"RICH at L1 Trigger"

TDAQ WG 6.4.2011

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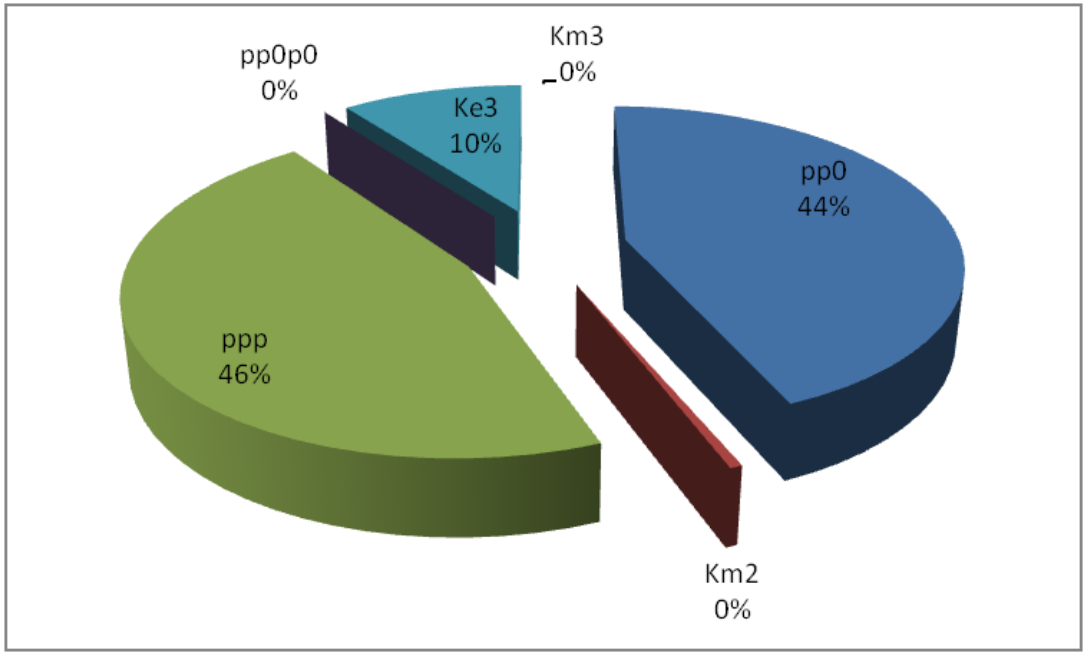
Goal of L1

	INITIAL RATES (kHz)	RICH+CHOD+ !MUV+!LKR +!LAV
$\pi\pi^0$	1859	85
$\mu\nu$	5719	1
$\pi\pi\pi$	503	89
$\pi\pi^0\pi^0$	158	0
$\pi^0 e\nu$	456	20
$\pi^0\mu\nu$	301	0
TOT	8998	**196**

- CHOD only acceptance
- LKr: no two clusters closer than 30cm
- LAVs or-ed

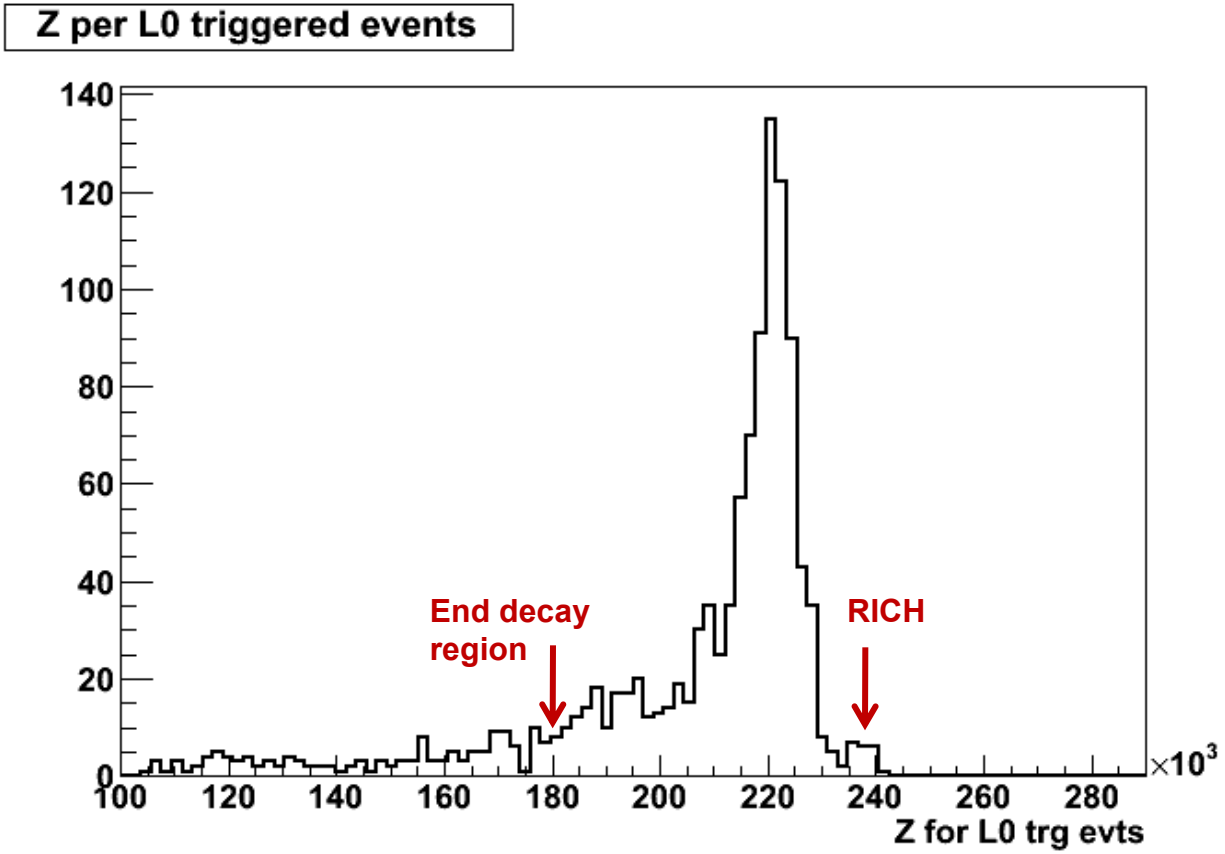
[Spasimir TDAQ 9.2.2011]



- Using LAV at L0 (or eventually at L1) the total rate in input at L1 will be ~200 kHz
- The L1 is supposed to decrease of a factor of 10
- The LKr ROI helps marginally in the rejection
- The CHOD is hard to be used as veto

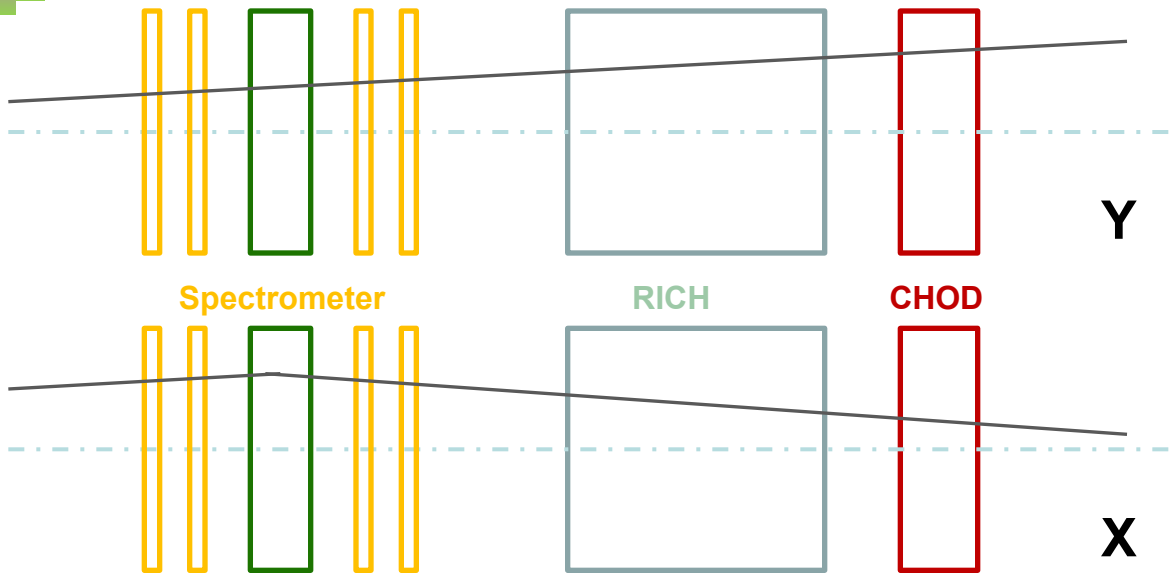
$\pi\pi^0$: Survivors Z distribution

- The Z distribution of the $\pi\pi^0$ after L0 is peaked out of the decay region
- Big rejection using the vertex position



- The STRAWs will be ideal!
- According to Giuseppe the reconstruction time is ~1.5 ms: @1MHz (total input of L1) means ~1500 computing cores → **Huge system** (only for L1 STRAW)!!!
- Alternative idea: use the RICH+CHOD

Vertex reconstruction with the RICH



- The ring positions on the RICH gives the track angles
- The ring radius gives the velocity (or the momentum assuming the particle mass)
- The position on the CHOD fix the point to track back the pion

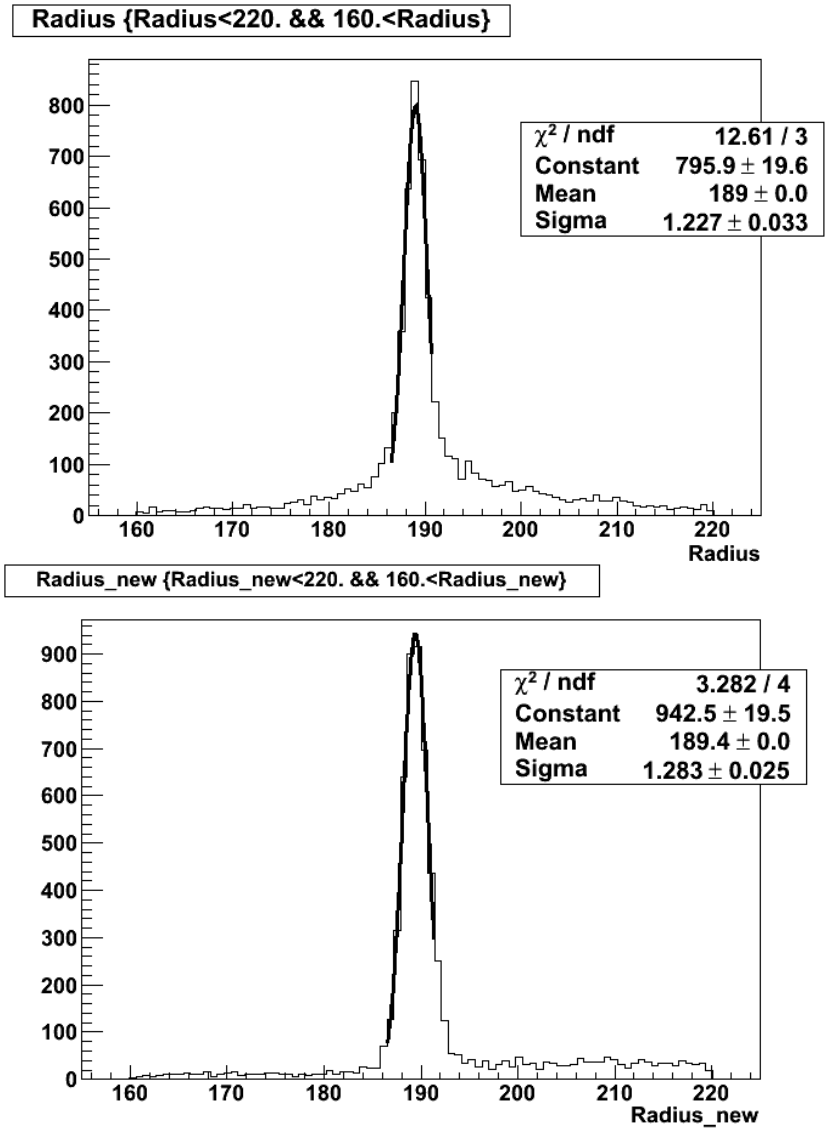
- Reconstruct the CDA assuming the beam axis to find the vertex: both X and Y directions are needed
- The Y is simple; for the X we need both the X center position of the ring and the radius (to calculate the effect of the bending)
- Problem with NA62MC due to a GEANT4 bug (discovered by Monica): all the rings are β=1
- For the moment only extrapolation using the unbent direction (Y)

Fast reconstruction (MATH)

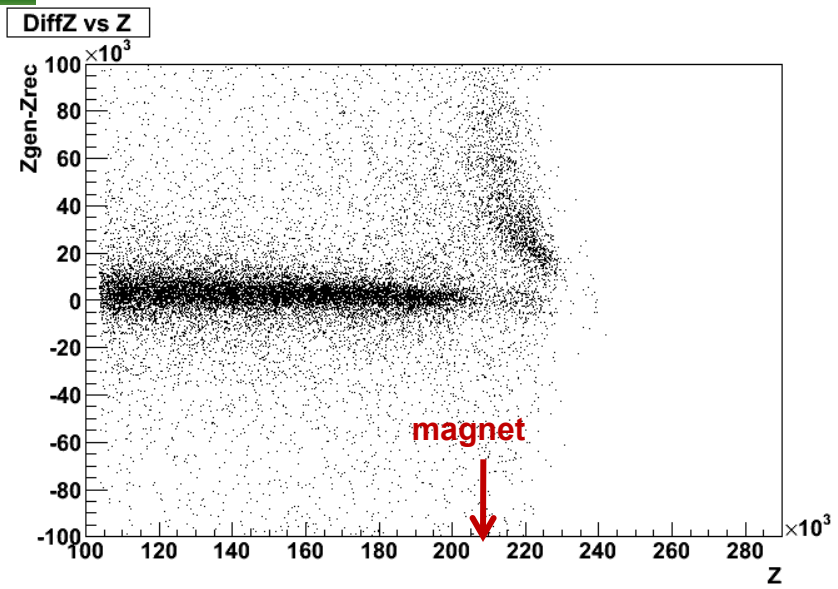
- The present reconstruction is based on minimization of a likelihood: iterative slow procedure (to be avoided at L1).
- The standard LSM doesn't work for rings because the equations for the analitic minimizations can't be inverted.
- The problem can be fixed with a simple translation in

$$\overline{X} = \frac{\sum x_i}{N}, \overline{Y} = \frac{\sum y_i}{N}$$

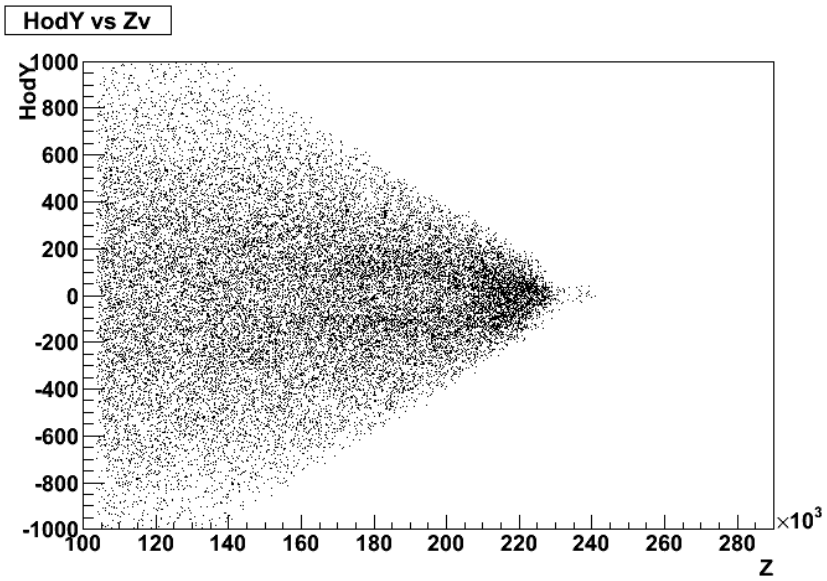
- In this space the first derivatives equations can be inverted analitically
- The resolution of this procedure is the same as respect to the likelihood fit but is, at least, a factor of 100 faster!

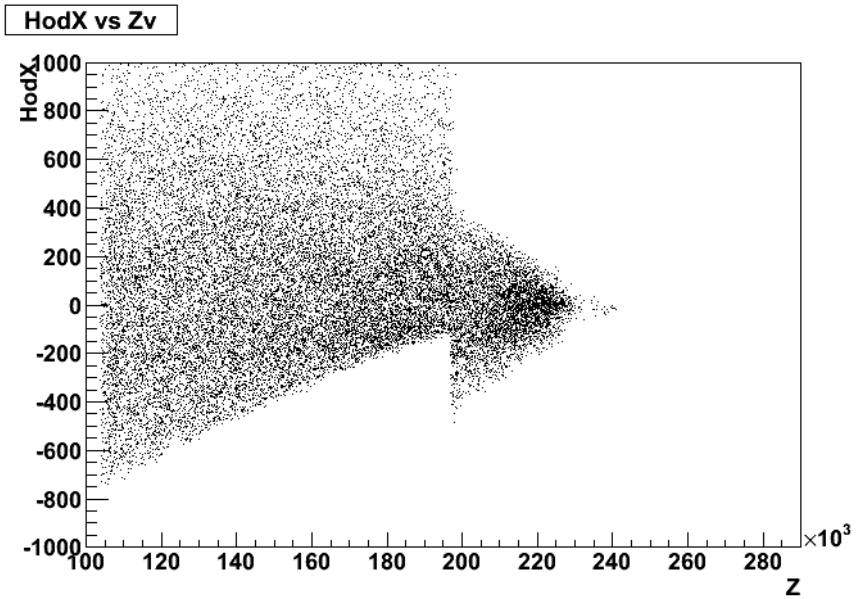


DZ vs Z



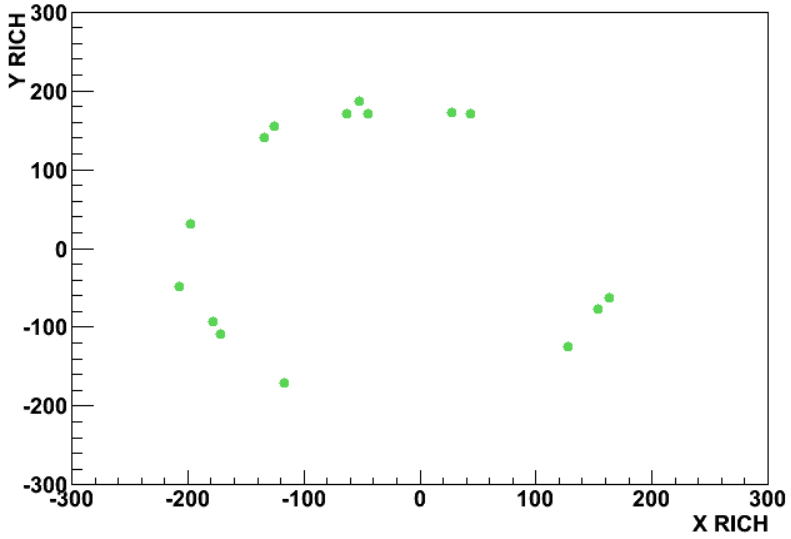
- The change of the acceptance introduced by the magnet degrades the quality of the procedure
- Further investigations



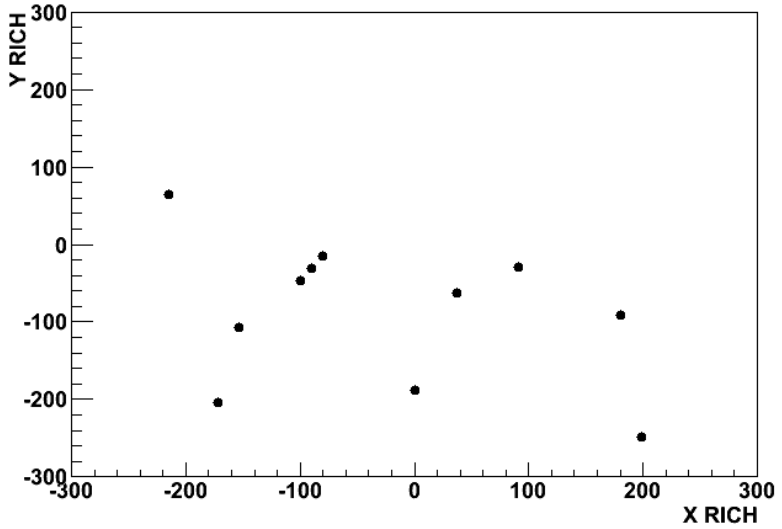


Rings before and after the magnet

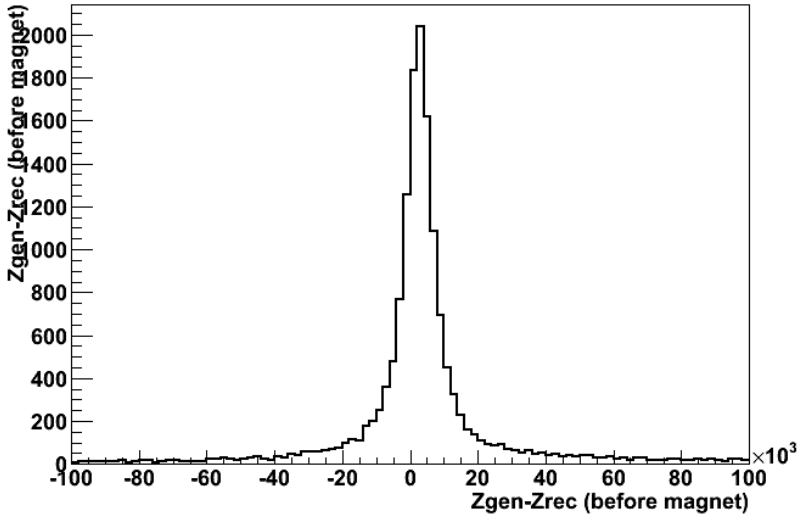
low Zv



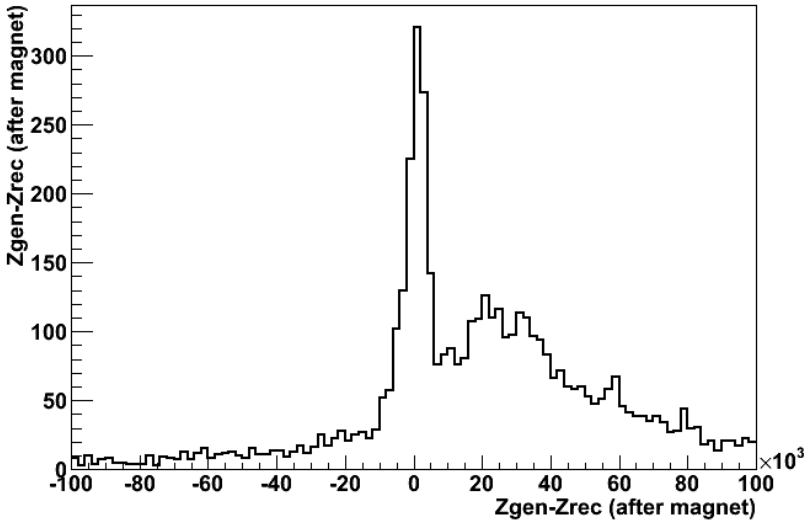
high Zv



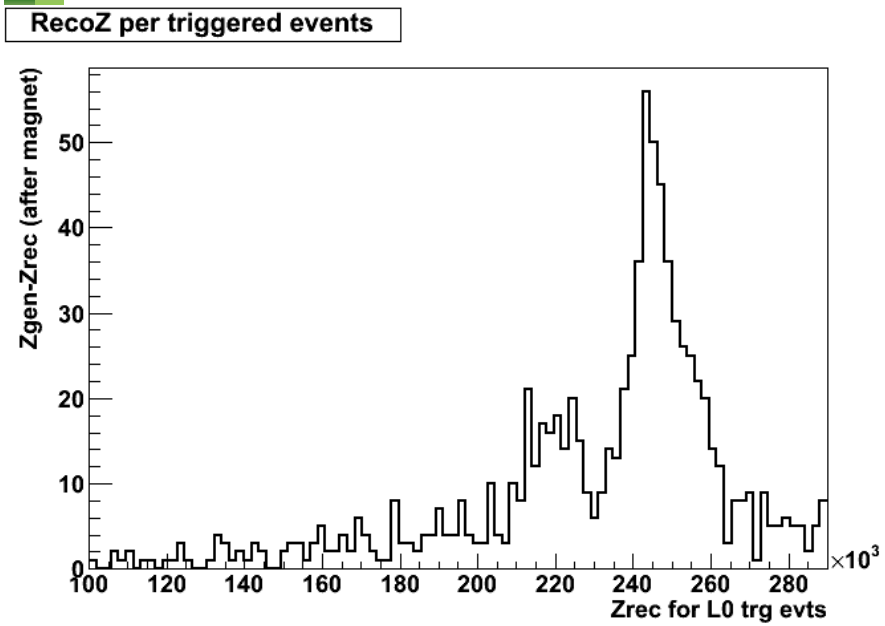
DiffZ before magnet

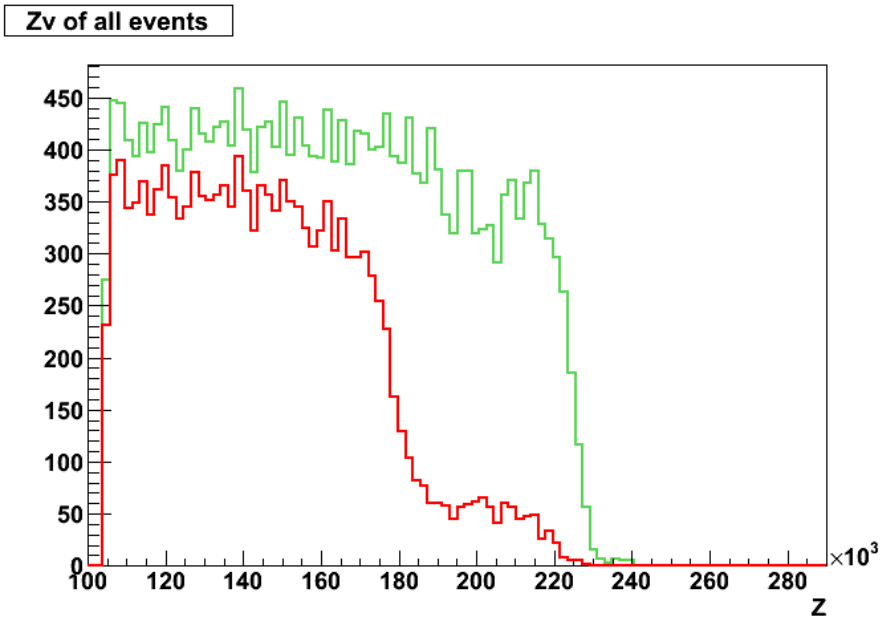


DiffZ after magnet



Cut on vertex

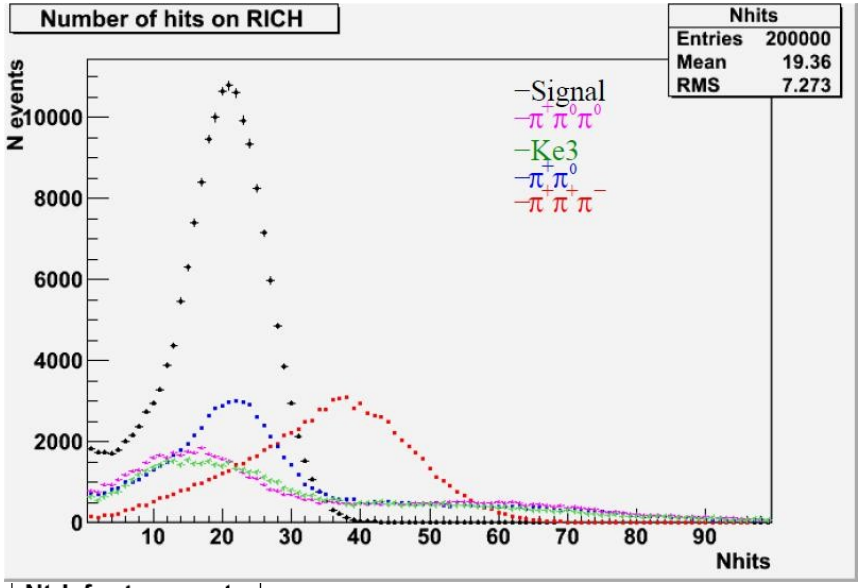


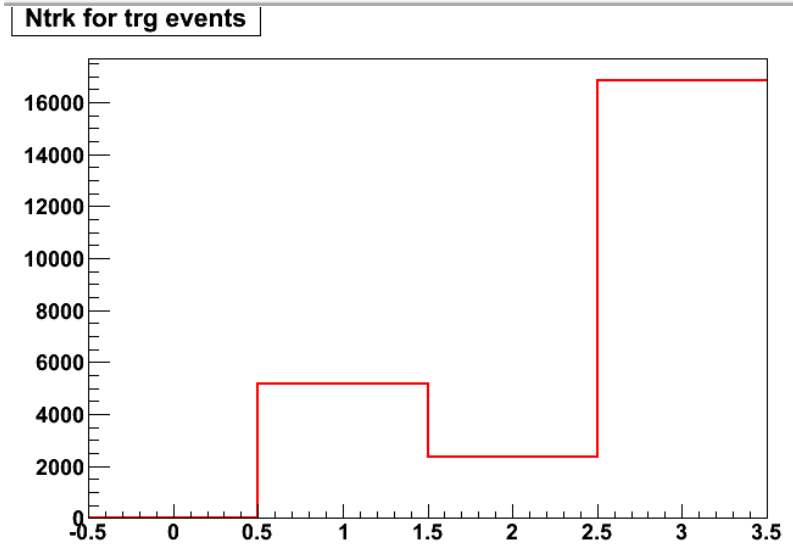


- A cut in the Zrec<180. reduce the $\pi\pi^0$ contribution of ~90%: ~ 85 kHz→ 8 kHz
- With the present procedure (only Y extrapolation) the inefficiency introduced on the signal is at level of ~10% (deduced from the effect on the $\pi\pi^0$ rejection in the decay region)

3π: number of tracks

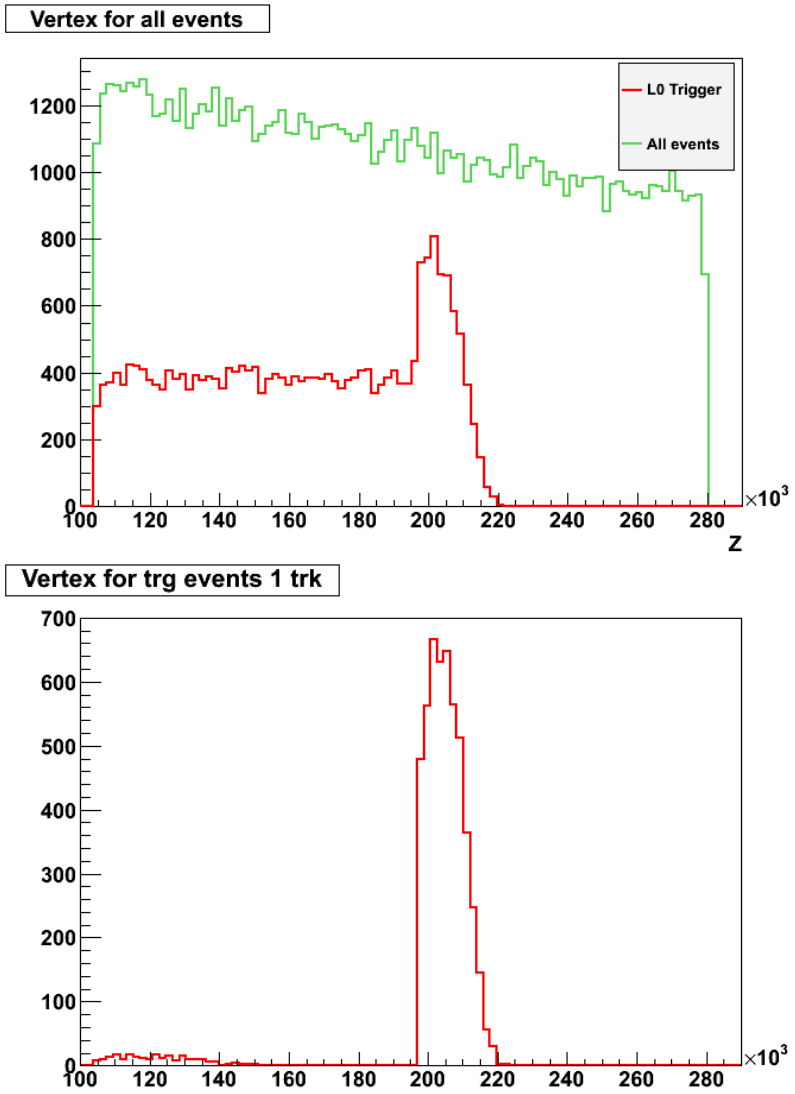
- ~60% of the πππ passing the L0 trigger have 3 tracks
- Some reduction can be simply obtained using the hits multiplicity in the RICH *[Mauro P. 2/2010]*
- A cut on 40 Hits (safe for the signal) affect only the 3 tracks: in the best case ~50% of πππ can be reduced with this cut





3π: Reduction with the RICH

- Also for πππ there is an important component of the remaining events from out of the decay region
- The 1 track πππ events, in particular, are concentrated close to the RICH
- Same procedure as for the $\pi\pi^0$
- ~90% rejection (vertex+multiplicity) : 89 kHz → 9kHz



Review of rings pattern recognition methods

Legenda:
- Too slow
- Only one ring
- Already implemented in GPU (in one ring version)
- to be investigated (probably slow)

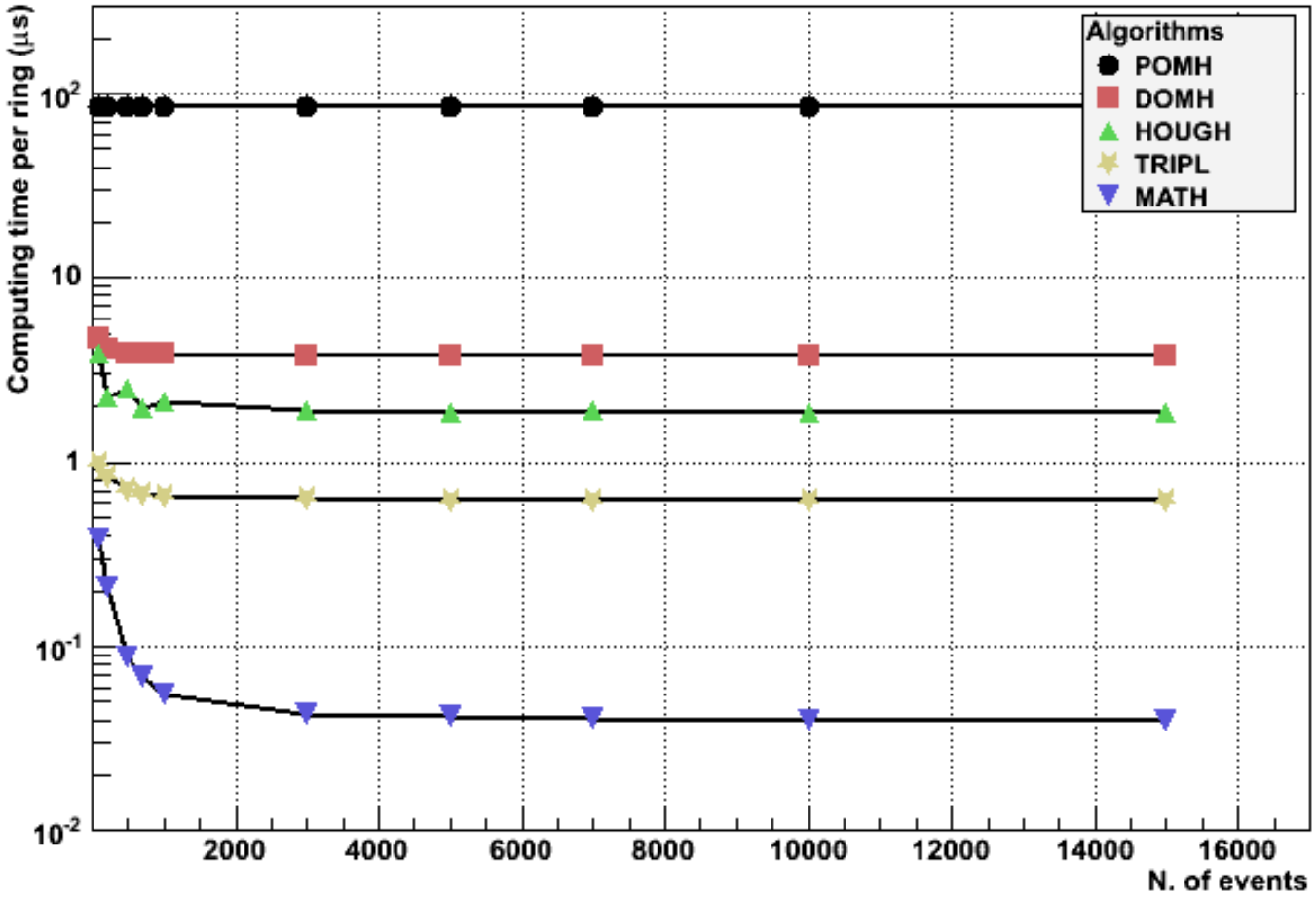
Geometric fits:
- Gauss-Newton
- Levenberg-Marquardt
- Triplets
- Reduced LSM
- Domh
- Riemann Fit
- Hough transform
- Conformal mapping

Algebraic fits:
- Kasa
- Chernov-Ososkov
- Karimaki
- Pratt
- Hyper
- Math

Statistical fits:
- Maximum likelihood estimators
- Kukush-Markovsky-Van Huffen
- Kanatani
- Possibilistic C-Spherical shells
- Metropolis-Hastings MC

- **Our requests:**
  - Trackless
  - No iterative and numerical→fast!
  - High resolution
  - 2 Rings

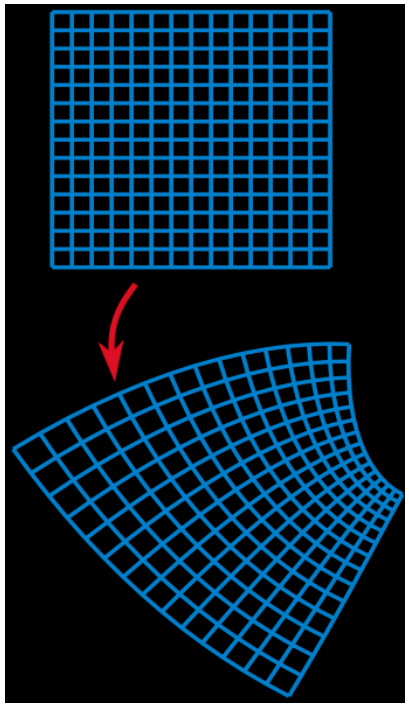
GPU computing times



Concurrent Conformal mapping

- The conformal mapping is a transformation which preserves the angles
- It's easy to show that the conformal transformation

$$u = \frac{x}{x^2 + y^2}, v = \frac{y}{x^2 + y^2}$$



transforms a circle, passing by the origin, in a straight line

$$(x-a)^2 + (y-b)^2 = R^2$$

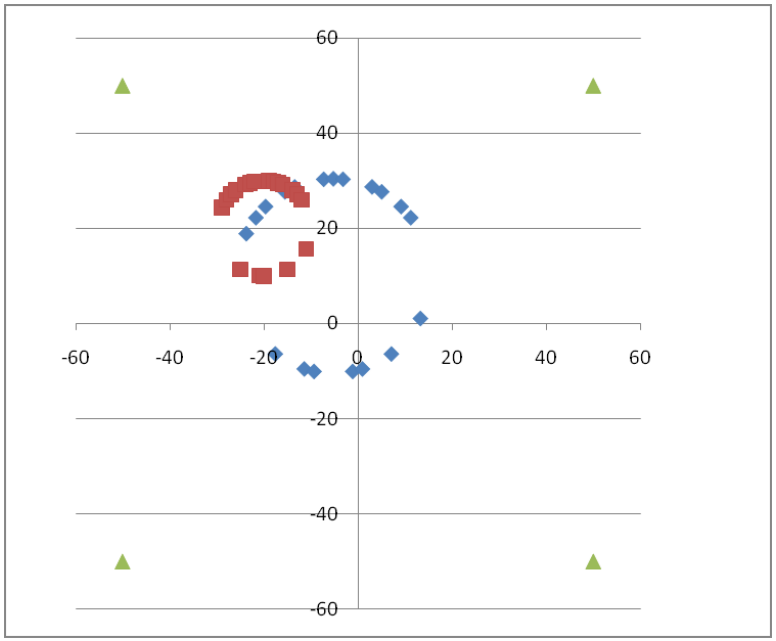
$$with \_ R^2 = a^2 + b^2$$

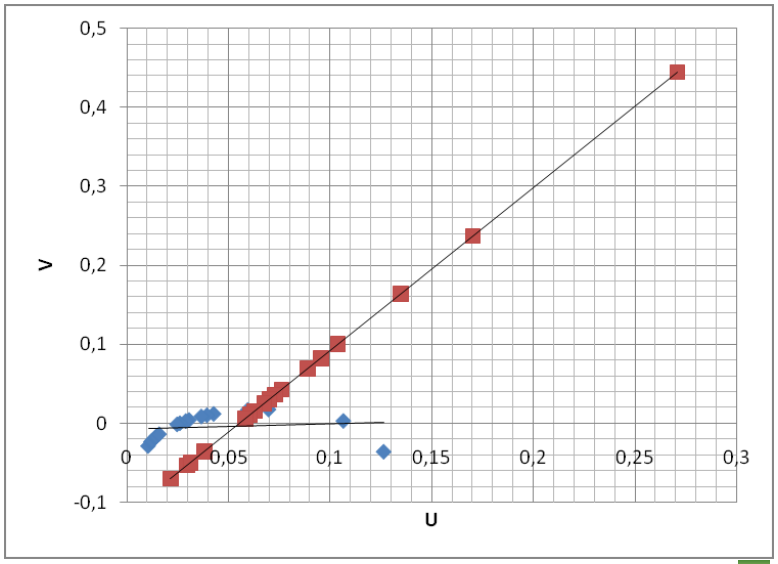
$$\Rightarrow \quad v = \frac{1}{2b} - \frac{a}{b}u$$

- A circle not passing by the origin is mapped in a new circle

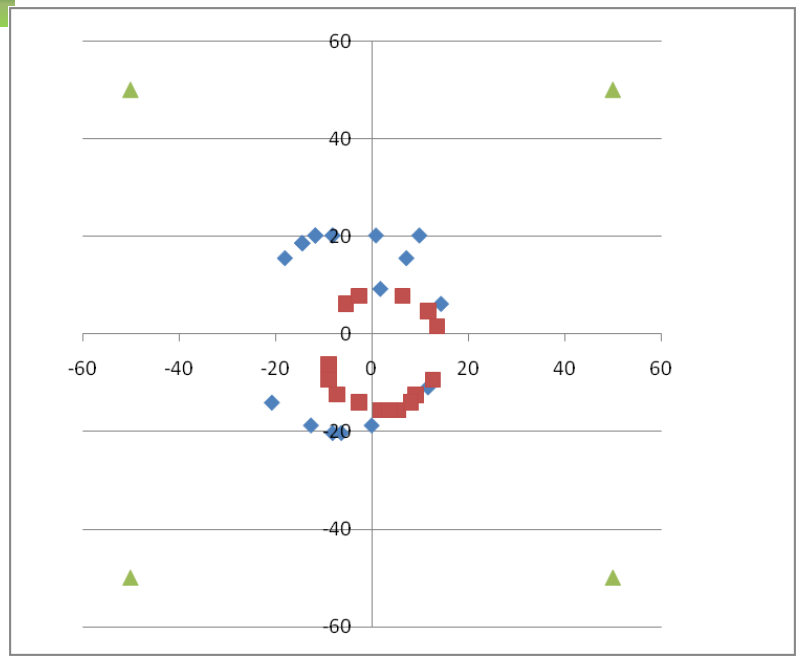
Concurrent Conformal mapping

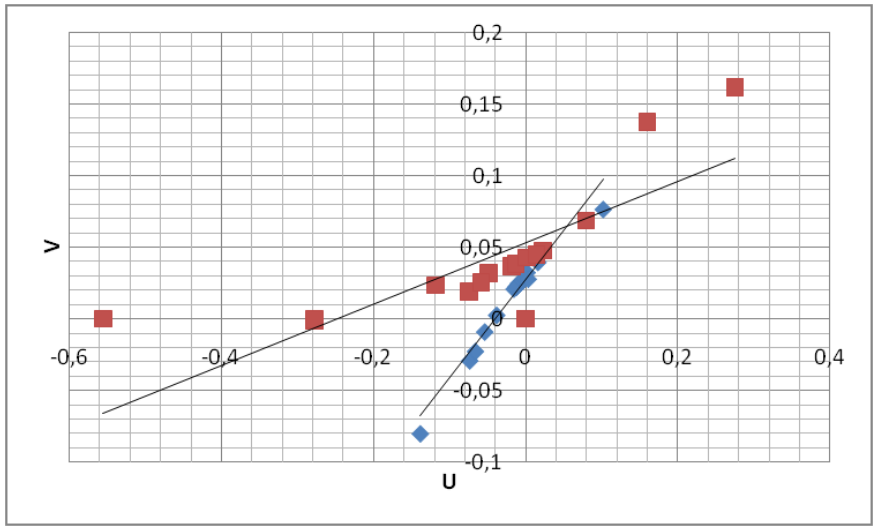
- Possible 2 rings algorithm :
  - Each RICH hit is considered as the (0,0) of a conformal transformation
  - The ring "owner" of the hit is transformed in a straight line while the other ring is mapped in a ring
  - For each transformed plane the two points more far from the origin are considered to trace a "strip" in which the points are considered for the linear fit
  - The "parallel" results obtained starting from different hits are combined together (histogram) to get the final ring positions





Present implementation of CC

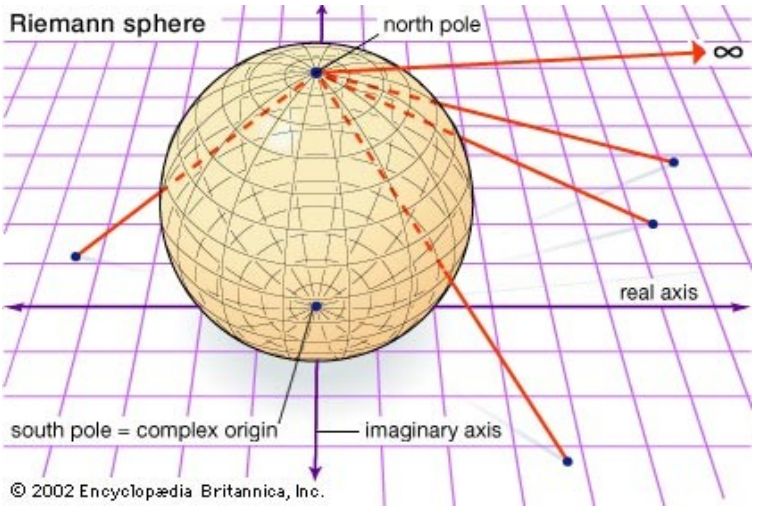


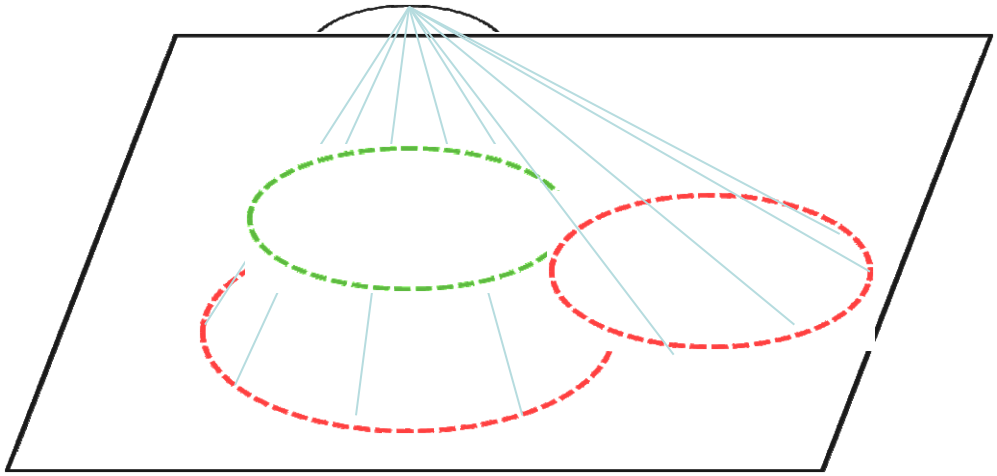


- In the real life the procedure to select the right result doesn't work properly, for the moment
- The conformal mapping project the points near to the center (the hit considered as reference for the mapping) very far
- The error for this points is amplified
- In the real RICH the position is known with a certain uncertainty
- All the errors have to be taken in to account correctly!

Selective Riemann sphere

- The fit on the Riemann sphere is based on the sterographic projection of the circle on the plane on the sphere surface
- The projected points belong to the same plane
- The fit of this plane in the space (linear fit) gives the circle's parameters.
- This procedure doesn't work directly for two rings (using fast linear fit methods)

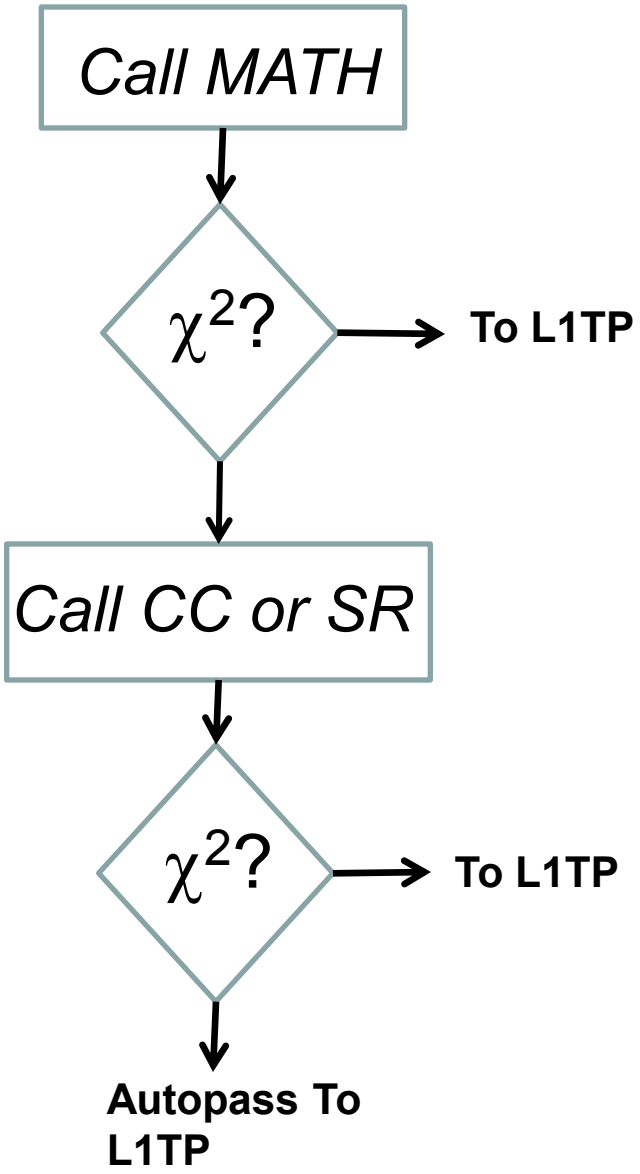




Possible 2 rings algorithm :

- Use the Hough transform with limitated number of bins to obtain the approximate centers of the rings
- Place a Riemann sphere in each center
- Project all the points
- Consider for the fits only the points in a band identified by the approximated radius

Total algorithm



- The 1 track event needs τ_{math}
- The 3 tracks event needs $\tau_{math} + \tau_{SR}$
- Assuming 50% 3 trks and 50% 1 trk (after L0) the average time per event is $\tau_{math} + \tau_{SR}/2$
- Assuming (with the GPU) τ_{math} = 50 ns and τ_{SR}= 2 us, 1 PC with 2 video card is enough for L1 RICH (providing that 2 us is feasible for CC or SR)

Conclusions

- Most of the events after the L0 is junk, coming from decays after the end of the decay region
- The use of the STRAW at L1 is penalized by the number of computing cores need to cope with 1 MHz rate
- The RICH+CHOD should be used to reconstruct the decay vertex
- Further studies as soon as the bug in GEANT4 will be fixed in order to use the X direction to improve the vertex resolution
- The L1 RICH needs a "Fast and Good" reconstruction: several proposal on the market, no one is completely suitable for us!
- Original algorithms (CC and SR) will be tested soon.
- Using GPUs the L1 RICH will be done in 1 or 2 PCs
- Without the L1, 90% of the events will be bring to the L2 to be totally reconstructed, processed and immediately put in the trash! (enormous (90%) waste of computing resources)