BentSolenoid & Wedge in Geant4: Status & Plan

P.Lebrun, FNAL

- Informal, yet brief outline:
  - Physics motivations:
    - Unbunched ("non-ischronic") cooling (i.e., 2D+cooling, i.e. P + transverse emittance).. If lucky, could lead to 6D cooling after bunching.
  - Simulation Technology : Geant4.
  - Status: A 4T., ~ 2 X 60 degree bend, instrumented, operational (as off last Friday)
    - Pictures
    - Caveats on Geant4
    - Dispersion measurements..
  - Plans + Discussions.

Physics Motivation for Bent Solenoid + Wedge

- "Unbunched Muon beams"
  - 6D cooling based on Bent Solenoid difficult because of spatial constraints on where to place the r.f., (too much drifts..), and nasty correlation (high dispersion can easily lead to non-isochronic transport)
  - => try something easier first!
  - Two possible applications:
    - a: A large emittance 2D+ cooler, (and scraper!), placed before the buncher, and/or the drift, to reduce $\Delta P/P$
    - b: A small emittance beam used to reduce P & ΔP, without blowing too much the transverse emittance, required to reaching "zero energy" cooling.

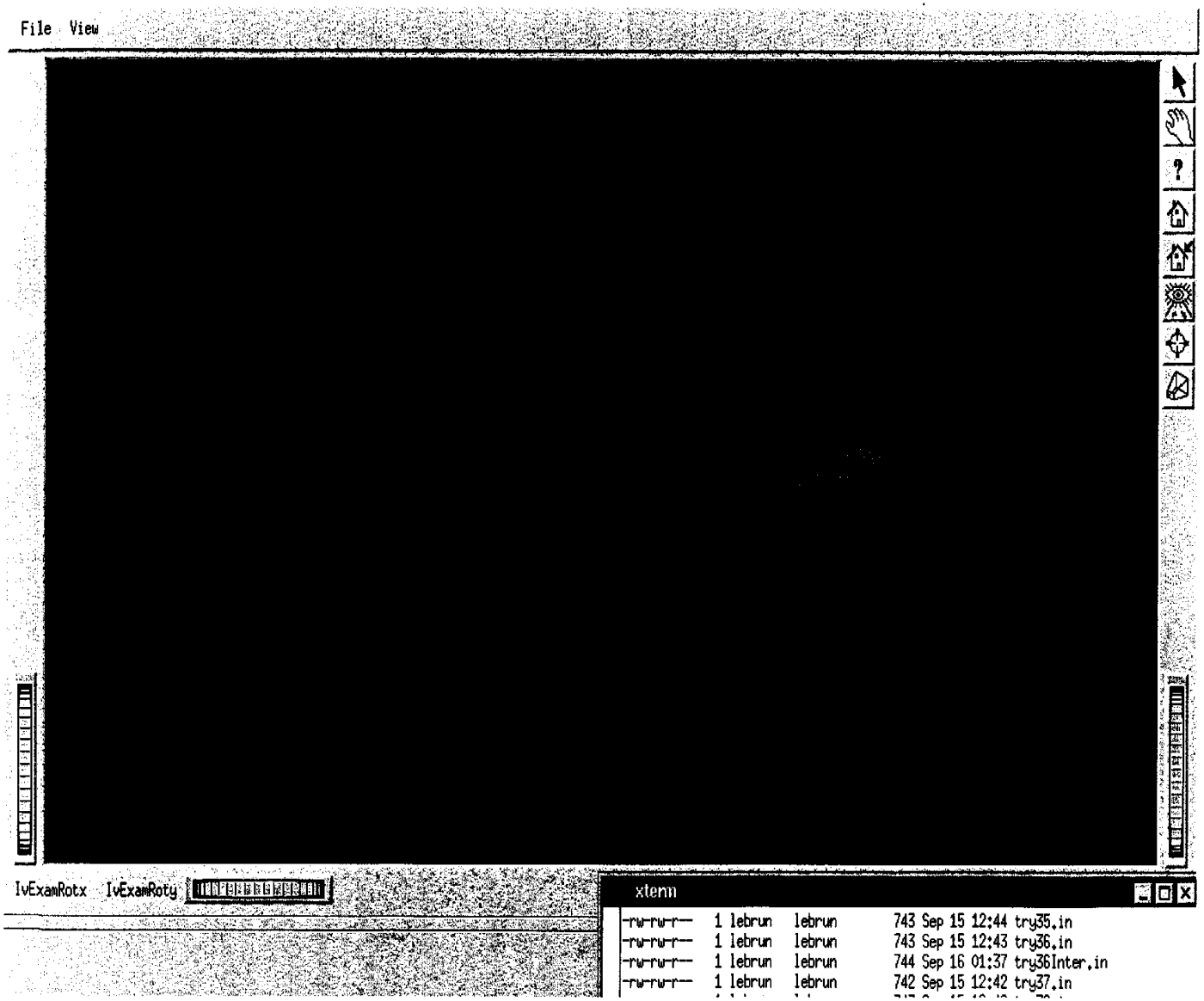
Probably dubious Physics scheme!..

- a. High emittance: 5D+ scraper : Mismatch in physical size of the beam with respect to practically achievable dispersion..
- b. Low emittance: Excessive multiple scattering using realistic wedge => significant transverse reheating, leading to excessive track angle and reflected tracks!
- However, we had to give it a try, because, in any event, if clever bunching is achieved, and therefore good 6D cooling, we need to test this in a detailed simulation package!

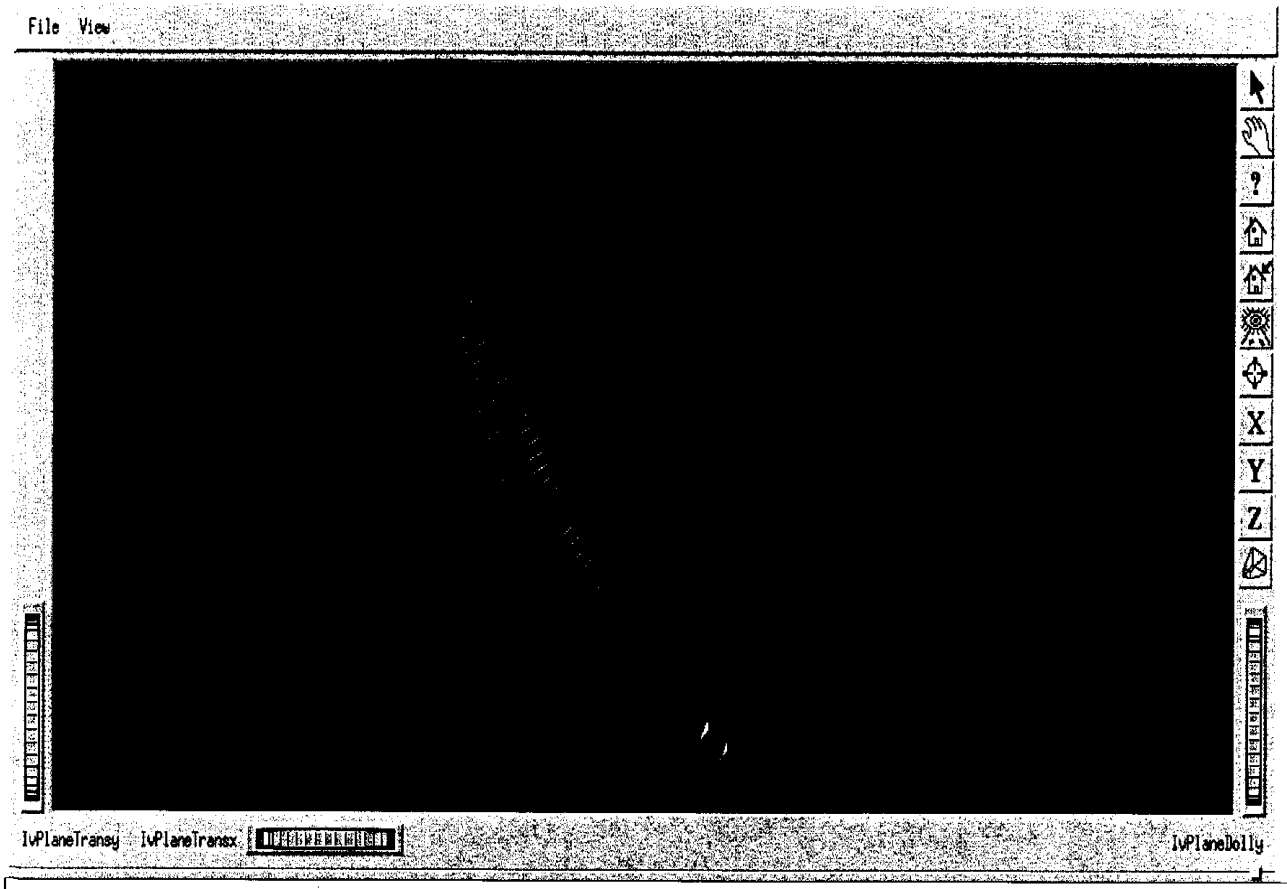
Geant4 : The right tool kit for the job

- Let assume "design success" : a "sketchy" simulation or ICOOL study will pan out!
- Then we urgently need a good "detailed simulation" tool kit: as for transverse cooler, the devil might be in the detail!!.. Need to feed some engineering constraints. (At least, check the floor plan!)
- A truly 3D problem! ==> good visualization helps.
- We are in for a long haul!
- ==> DPGeant not optimum..

Status of Geant4 Implementation.

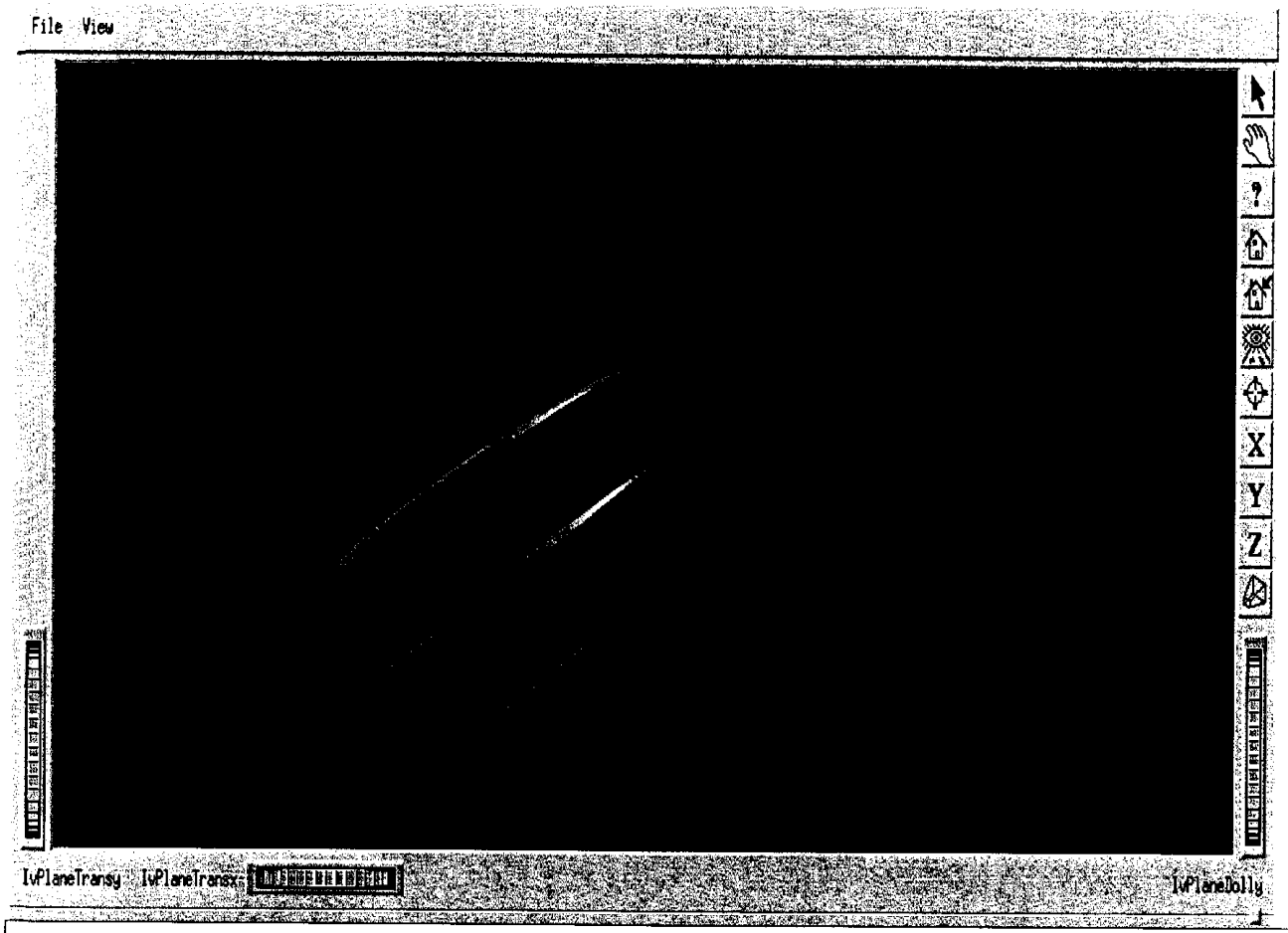


..The Bend Solenoid is contructed based on ~150 individual, straight Solenoid, of 4 different lengths.. In Planar XZ view:



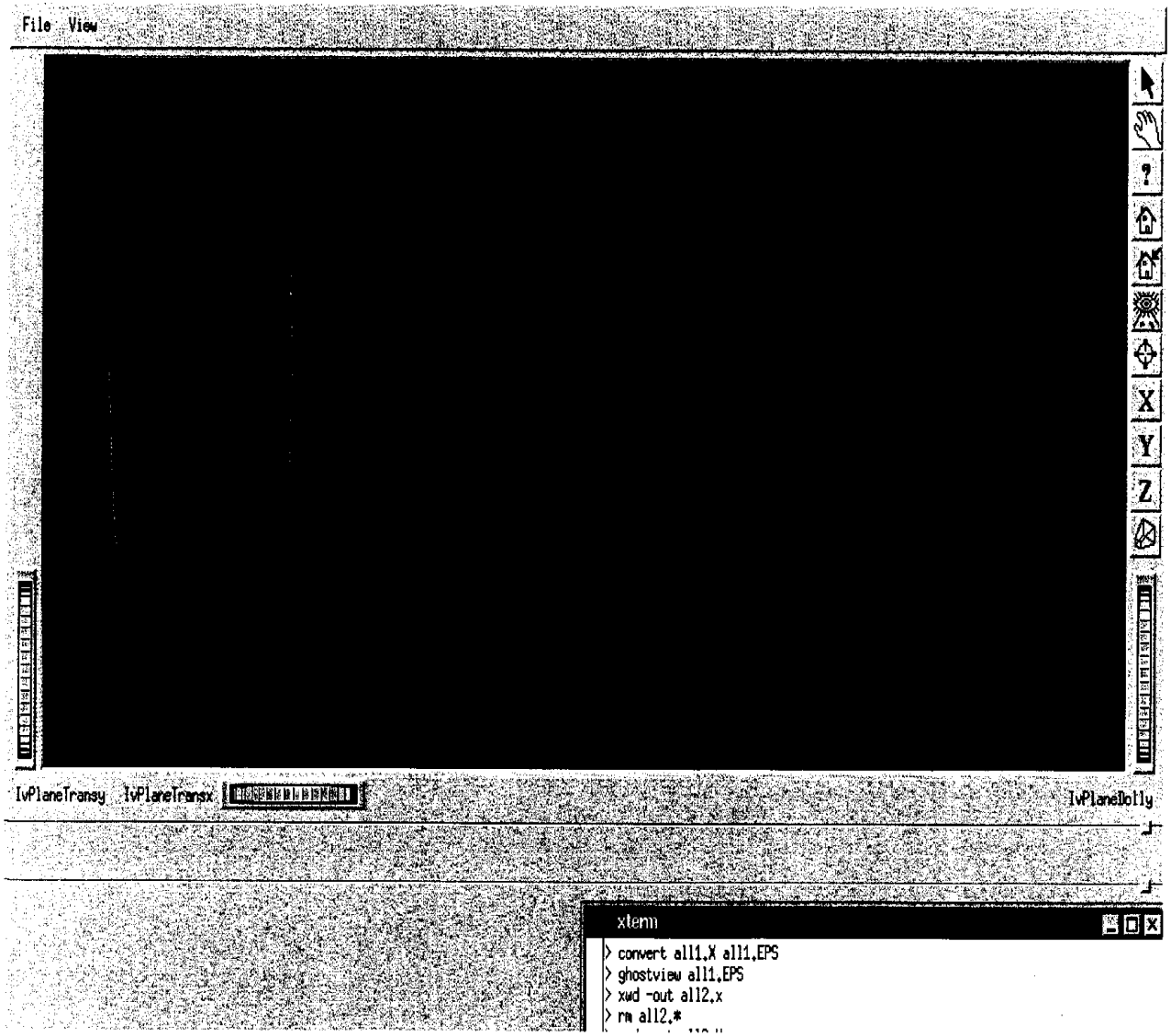
An extra space has been provided to insert some unspecified device ... (It will distort the field)
Note: Volumes don't overlap !..

Other images, in the XZ plane, close up

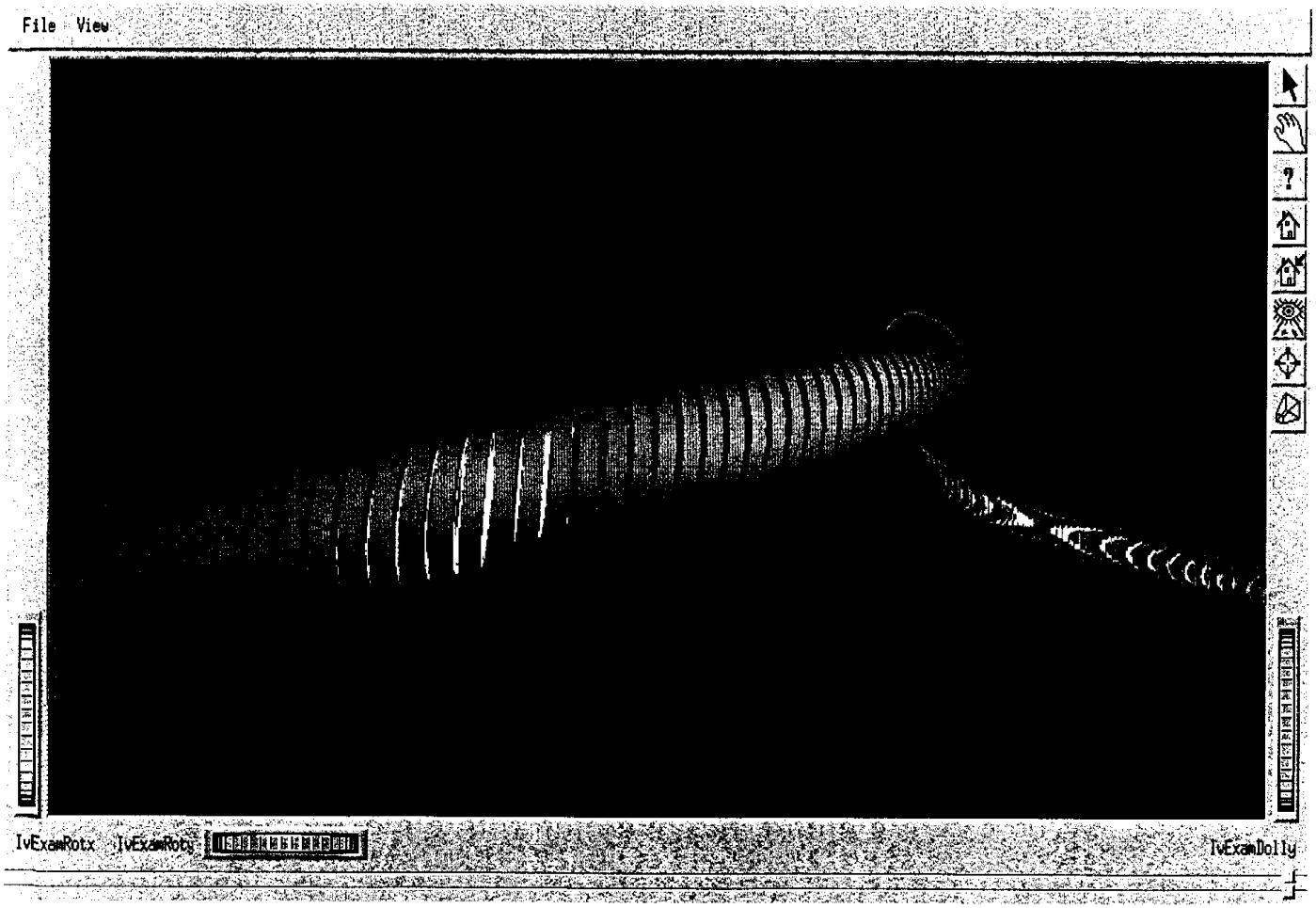


Short Solenoids in the bend (hoops) are shifted and rotated in the XZ plane, and rotate in the YZ plane (provide dipole field corrector..).

In the YZ plane:



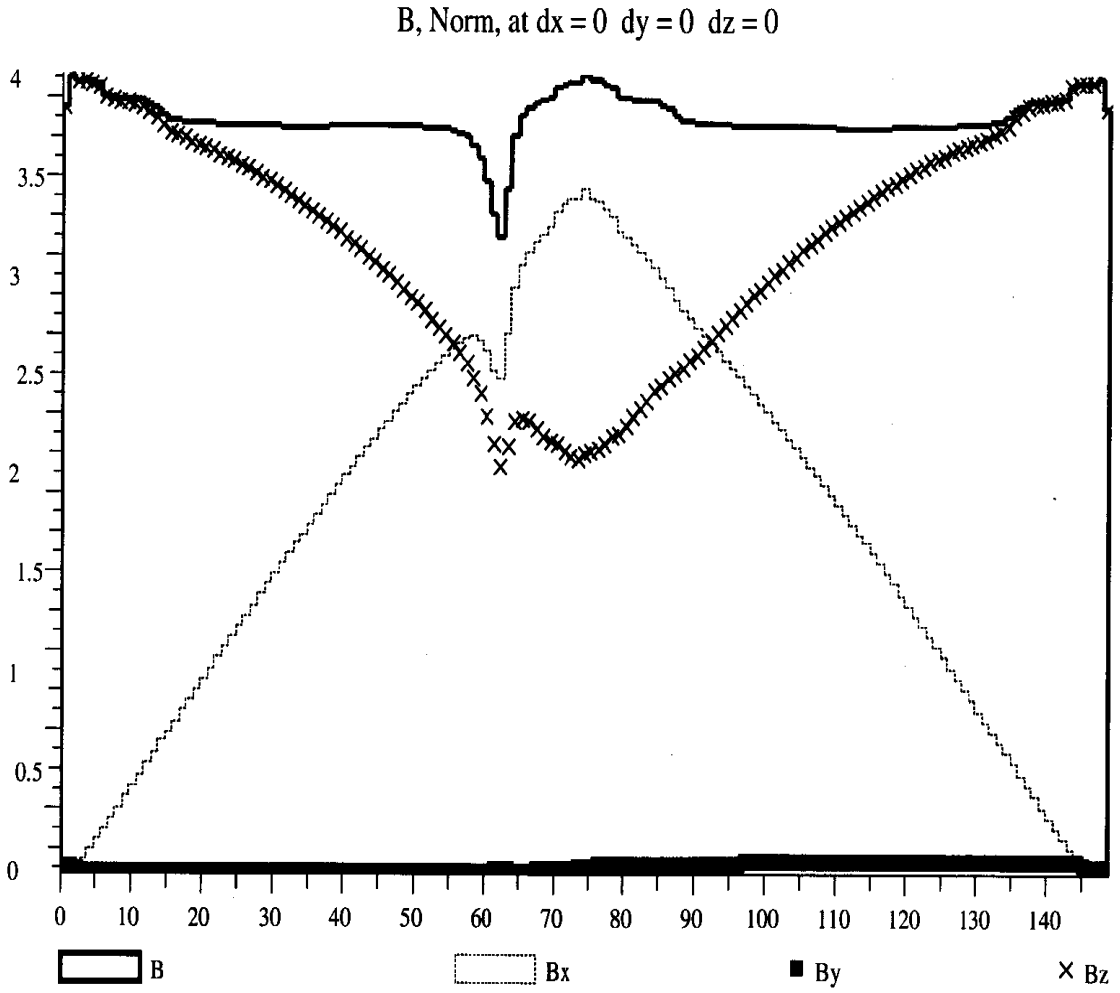
It is easy, from data cards to twist the solenoid in various shapes.



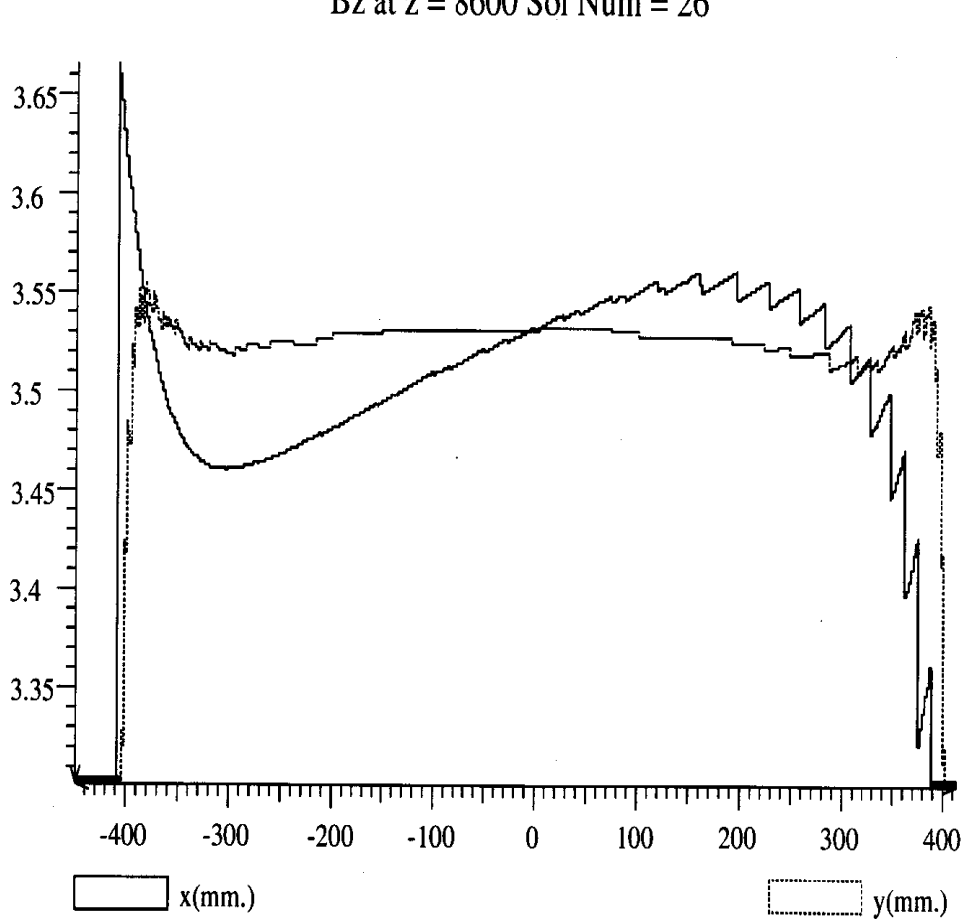
Design and implementation...

- Volumes : 1 cylinder + 3 simple tubes (container, conductor, shield, detector (vacuum)
- Magnetic Field : set as the volume are placed: the geometry of the field is entirely dictated by the geometry. In this examples, 4 types of basic straight solenoid (5 current sheets each) are used. For each of them, the field is computed on a 2D grid with cubic spline interpolation, over (L + 10* R X R). Then, we add all relevant contributions.. Based on the fact that fields add linearly (albeit a bit slowly on the computer..) Although the design has provision for creating a 3D map and do multi-dimensional spline interpolation, but it is not implemented yet. . Advantage of this design : the field changes automatically as the solenoids are moved. prevent discrepency between physical volumes and fields .
- ==> could be used for constructing a Helical Channel , simply change the rotation matrices and place them in a straight line.

The field, measured at the center of each solenoids



Along the X or Y, at the beginning of the bend (8.6 m from the origin).



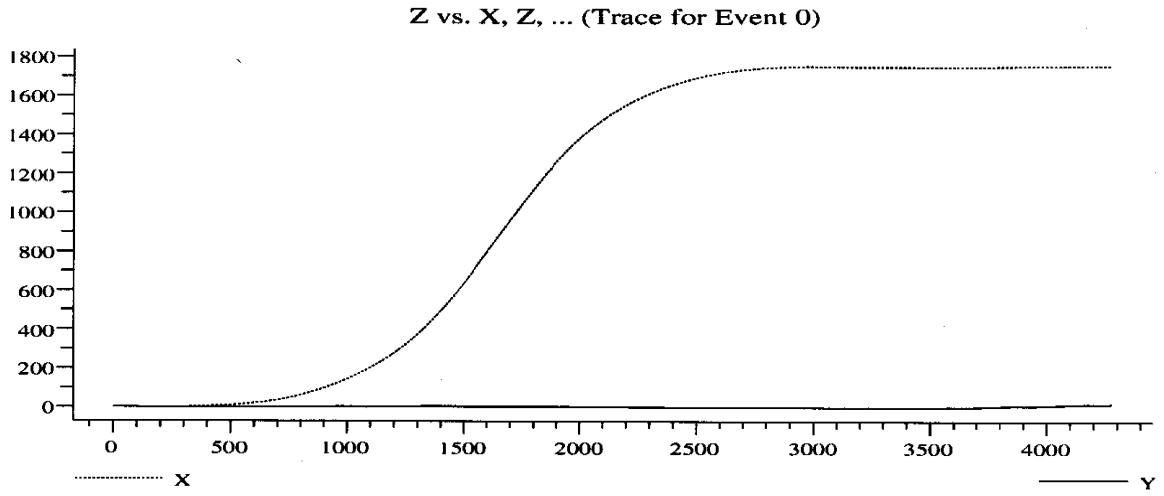
Details about this Bent Solenoid Configuration:

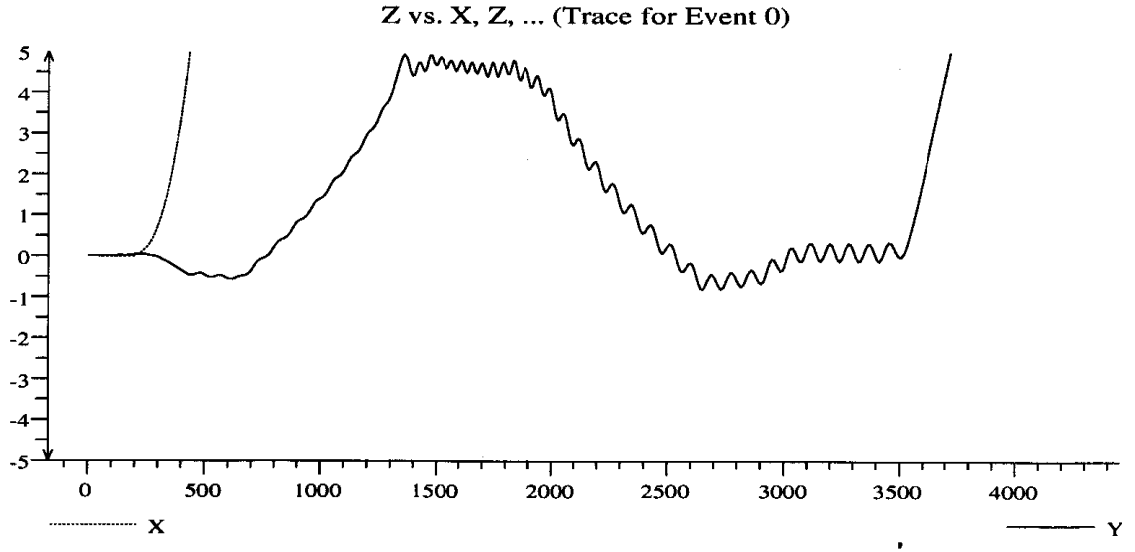
- Bore radius = rb = 40 cm., shield 10 cm. thick, 5 current sheets placed at rb+i*2 cm,
- L = 2., 0.5, 0.25, 0.125 m + dl of 1.5 cm min. between coils.
- Adiabatic increase of bent angle, crude hyperbolic tangent.
- Maximum turn angle in the XZ plane per 12.5 cm hoop is 15 mRad. There are 48 such hoops per bent Sol.
- Y tilt angle ~= X rotation (accidental coincidence, tune for 0.15 at 4 T.).

Caveats & Difficulties..

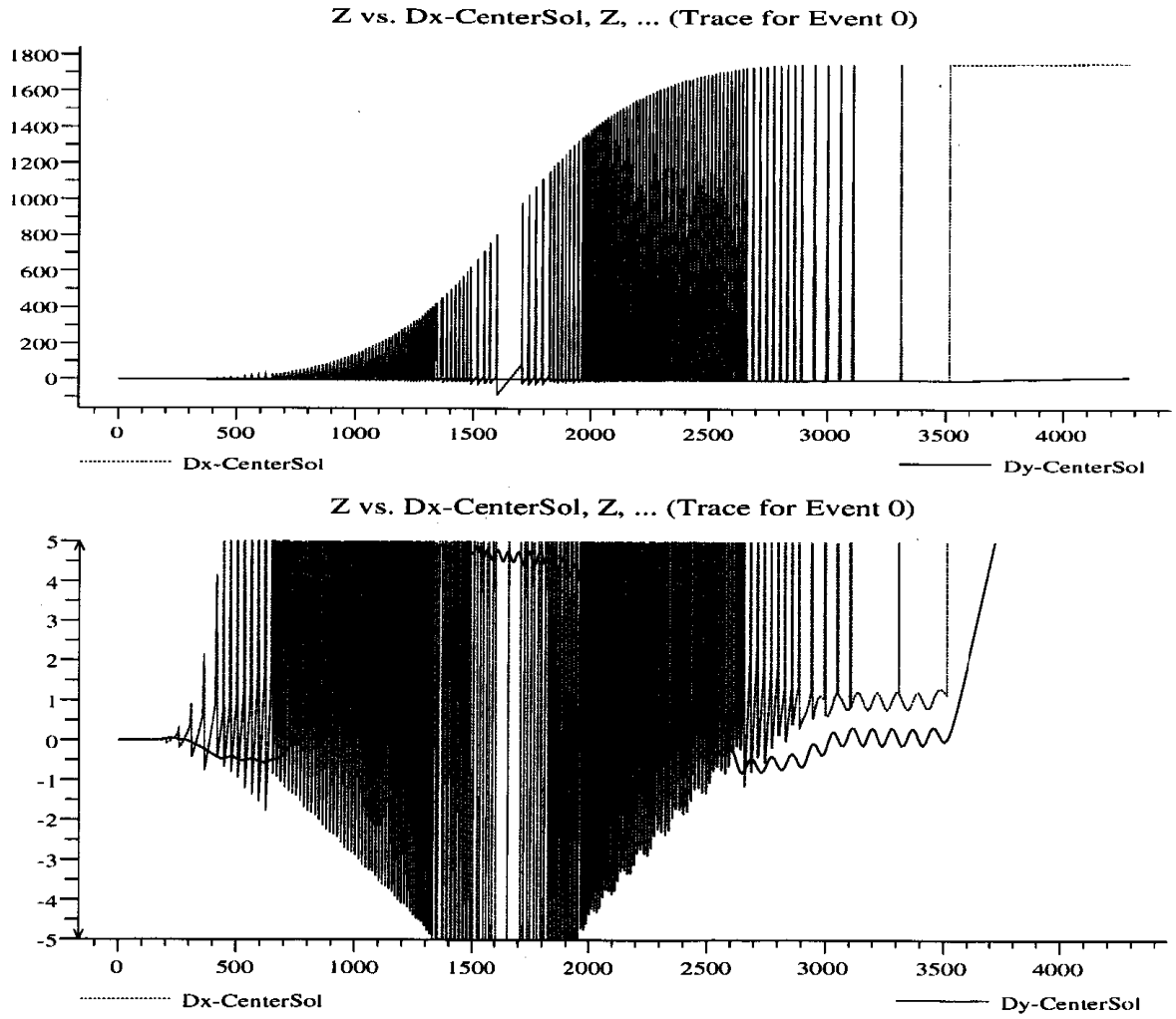
- The field is presumed to 0. outside rb.. (in the ref. frame of each straight solenoid.) Need a better model of what's going on inside the coil pack, and asume perfect return flux .. Not correct at 4T. !
- Geant4 tricks..
  - Volume rotation counter intuitive (inverse rotation needed ?).
  - Graphical culling or invisble confusing.
  - C++ is great, but I did not had the physical strength to bring the 1,000 Stroustrup bible with me!

The nominal trace, in the lab ref. frame.

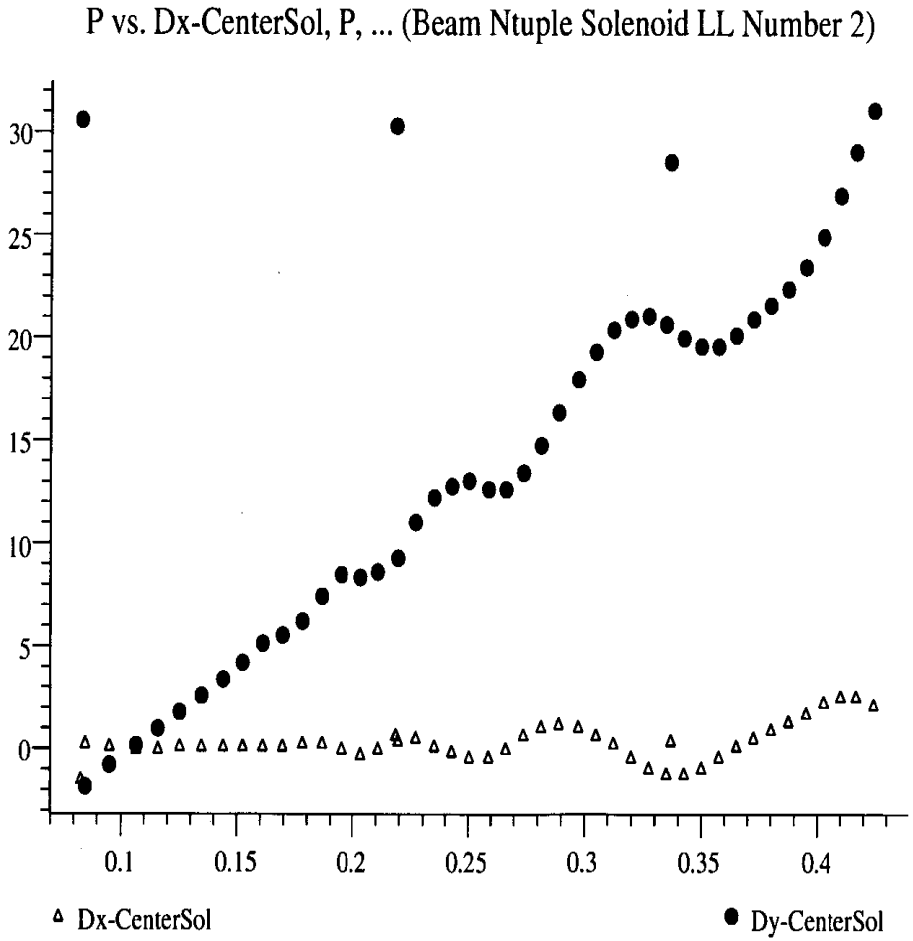




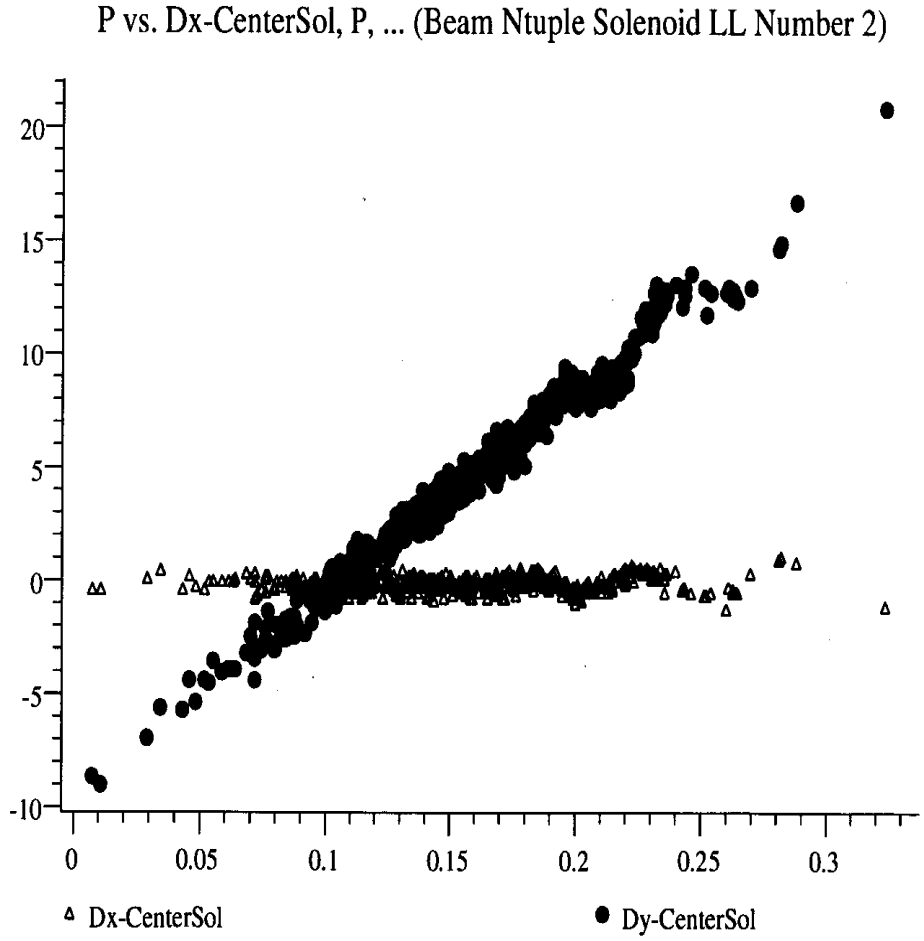
With respect to the center of placed volume (Lab or Sol. container).



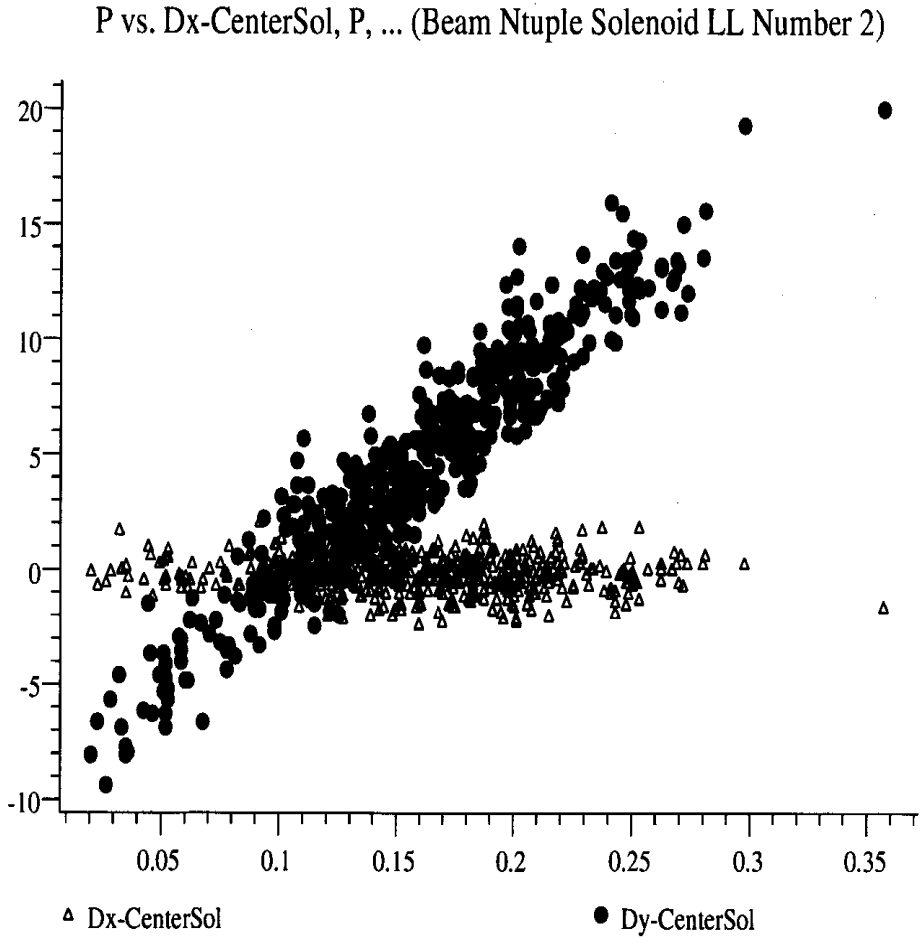
Dispersion Plot



Same, with σx = 5 mm., matched at 4.0 T., entering the channel..



And with σx = 15 mm., (3 x times previous)



Plans & Discussion

- Install the wedges.. .. Coding..
- Real beam from a front-end.. minor coding.
  - From 800 MeV proton set-up.
  - Your favorite one..
- Determine "isochronism" Delta tau vs bend.. (no coding..)

- Study the lattice defects.. (no coding..)
- Make an example of an Helical channel, compare with perfect dipole implementation of Daniel
- Allow for lattice building in the bend: shape B by tuning all coils individually.. (few lines of codes..) need definition of R-FoFo..
- Fix-up the visualization, if need be..
- ...