Wake Fields and other Collimation Studies

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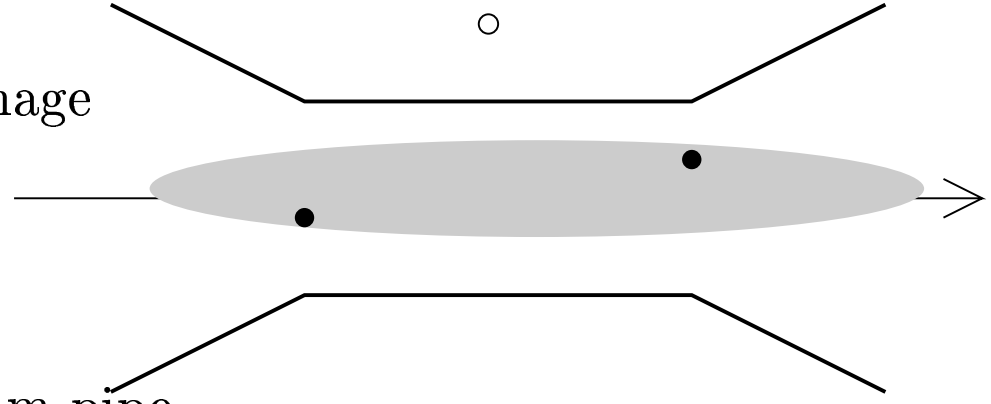
What is a wake field?



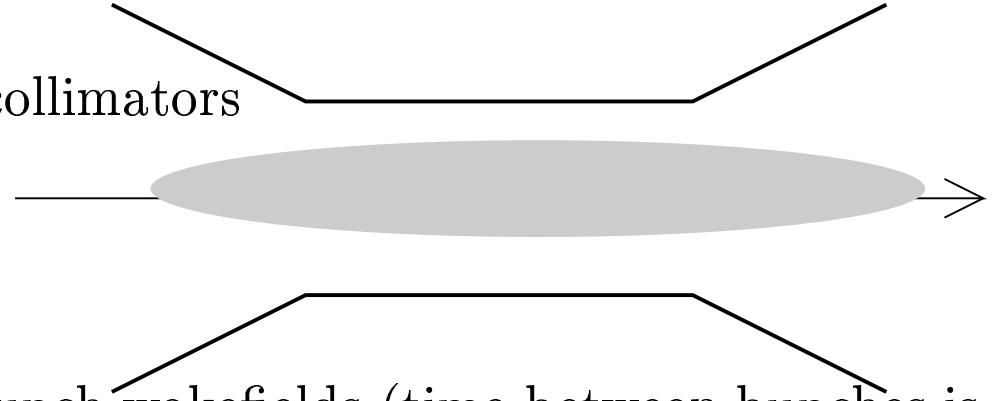
Effect on particles of image charges produced by other particles.

Vanish for perfectly conducting uniform beam pipe

Distinguish
Resistive Wakefields due to finite resistance
Geometric Wakefields due to changes in beam pipe.

Distinguish
inter bunch wakefields
intra bunch wakefields.

Wake fields and the ILC BDS



Particles *very* close to collimators
Effects might be large.
Blow up bunches
Dilute emittance.

Concern is with intra-bunch wakefields (time between bunches is long)

Concern is with geometric wakefields (length of collimators is short)

Concern is with transverse wakefields

Wake Potentials

Wake field in an element changes the momentum but not the path (much)

$$\Delta\vec{p} = \int ds\vec{F}(s) = q\left(\int ds\vec{E}(s)\right) = q\vec{W}$$

$\vec{W}$ is the *Wake Potential*. (!)

(According to Chao: Stupakov calls it the Wake Function or Wake).

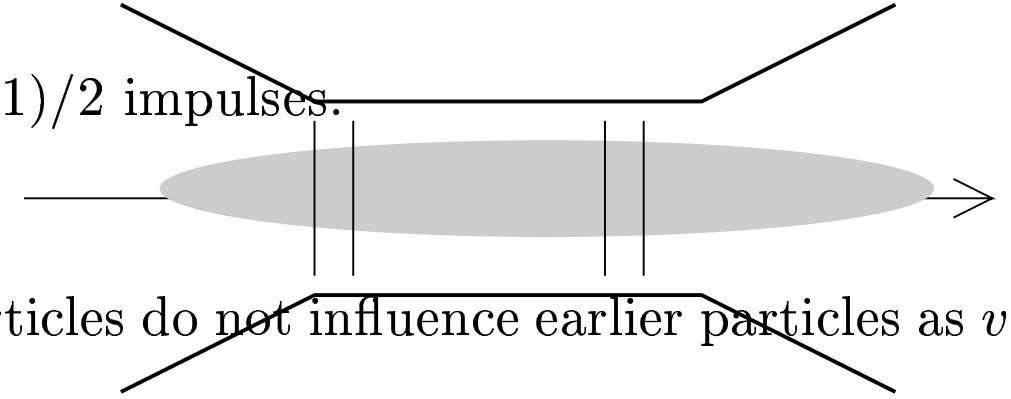
Ignore transverse velocity during transit. $\vec{W}(r_1, \phi_1, r_2, \phi_2, s)$

For circular symmetry have $W_{||}$ and $W_{\perp}$

Details

Can't consider $N(N-1)/2$ impulses.

Divide into slices.



(Factor of 2 as later particles do not influence earlier particles as $v \approx c$)

Wake potential can be expanded as

$$\vec{F} = -e \sum_{m=1} W_m(s) m r^{m-1} \hat{r} Q_m cos(m\phi)$$

$W_m(s)$ - the *Wake Function* - (according to Chao) - depends on the (longitudinal) distance between the two slices and the nature of the aperture.

Q_m are moments of the distribution in the leading slice.

The leading term

Take $m = 1$ term

Force does not depend on position of particle in trailing bunch - same everywhere.

Force depends on C of G of leading bunch.

Useful first approximation - but not enough!

Kick Factors

Work (only) with leading term

Symmetric (Gaussian?) bunch off axis by distance y

Impulses on all particles proportional to y

$\rightarrow$ average impulse proportional to y

Kick Factor $\Delta y' = Ky$

Describes jitter but not emittance growth and banana bunch effect

Does give something we can measure and benchmark against.

What's in MERLIN

Take leading $m = 1$ (dipole) term.

Use supplies Wake Function for any element. MERLIN calls it the Wake Potential.

```
double WakePotentials::CalculateWakeT(double s);
```

In neat double loop, apply Δp to each particle in trailing slice for each leading slice, according to wake potential and C of G of leading slice.

What we do

1: Need to put higher order modes in Merlon

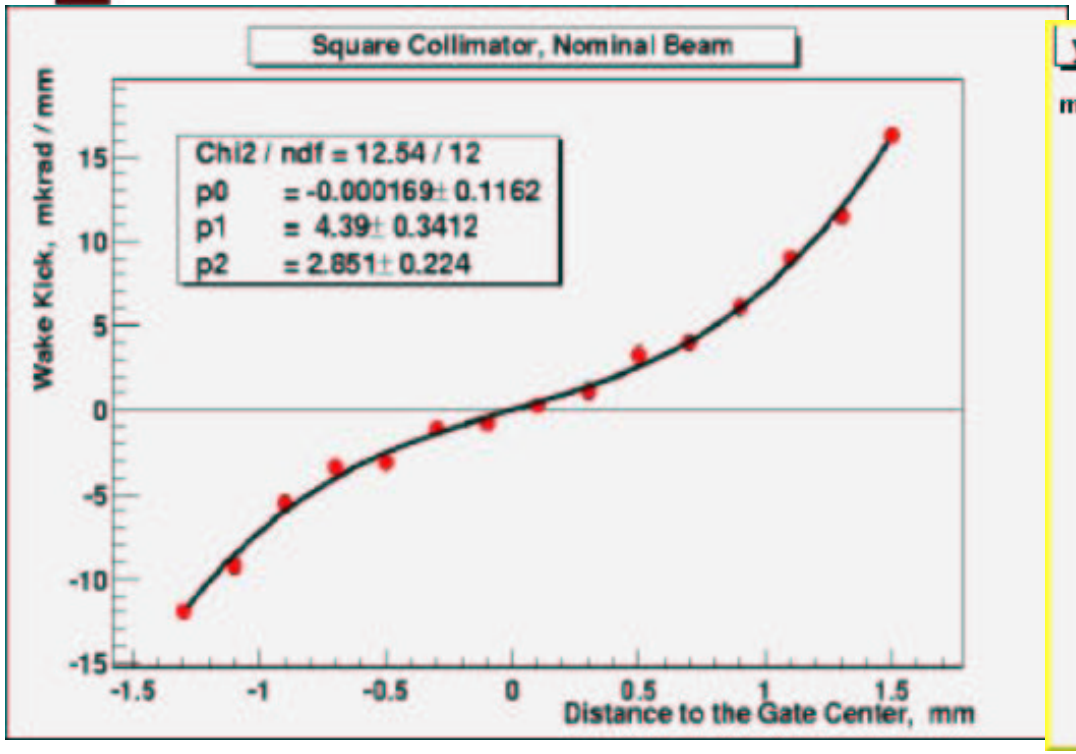
Add `nmodes` as data member

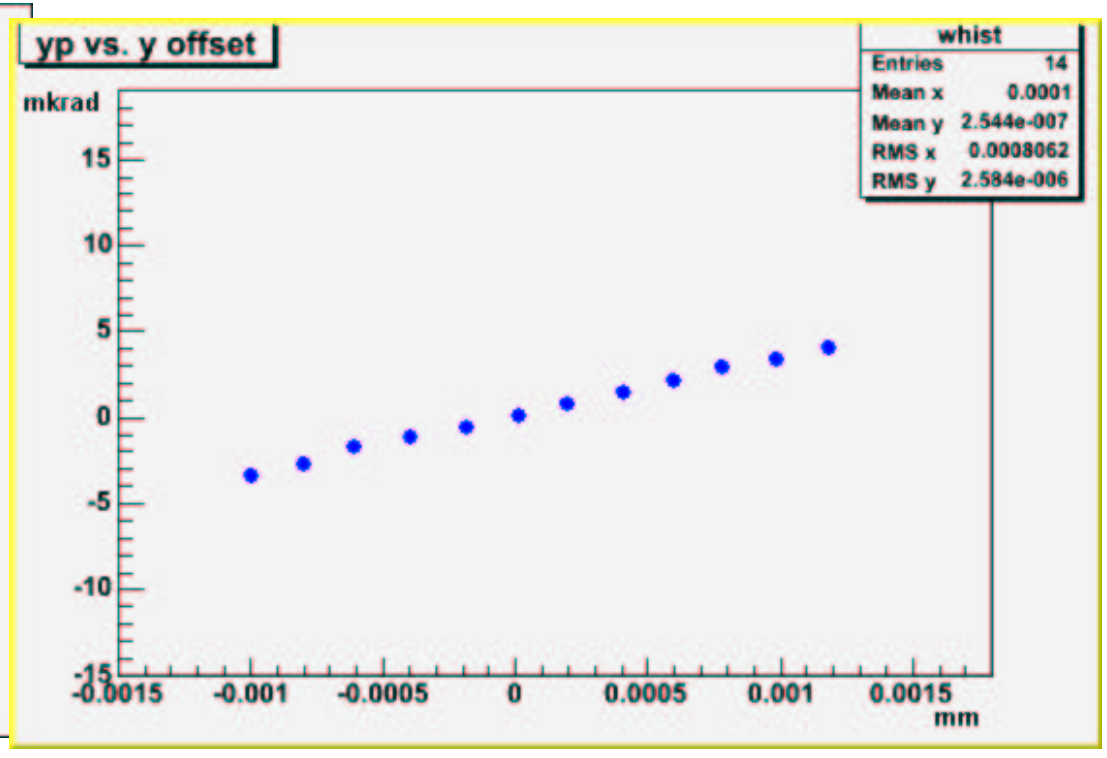
Provide `double WakePotentials::CalculateWakeT(double s, int m);`

In double loop calculate higher moments for leading bunch, use all (`1` to `nmodes`) wake functions, use correct spatial moment of trailing particle.

2: Need separate x and y functions as slits are not axially symmetric.

Test the program

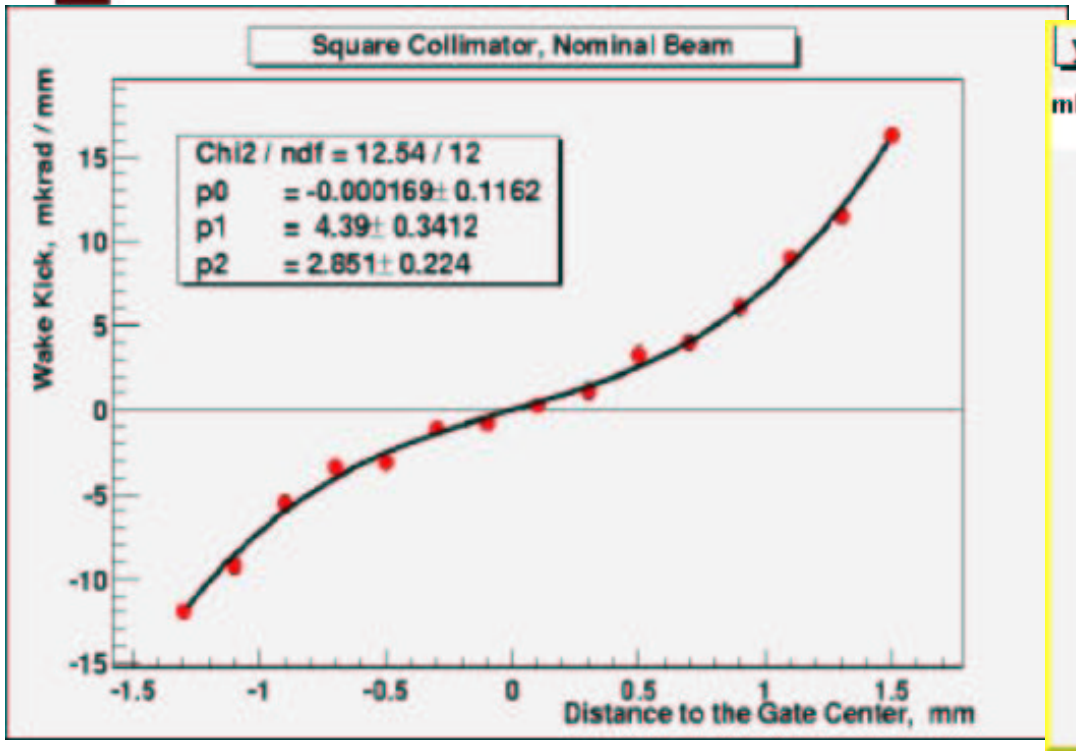


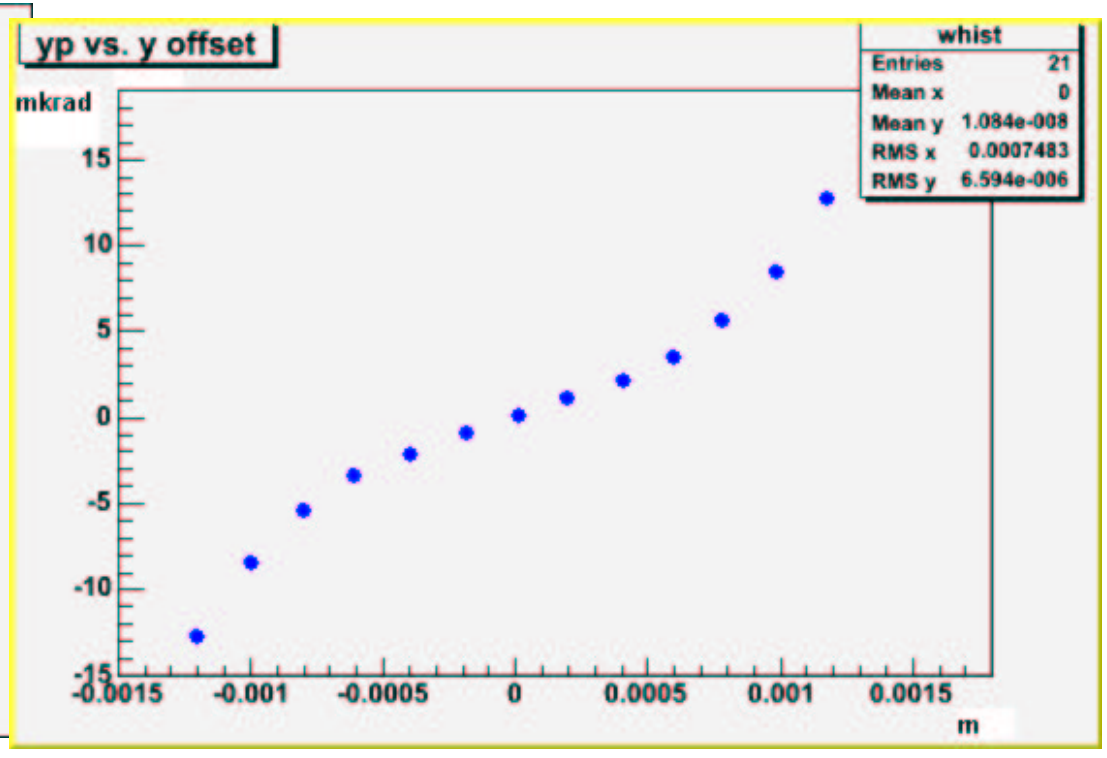


Data from Onoprienko et al, SLAC measurements

Linear approximation is approximate near centre, poor near edges.

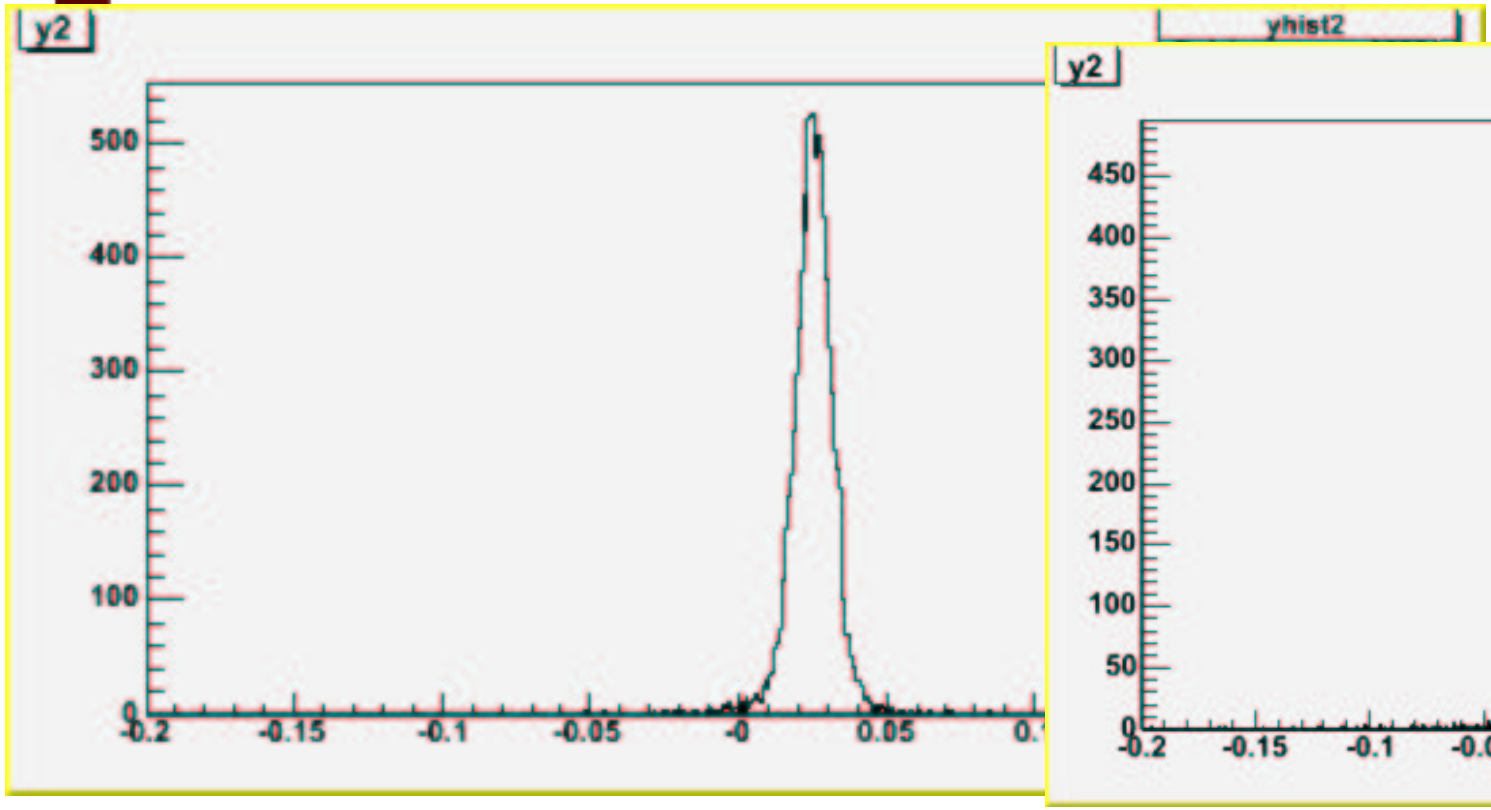
Test the program

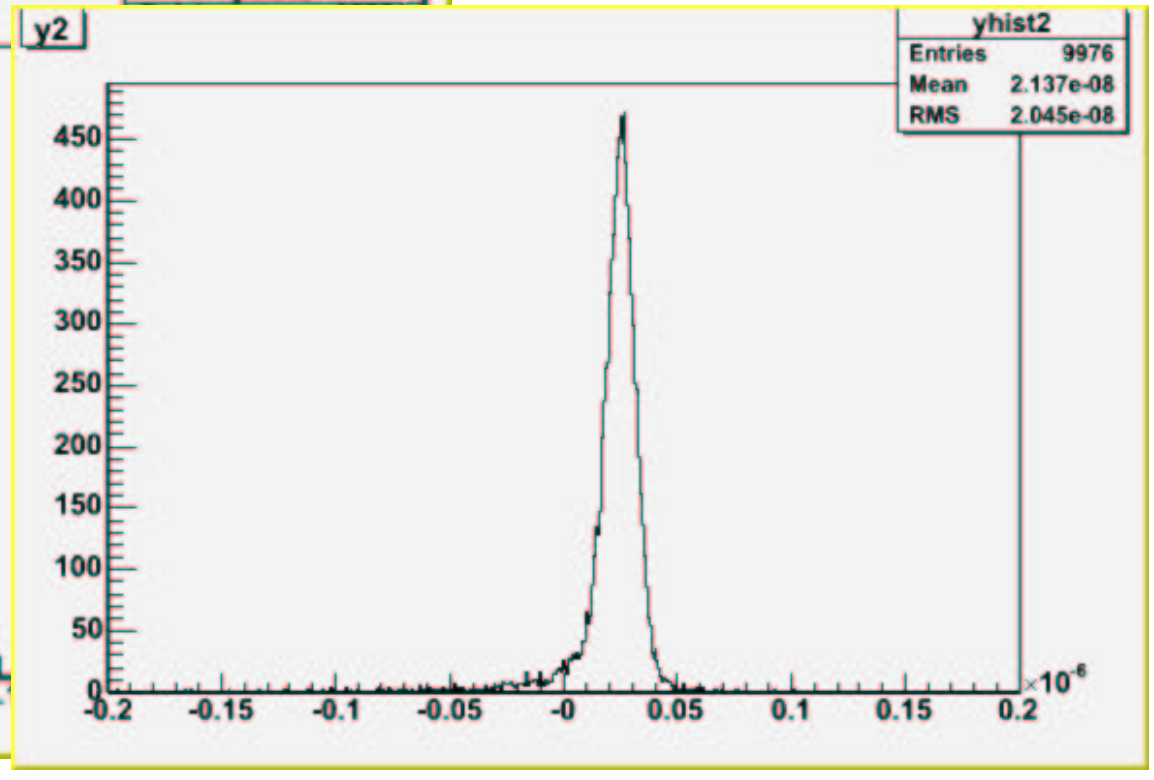




5 terms give a good descruption.

Results for TESLA BDS (use 8.02 optics)





Effect is visible but small.

Outlook

Still to do:

How many terms do we need? $(1 > n \leq 5)$

Resistive Wakefields. Same general approach, just different.

Automatic or semiautomatic CalculateWake functions. Need to get MAD deck language sorted (presently Aperture+Drift used for Collimator).

Tidy up and put into library.

Predict/analyse next data (November)

Other Activity (1)

Using ANSYS to study what happens to collimators when struck by
(i) beam, once or twice
(ii) halo, repeatedly

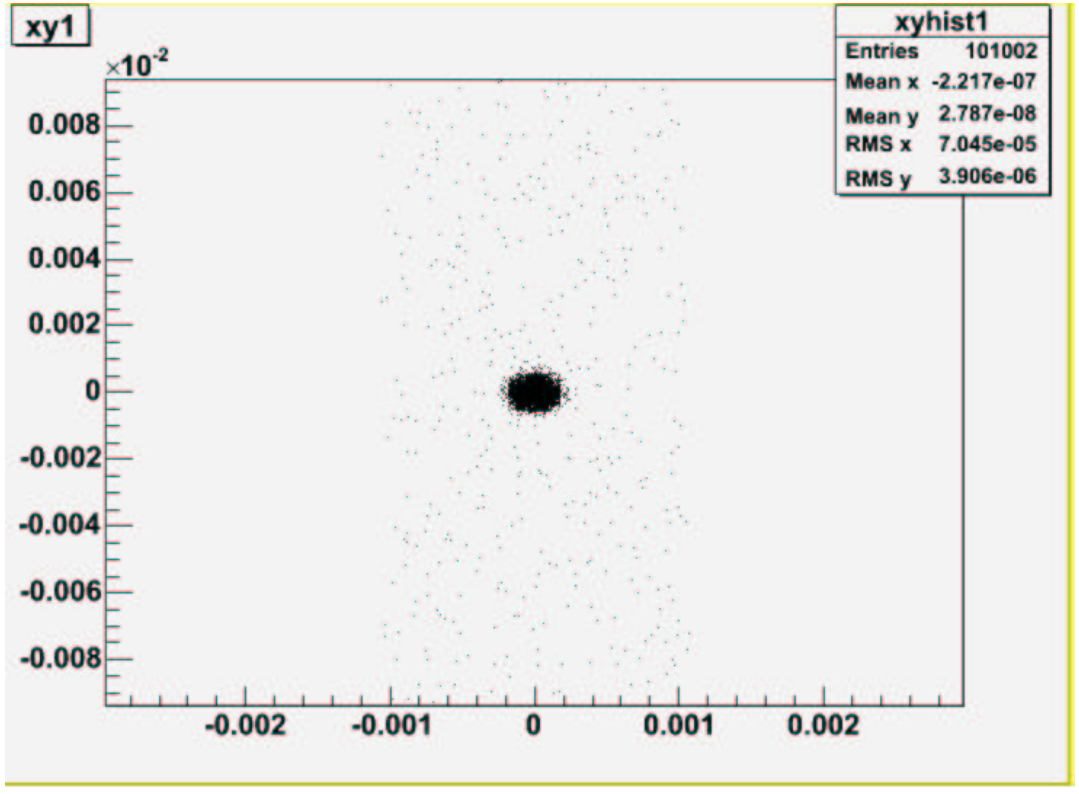
Thermal expansion, shock, surface damage...

Compare with actual experiments

Other Activity (2)

Simulate halos in Merlin

See where the losses occur



And finally

We have a vacancy for a new RA (EUROTeV)

- send us your students!