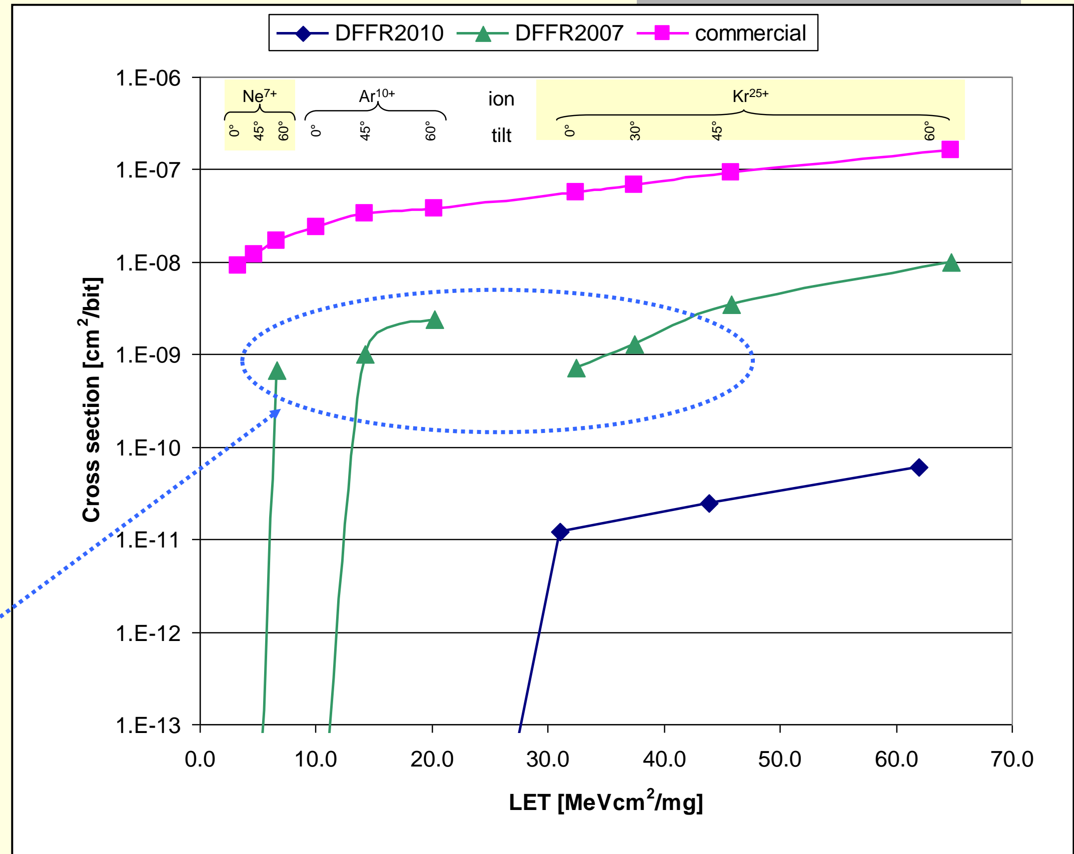
Available radiation data for "hardened" cells (proton tests)

- Wide range of "hardened" cells custom designed and tested (200MeV protons) by FNAL. Results presented by J.Hoff in 2006.
  - Some of them have cross-section 3 orders of magnitude below the one measured for a commercial cell
- DICE cells custom designed and tested in 2008 by the ATLAS Pixel detector collaboration
  - results presented by M.Menouni at TWEPP 08
  - 3 different layouts integrated
  - Tests done with the CERN 24 GeV/c proton beam
  - Cross-section varies with layout but mainly around **$2\text{-}3\cdot 10^{-16}$ cm^{2}bit^{-1}**.
    - This is 10 times larger than what measured by FNAL on the same design in 2006
    - (but different layout and proton energy).

Type	Cross Section
LBL Dice	3.84e-17 cm^2/bit
RT Dice	5.86e-17 cm^2/bit
RT Seuss	1.03e-15 cm^2/bit
RT SR-ff	3.85e-14 cm^2/bit
RT normal	3.23e-14 cm^2/bit
TR Seuss	4.7e-15 cm^2/bit
TR SR-ff	8.91e-15 cm^2/bit
Hit	1.59e-15 cm^2/bit
Liu	2.69e-16 cm^2/bit
Dice	4.55e-15 cm^2/bit
Seuss	1.05e-14 cm^2/bit
SR-ff	5.02e-14 cm^2/bit
COMMERCIAL	4.86e-14 cm^2/bit
Normal	5.63e-14 cm^2/bit

Available radiation data for "hardened" cells (heavy ion tests)

- DFFR2010, "Modified" DICE latches custom designed and tested in 2010 by the CERN ESE group.
  - Tested in dynamic (clocked) mode
  - Results presented at this conference (see poster!)
  - >3 orders of magnitude better than standard commercial cells at high LET
  - No errors at low LET
    - <20 MeVcm²/mg
      - No errors in LHC ?
- DFFR2007 latches
  - large dependence on incidence angle for low LET
  - 1 order of magnitude better than standard commercial cells at high LET
  - Results TWEPP07-JINST
- Tests done at UCL-CRC, Belgium



- See poster in this conference for more details

Error rate projection for “hardened” cells

- it appears that some hardened cells have a cross-section 3 orders of magnitude (or better) below the one measured for the commercial cell
  - CERN tests with heavy ions (2010)
  - FNAL tests with 200MeV protons

- Comparison with other data reveals large uncertainty on the actual rate for the DICE cells (is this due to layout, proton energy, systematic difference in experiments?)

- Summary:
  - Error rate depends on the detailed implementation of the cell (architecture, layout) and operation (static, dynamic)

SEU protection using standard library and automatic P&R tools

- Triple Module Redundancy
  - Easily passes through RTL Compiler (Encounter)
    - … if input/outputs or clocks are triplicated
- SEU-robust cells
  - Not included in our library yet
  - Timing must be characterized for inclusion in the library
    - P&R can work without timing characterization… but no timing checks!!

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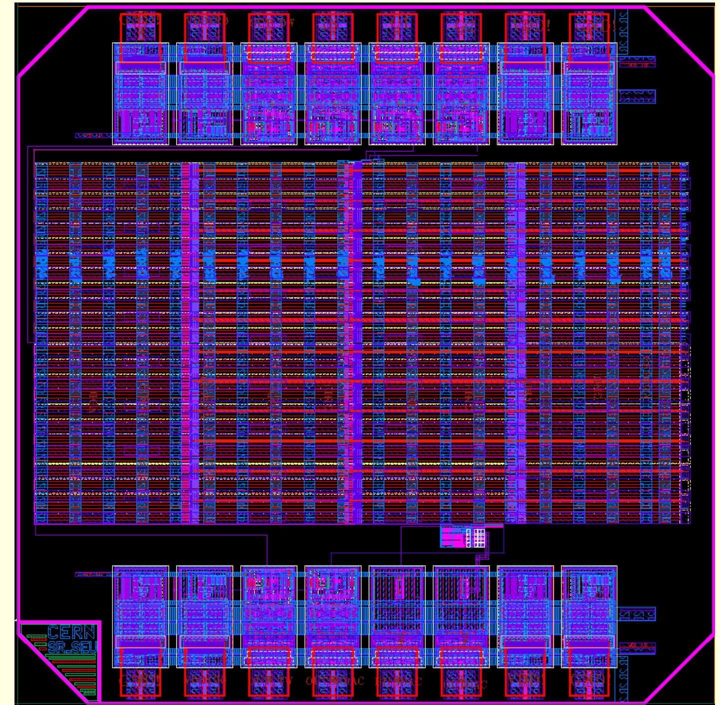
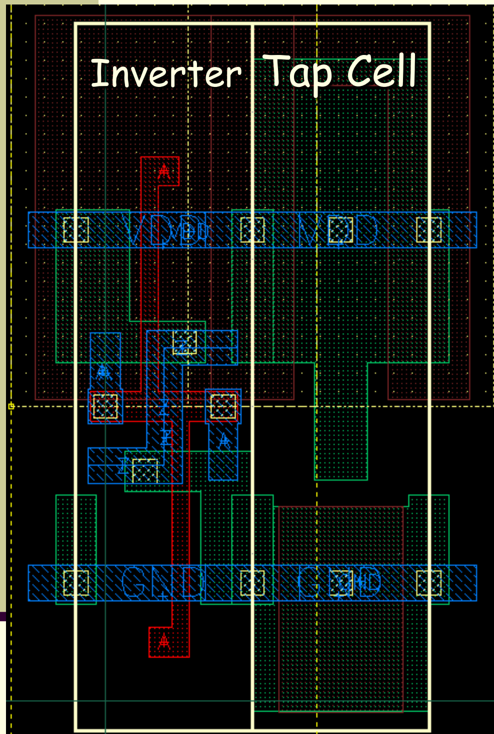
Future tests on 90 nm technology

- A shift-register test chip with 60k FFs was fabricated and will be tested (by end 2010)
  - Two types of FF are present, using
    - Dual-Well devices
    - Triple-Well devices
    - TW could have advantage over DW due to thinner charge collection volume
    - But higher resistivity of well + parasitic bipolar effect may dominate
- An SRAM chip is under development (~1 Mbit)



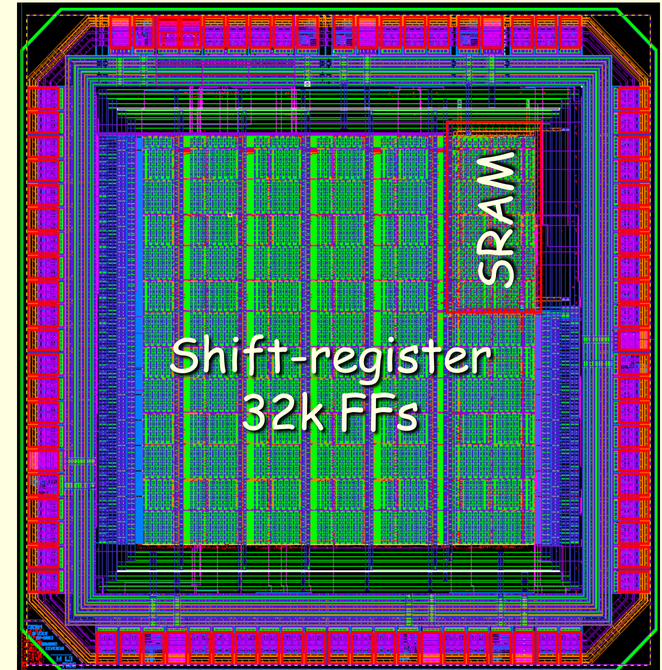
- Developer:
  - Lorenzo Pierobon CERN PH/ESE

Single-Event Latchup tests



- Standard cell library needs tap cells for substrate/n-well contacts
  - By default placed at ~15 um distance in our automatic P&R scripts
    - (30 µm in same row w/ checkerboard pattern among rows)
  - Design rules require ~70 µm max distance

- Planned irradiation tests to assess SEL immunity
  - Test chip
    - 32kbit FF (foundry)
    - 17kbit SRAM (foundry)
  - Expected delivery Dec/2010
  - SEL tests
  - SEU tests
  - (TID tests on SRAM…)
- Library pads (foundry) were tested and proved functional
  - at LET > 60 MeVcm^2/mg



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Summary

- Error rate of ‘standard’ register/memory in 130nm is considerably larger than for the 0.25um designs used for LHC
  - Estimated cross-sections for both SRAM and FFs are available and can be used to compute error rate and judge compatibility with application
- Characterized hardened cells exist achieving error rates >3 orders of magnitude better than ‘standard’
- SEL test structure representative of automatic P&R in the 130nm is being manufactured and will be tested
- More tests in 130 and 90nm are planned

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