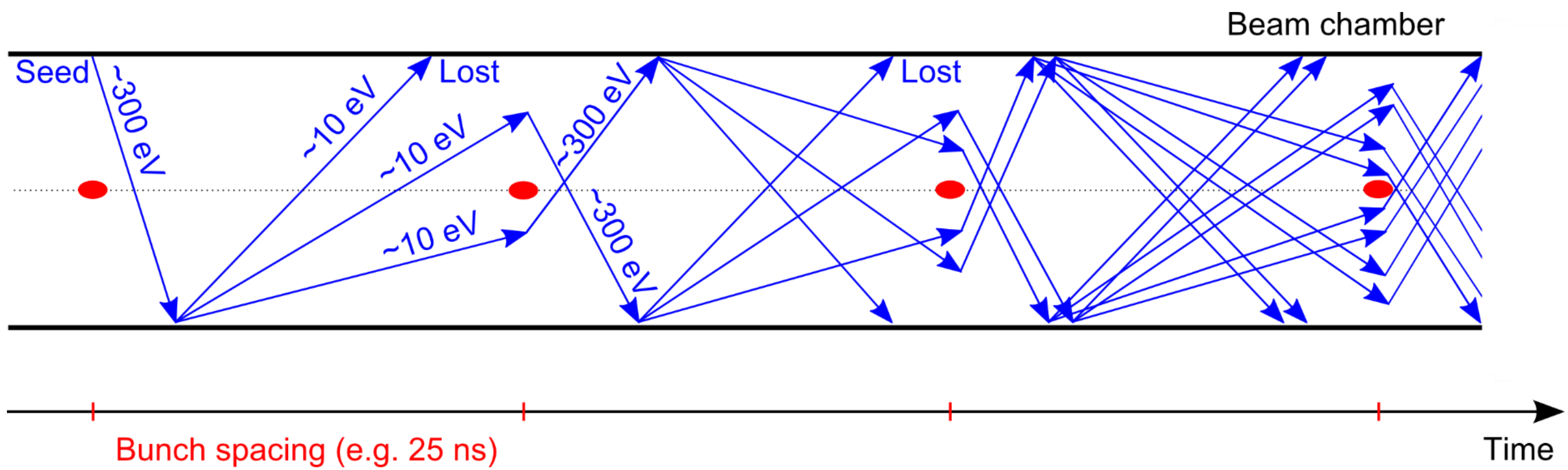
Status of electron cloud studies

L. Mether (CERN), K.Ohmi (KEK), G. Rumolo (CERN)

Outline

- Introduction
- Review of electron cloud studies
    - Build up
    - Instability
- Further studies & desired input

Electron cloud



- Seeds: photoelectrons from SR
- Seed electrons accelerated by beam, produce secondary electrons when hitting beam screen
- May lead to:
  - Avalanche electron production (multipacting)
  - Exponential growth of electron density

- Trailing bunches of the train interact with a dense e-cloud
  - Transverse instabilities
  - Transverse emittance blow-up
  - Particle losses
- Other unwanted effects:
  - Heat load on the beam chambers
  - Vacuum degradation

Electron cloud studies so far

Build up (CERN)

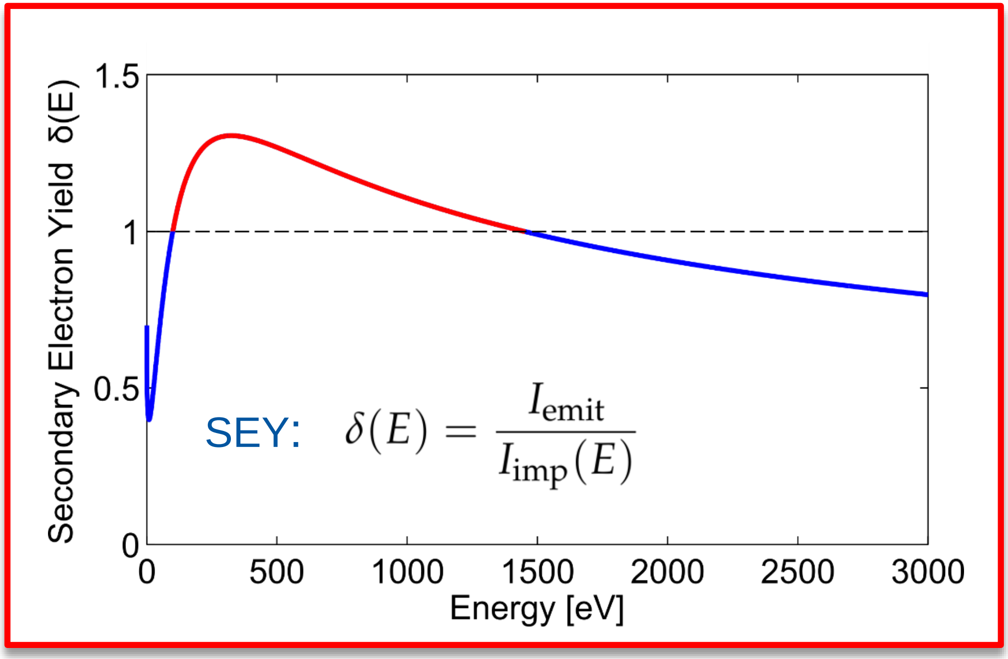
- Simulation studies
- Initial estimates for LHC-type beam screen
  - Dipole, quadrupole, drift
  - 25 ns and 5 ns beam
- Estimated
  - Threshold SEY for multipacting
  - Heat loads on beam screen
  - Electron density around beam
- Parameter scans

Instabilities (KEK)

- Simulations and analytical estimates for single bunch instability
- LHC-type beam screen
  - Dipole
  - 25 ns and 5 ns beam
- Estimated
  - Threshold electron densities for instability

Build-up simulations

- The build-up depends crucially on:
  1. Number and distribution of photoelectrons
     - In magnetic fields, electrons produced in direct impact point of SR are trapped by magnetic field lines, and do not contribute significantly to multipacting
     - Depend on SR energy, angle of incidence, beam screen surface properties
     - Needs to be experimentally determined
  2. Secondary electron emission[1]



1. G. Iadarola, "Electron cloud studies for CERN particle accelerators and simulation code development", PhD Thesis, CERN, 2014.

Build-up simulations

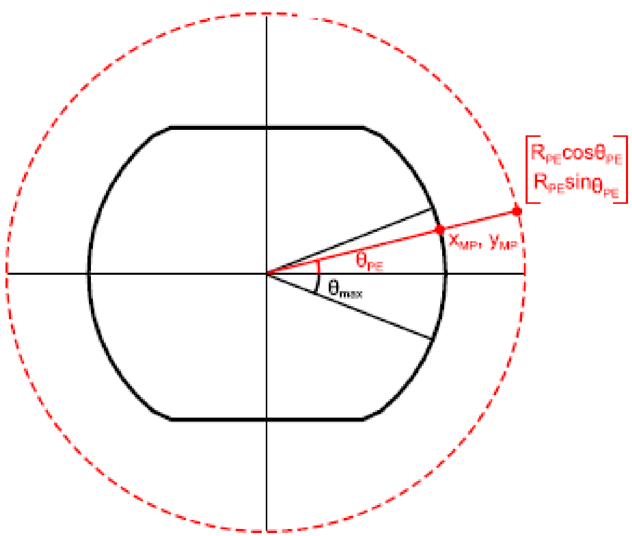
- Simple model for photoelectron emission determined by two parameters:
  - Photoelectron yield: Y ($N_{pe} = N_{\gamma}*Y$)
  - Fraction of photoelectrons produced by scattered photons: R

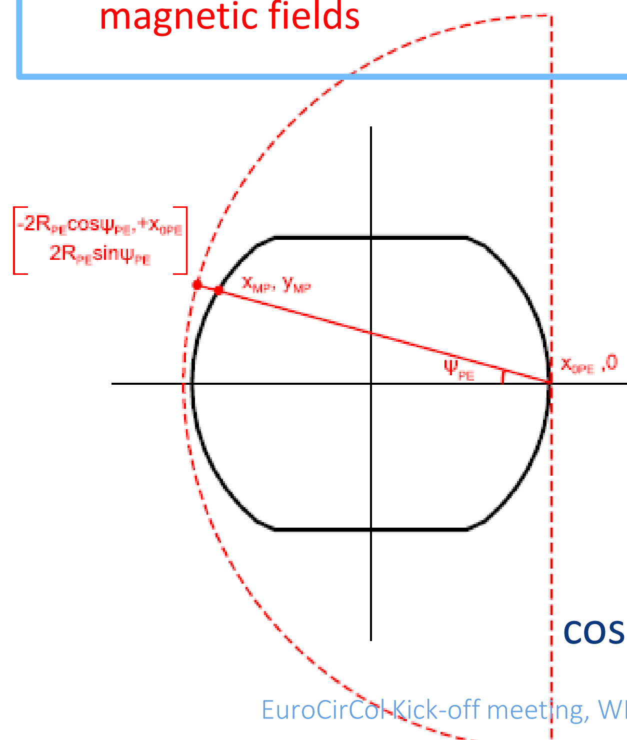
Electrons from direct SR photons

- $N_d = N_{pe}*(1\text{-}R)$
- Contribute to build-up mainly in field-free regions

Electrons from scattered photons

- $N_{rf} = N_{pe}*R$
- Main contribution to build-up in magnetic fields

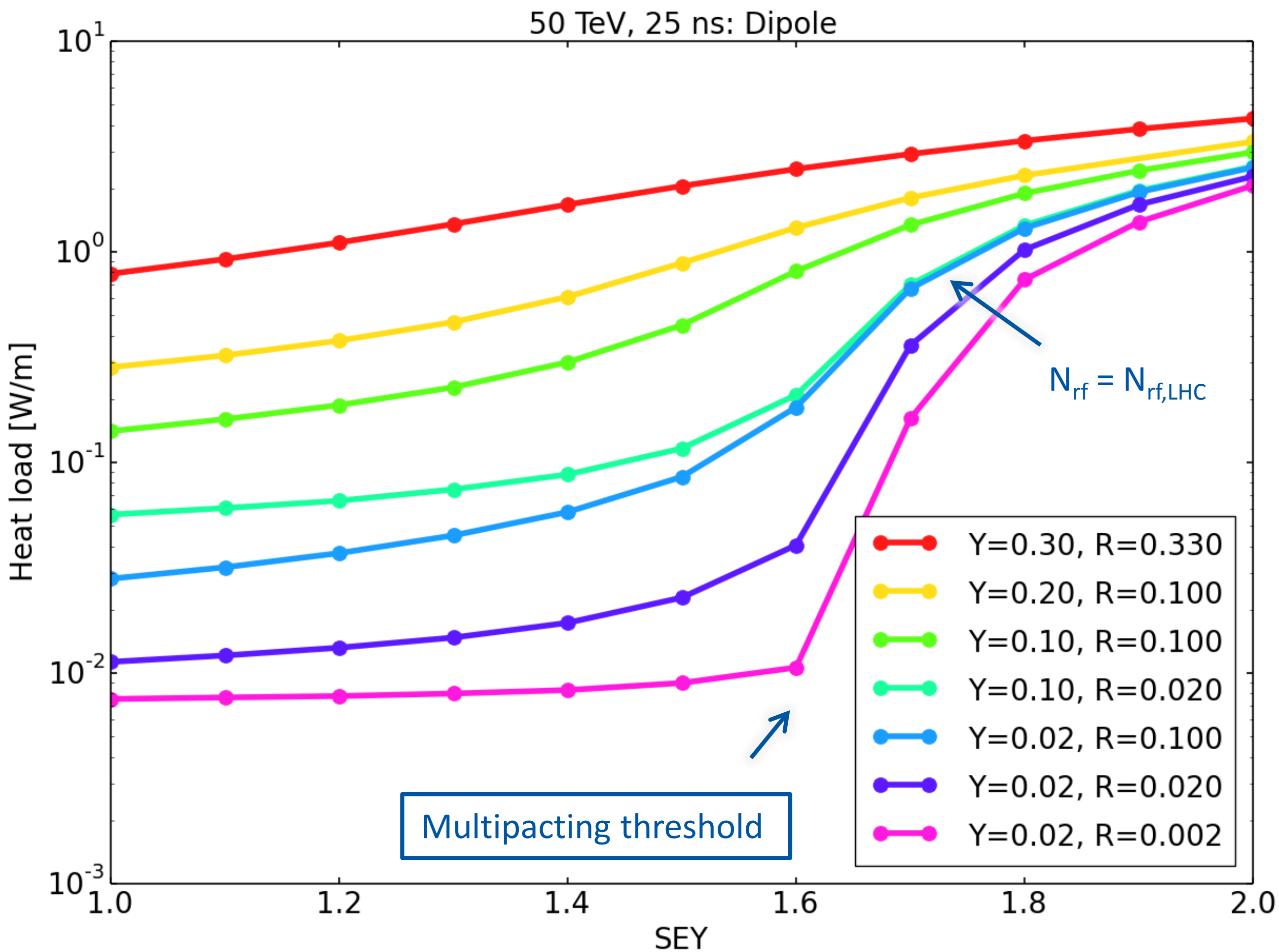




$\cos^2$ distribution

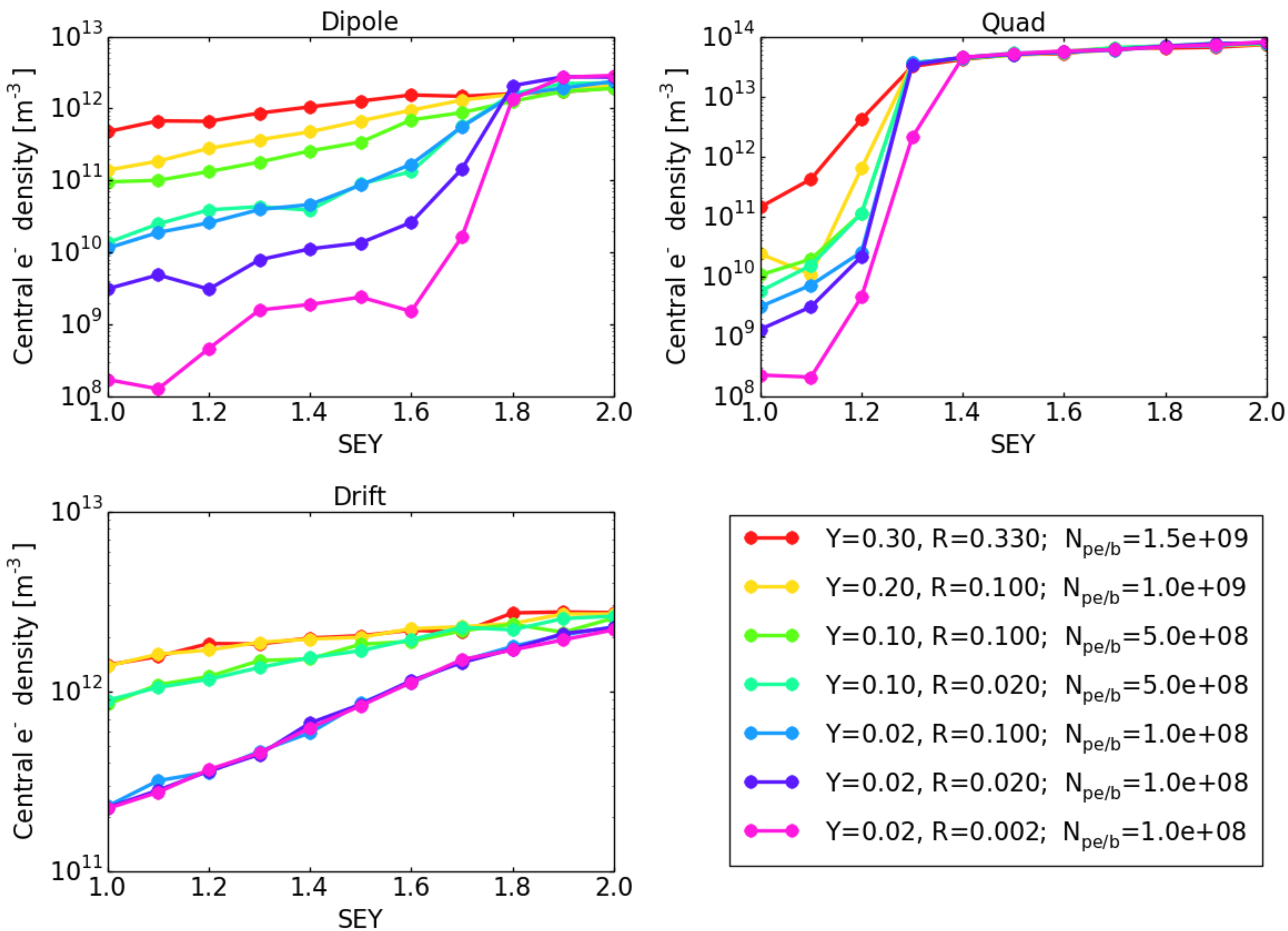
Effect of photoelectrons on build-up

- Heat load for 50 TeV 25 ns beam in Dipole magnet, scan over SEY and R,Y



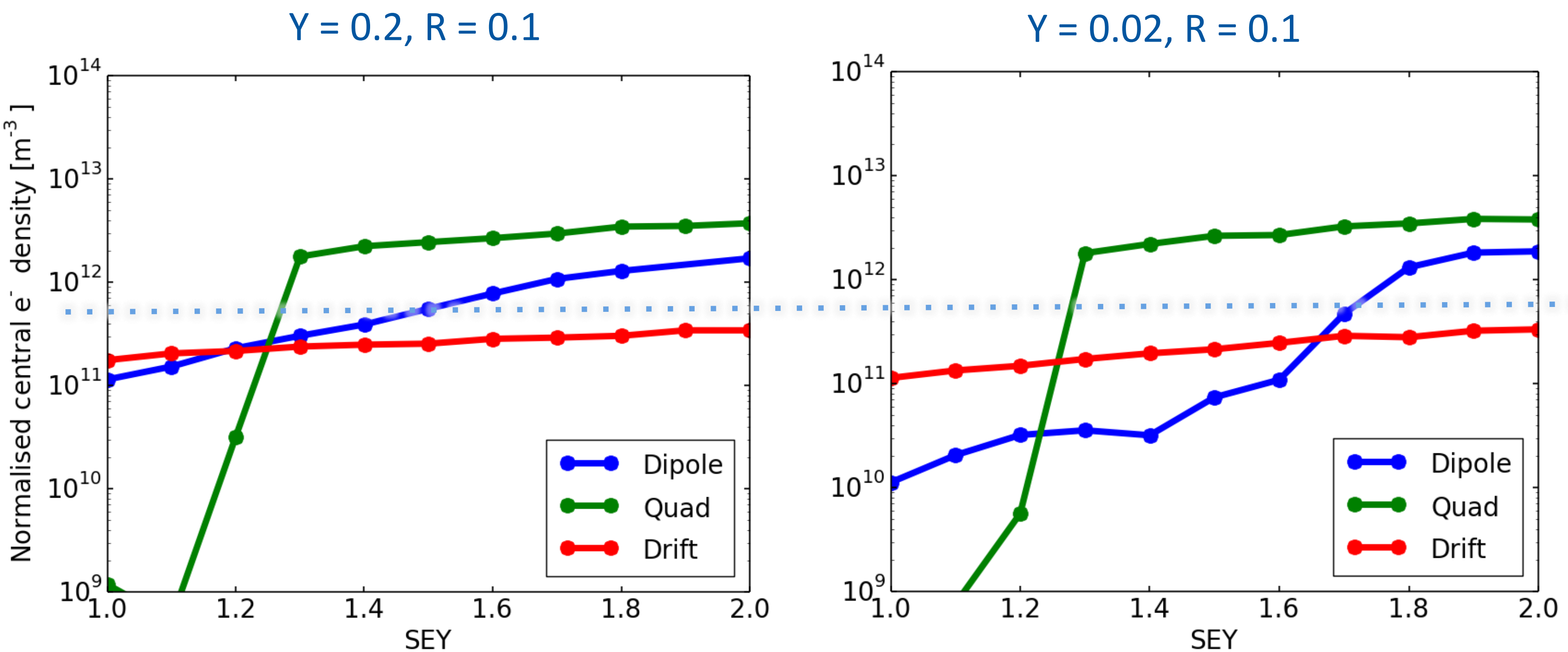
Build-up in different arc components

- Central electron density for 50 TeV 25 ns beam, scan over SEY and R,Y



Central electron densities along FODO cell

- Central electron density, scaled to fraction of element in FODO cell, 50 TeV 25 ns



- Instability threshold estimate ρ ~ $5\times10^{11}/m^3$ (for dipole)
- Length of arc elements
  - FODO: 208.14 m, Dipole: 170.40 m, Drift: 26.40 m, Quadrupole: 10.34 m

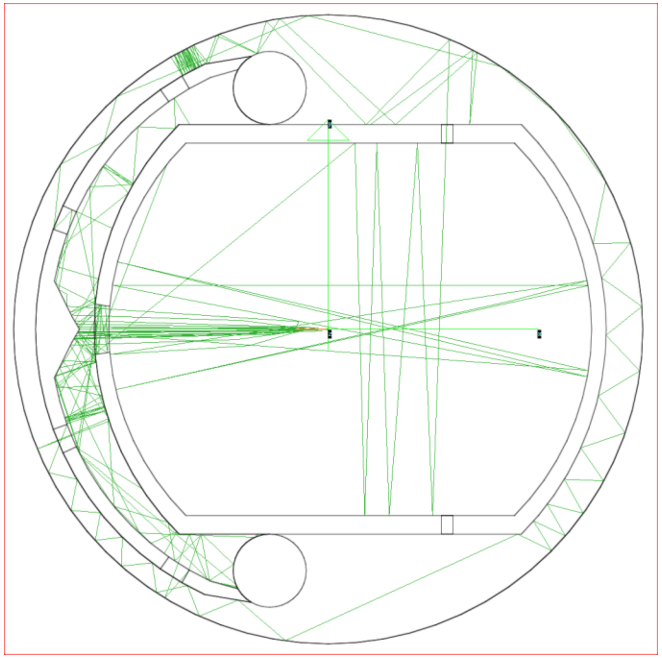
Summary

- Build-up studies
  - Compared to the LHC with 25 ns beam, the situation seems a little bit worse
  - Similarly to LHC, the component with the worst behaviour is the quadrupole
  - Drift spaces are most sensitive to the photoelectron yield
  - The 5ns beam is worse than 25 ns, but less sensitive to the photoelectron yield

- Instability
  - Threshold for instability $\rho \sim 5 \times 10^{11}/m^3$ (for dipole)
    - Central electron densities in dipoles above or below threshold depending on SEY, Y, R
  - Central density in quadrupoles worryingly high
    - In LHC instability threshold for quadrupoles is lower than for dipoles

Further studies

- Refine studies on LHC type beam screen
  - Study electron cloud build-up using accurate boundary
  - Cross-check of codes between KEK and CERN
  - Instability thresholds for all components
  - Details of instability
  - Better input for build-up simulations may play bigger role
- Intermediate bunch spacings
  - 12.5 ns?
- Study beam screen with SR chamber
  - Requires detailed knowledge on where photoelectrons will be produced
- Electron cloud in injectors



R. Kersevan