ISR neglected, this affects the distributions in asymmetric way

New method (1)

ISR

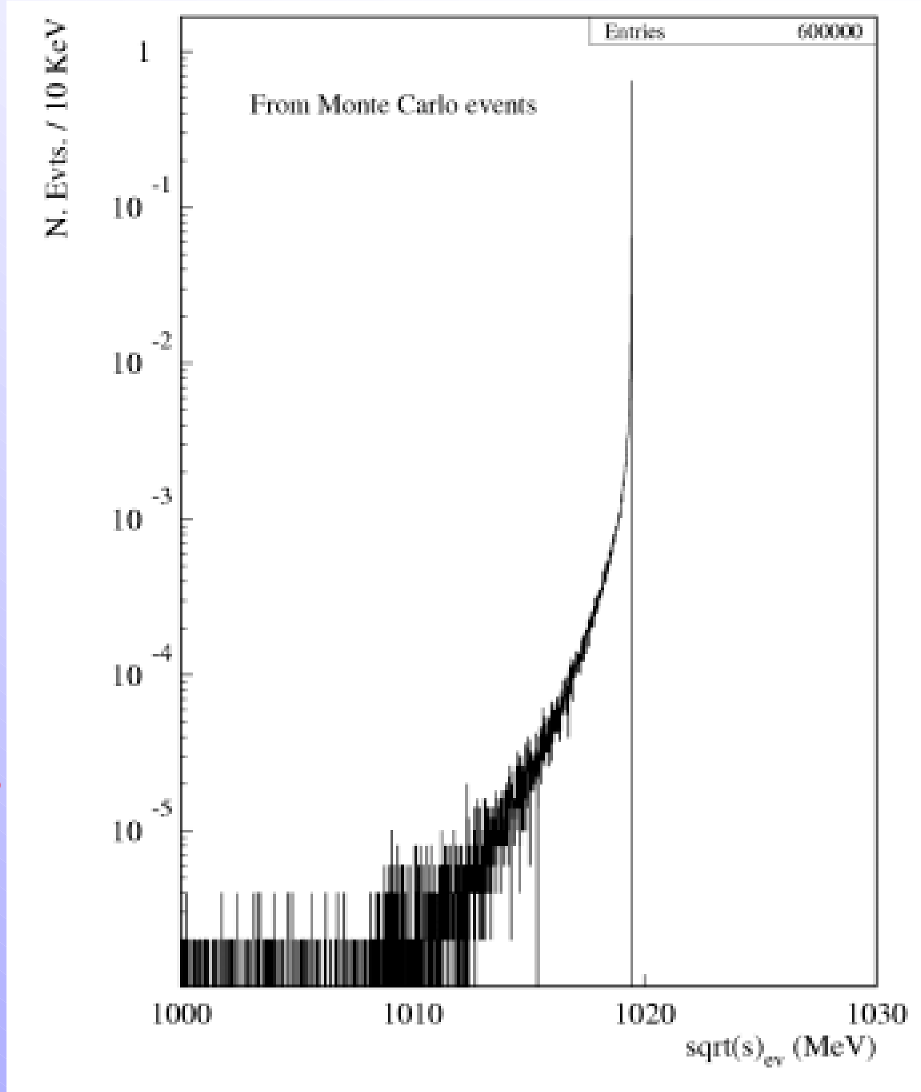
- Including ISR:
- 1) Sum = $\mathrm{sqrt}(s)_L + \mathrm{sqrt}(s)_S = x + y + 2b + 2s$
- 2) Diff = $\mathrm{sqrt}(s)_L - \mathrm{sqrt}(s)_S = x - y$
- From the distribution of the difference one can obtain that of the sum:

$$S(g) = \int R(x)R(y)B(b)F(s)\,\delta(g - x - y - 2b - 2s)\,dx\,dy\,db\,ds =$$
$$\int B(b)F(s)\,\delta(g - \nu - 2b - 2s)\,db\,ds \int R(x)R(y)\,\delta(\nu - x - y)\,dx\,dy\,d\nu =$$
$$\int B(q/2) \quad \int D(\nu)F(s)\,\delta(g - \nu - 2s - q)\,d\nu\,ds\,dq$$

if R(y)=R(-y)

New method (2)

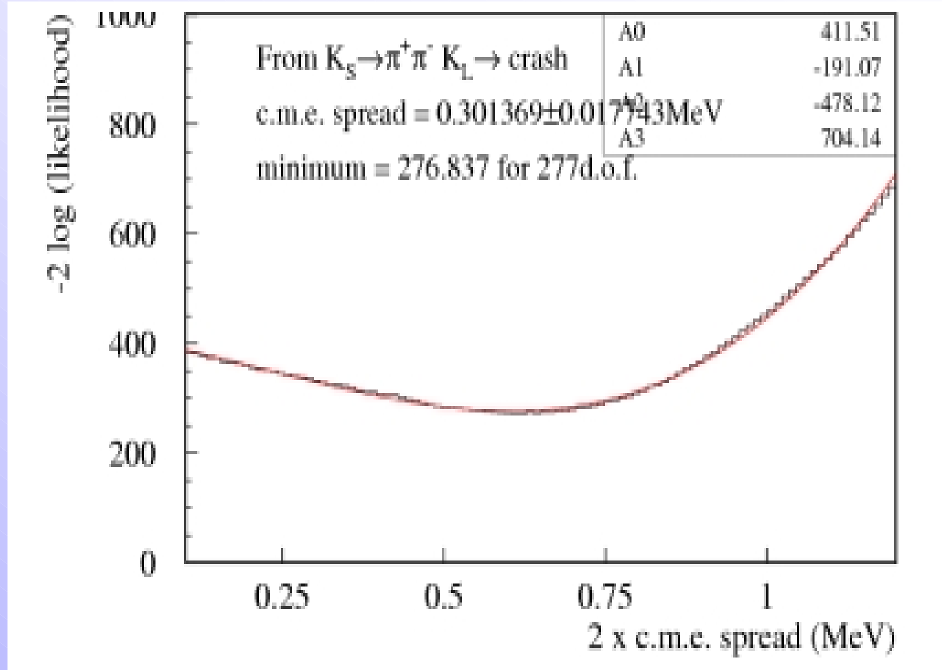
- 1) Convolve the Diff distribution with that of ISR, taken from Monte Carlo (thanks to Mario)
- 2) Fit the resulting histogram + convolution with a gaussian to the Sum distribution
- 3) Leave as free parameters of the fit the c.m. energy spread + a global offset



New method (3)

- 1) Likelihood takes into account fluctuations in the MC + those on the data

- 2) Directly find the maximum of the likelihood, fitting -2log(L) in each parameter to a polinomial of third degree

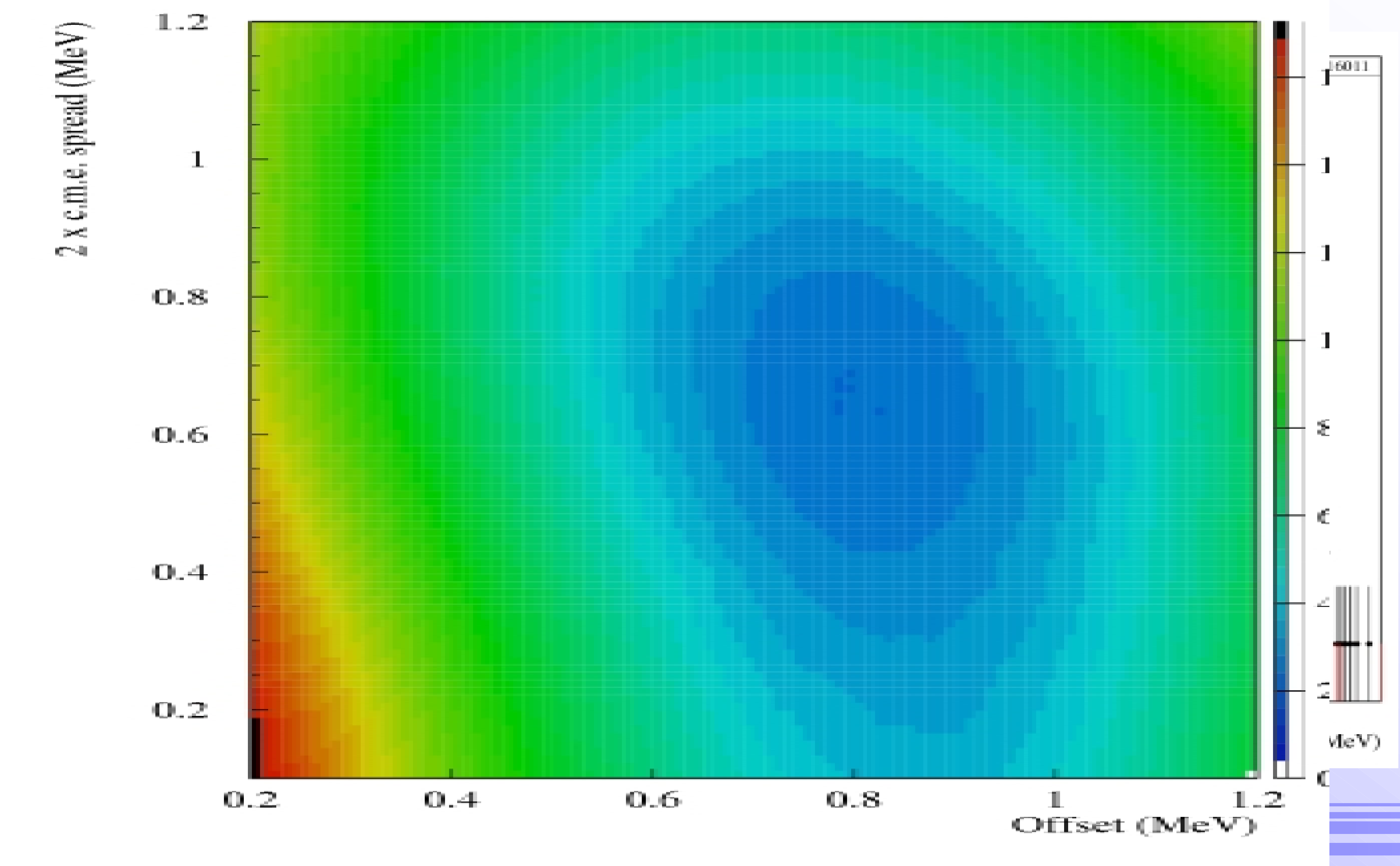


- 3) Analitically calculate the minimum and numerically the parameter interval corresponding to

$$\chi^2 = \chi^2_{min} + 1$$

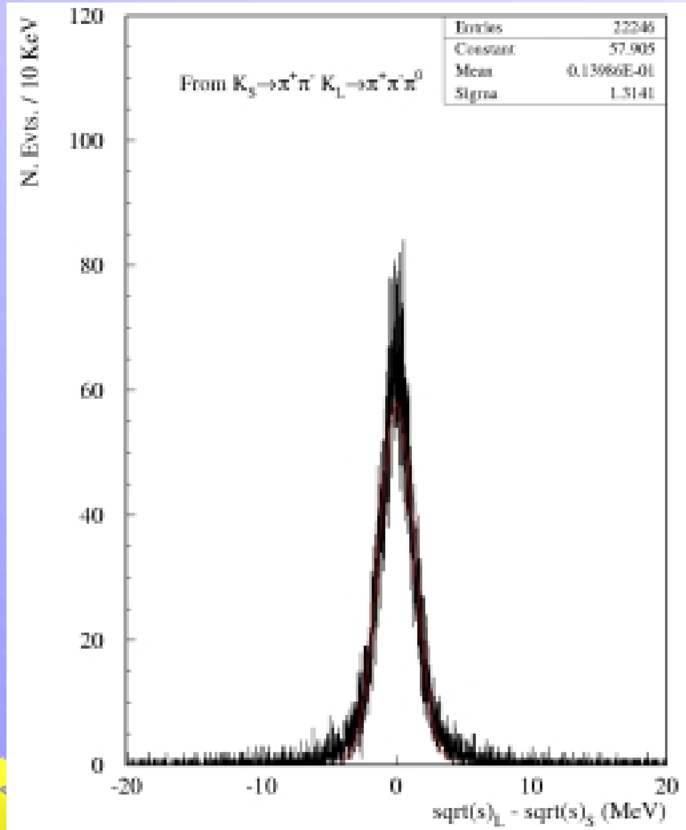
New method

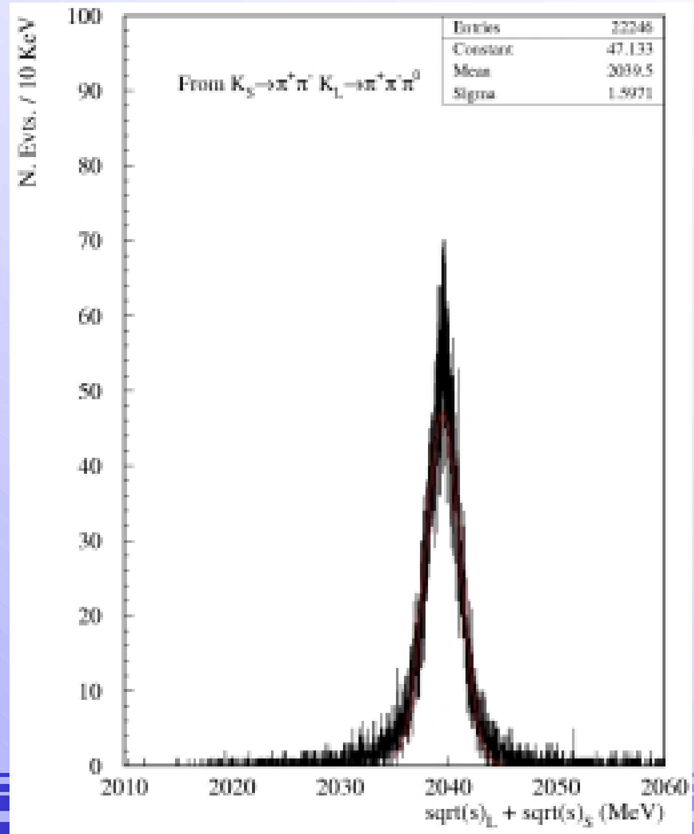
- Some correlation between spread and offset



Check of the method (1)

- Same method can be applied in $K_S \to \pi^+\pi^-$ + $K_L \to \pi^+\pi^-\pi^0$
- $\mathrm{sqrt(s)}_L$ from both γ's from K_L (T_0 from K_S π clusters)
- Here, $\mathrm{sqrt(s)}_L$ estimate has a more symmetric behavior





Check of the method (2)

- Both methods applied on the same range of runs:

Method	c.m.e. spread (MeV)	Offset (MeV)
Kcrash	0.301 ± 0.018	0.848 ± 0.018
$K_L \to \pi^+\pi^-\pi^0$	0.304 ± 0.018	0.766 ± 0.017

Check of the method (3)

- The method has been applied on Monte Carlo events with no beam spread, yielding a result compatible with 0
- On MC events generated using a c.m.e. spread of 575 KeV, one gets: 569$\pm$1 KeV. Systematic error of 5 KeV?
- Results does not change significantly applying on the Monte Carlo the same θ cut as on data

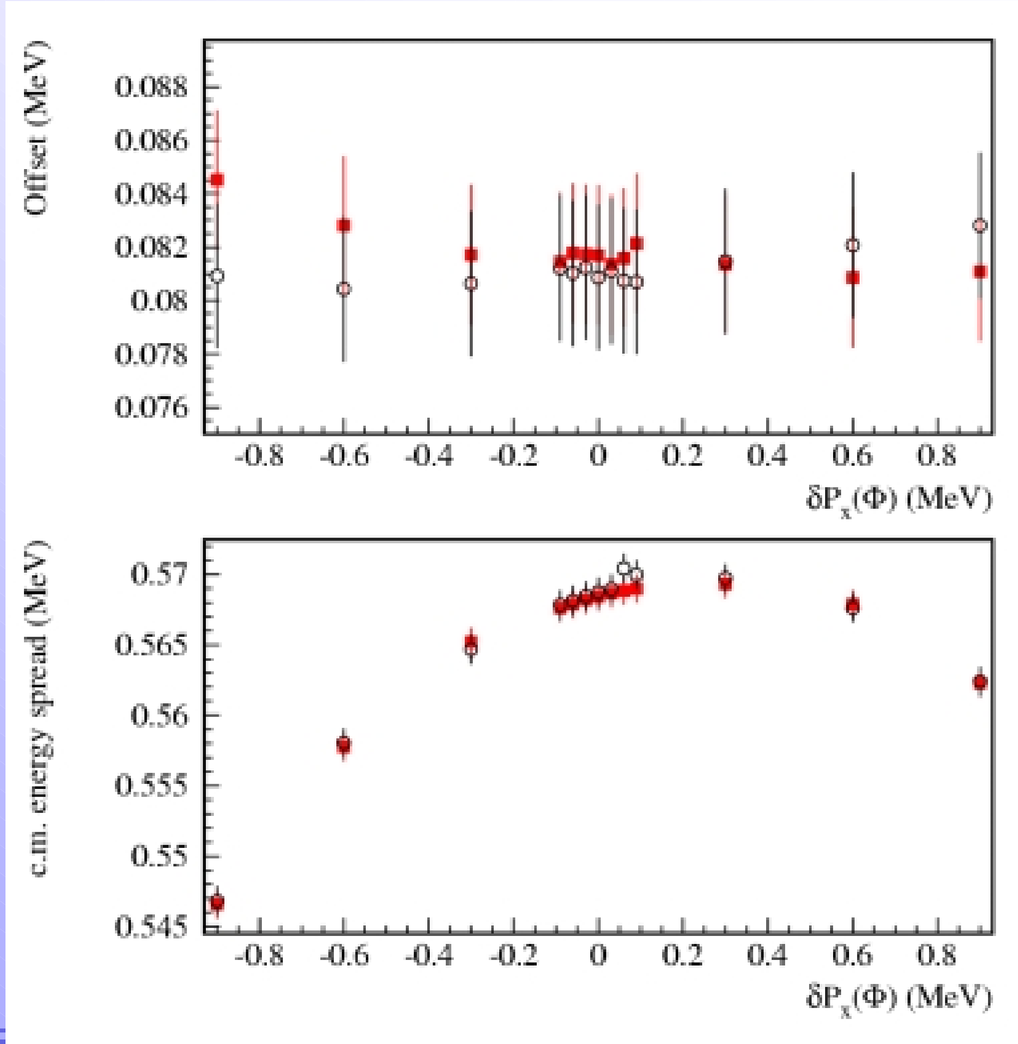
Check of the method (4)

- Correlations between sqrt(s)S and sqrt(s)L can lead to a systematic error
- These can be due to the usage of the same nominal value of $\mathbf{P}_\phi$ in both calculations
- Event by event the real ϕ momentum is different from the nominal one and is correlated to the beam energy fluctuations, either due to beam spread or to ISR
- Sum variation with an error $\delta\mathbf{P}_\phi$ on $\mathbf{P}_\phi$: $\propto -\mathbf{P}_\phi . \delta\mathbf{P}_\phi / E_S$
- Diff variation with an error $\delta\mathbf{P}_\phi$ on $\mathbf{P}_\phi$: $\propto (2\mathbf{P}_S - \mathbf{P}_\phi) . \delta\mathbf{P}_\phi / E_S$

Check of the method (5)

- Check done on Monte Carlo events, varying nominal $\mathbf{P}_\phi$ in a $\pm 30\ \sigma^*$ around the correct value
- Maximal variation around 25 KeV (5KeV in a $\pm 30\ \sigma$ interval)

$*$ Estimated by S. Dell'Agnello to be 30 KeV



Conclusions

- New method guarantees:
    - better control of the systematics
    - independence from the fit range
    - freedom from particular assumptions on the shape of resolutions

- Procedure almost ready to run over the whole data set, need to make the procedure fully automatic (1 pb^{-1} 30 KeV error)

- Have to check the dependence on an errror on the ϕ momentum directly on data