Irradiation test of ABCStar ASICs in CSNS

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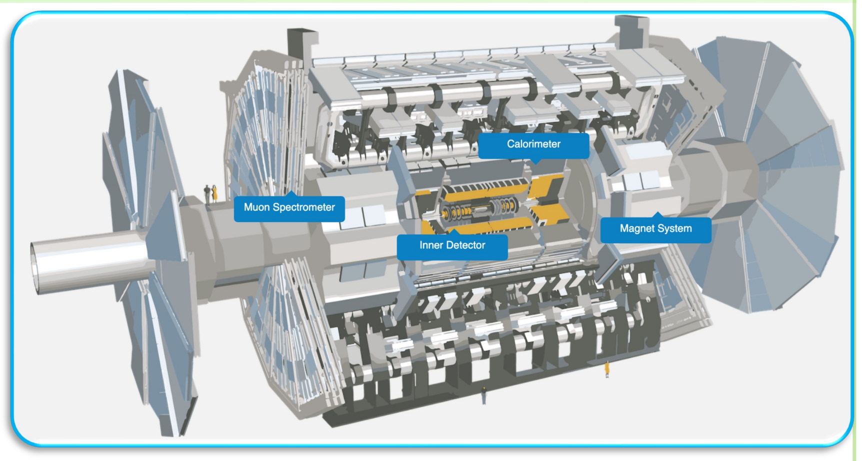
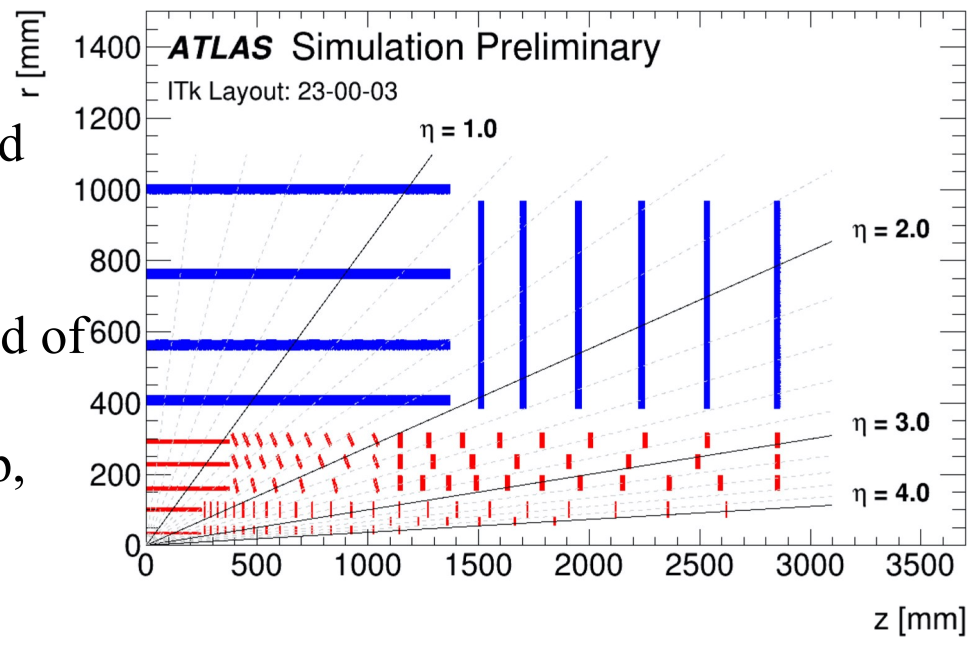
Introduction

- The ATLAS experiment will build an all-silicon tracker in the Phase II upgrade for the High Luminosity LHC (HL-LHC) at CERN.
- The new detector will maintain or improve the current ATLAS tracking performance to cope with the increased pile-up, data rates and radiation levels of the HL-LHC .
- A new readout system has been designed to cope with the increased occupancies and harsher radiation environment.
  - ➢The readout system is comprised of the **ABCStar (ATLAS Binary Chip),** the analog front-end chip, and the **HCCStar (Hybrid Controller Chip),** the active interface chip between the ABCStars on the hybrid and the off-detector electronics.
  - ➢The injection of high-energy particles into the chip will cause **single event effects (SEEs)** such as bit flips of electronic devices.



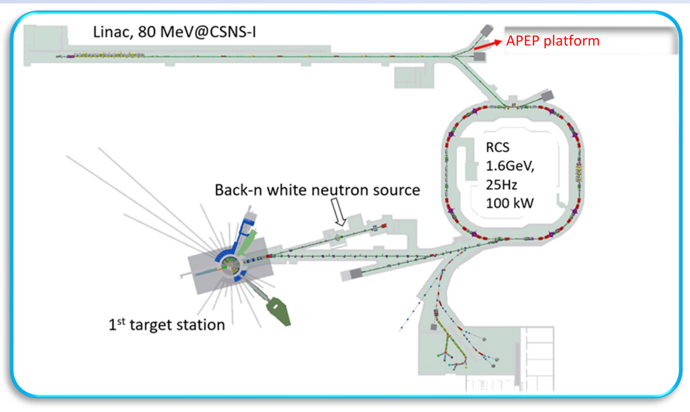


CSNS irradiation

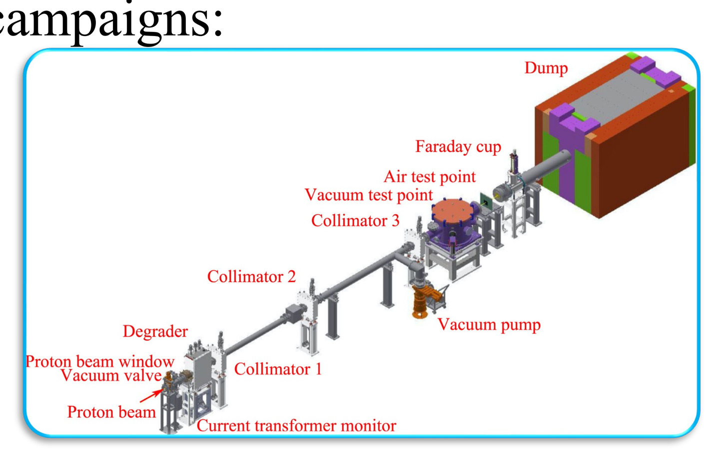
China Spallation Neutron Source (CSNS)

The first major scientific facility in south China.

- Mainly consists of:
  - An H- linac
  - A proton rapid cycling synchrotron



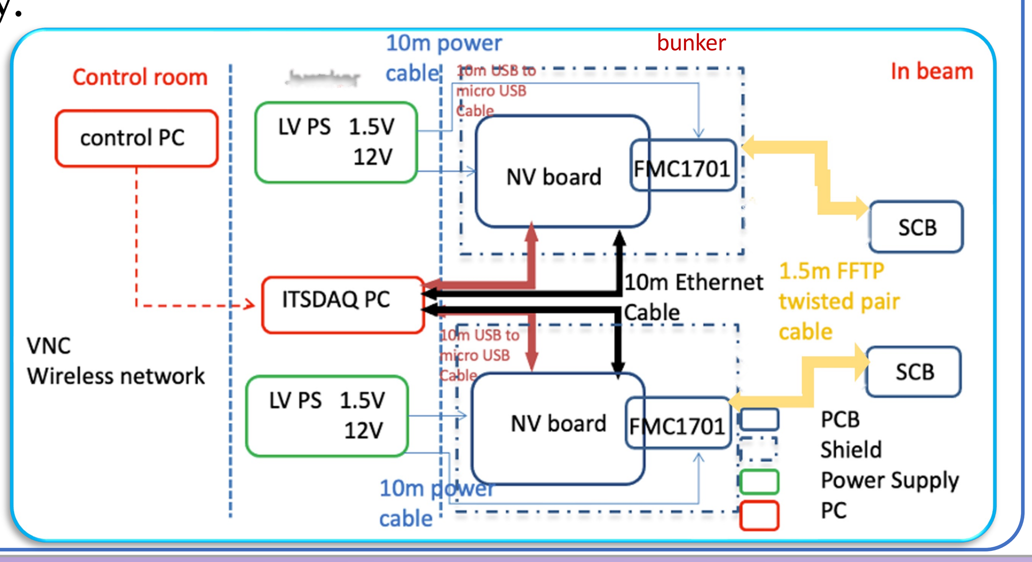
- We utilize the **Associated Proton Experimental Platform (APEP platform)** to have irradiation on ABCStar chips at the end of the CSNS linac.
- We use a 20 mm × 20 mm beam spot.
- **V0:=prototype version, V1:=production version of the ABCStar**
- The ABCStar chips have been irradiated in 4 campaigns:
  - ✓ August 2020: 480 MeV, three V1 chips and one V0 chip @ TRIUMF
  - ✓ December 2020: 480 MeV, four V1 chips
  - ✓ May 2022: 80 MeV proton, one V0 chip @ CSNS
  - ✓ April 2023: 20 MeV ~ 80 MeV proton, four V1 chips



SEE irradiation setup and experiment procedure

We use lead bricks as bunker, and put the FMC1701 and FPGA boards under the bunker.

- ABCStar V1 chips under the same energy undergo different running scenarios(clk_disable、glitch_filter、bcid、Idle、Latency 20/503).
- It takes around 170 hours totally.



Results

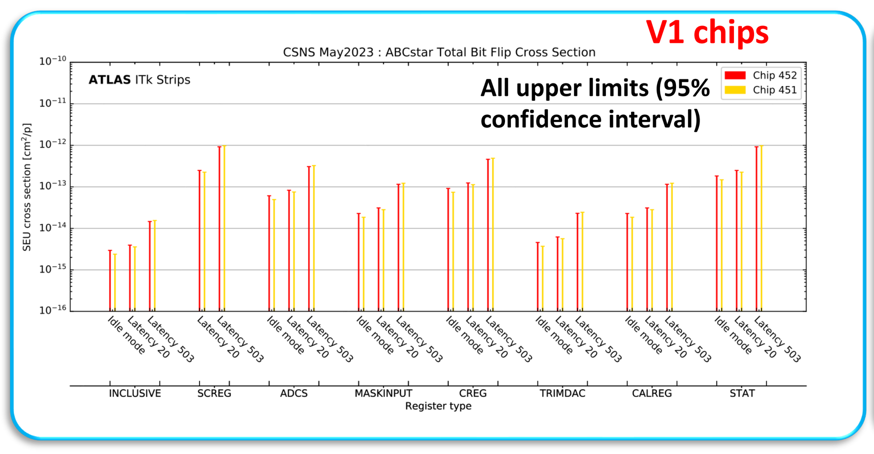
1. Bit flips in physics packet at different energies

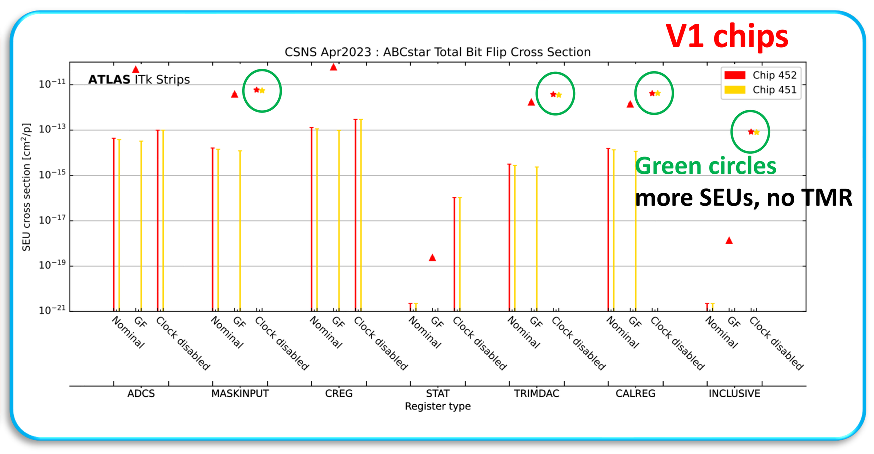
- ➢For physics packets, measured/expected clusters are converted to 256-bit strip data and compared.
- ➢The analysis of SEE cross section in physics packets is ongoing.

2. Bit flips in register at different energies

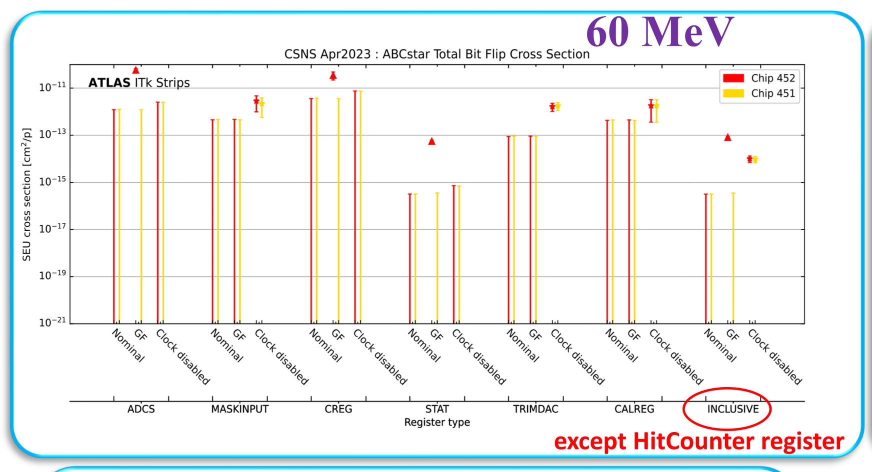
- ➢The cross-section (XS) for a particular calculation process (e.g., number of SEUs) is given by: XS = (number of occurences) / (integrated fluence).
- ➢There will be more bit flips in the clock disable mode as expected.
- ➢It's basically consistent with expectation and it shows the effectiveness of the **Triple Modular Redundancy(TMR),** compared to ABCStar V0, V1 chips use full TMR technology and there are less bit flips in the same mode under the same energy.

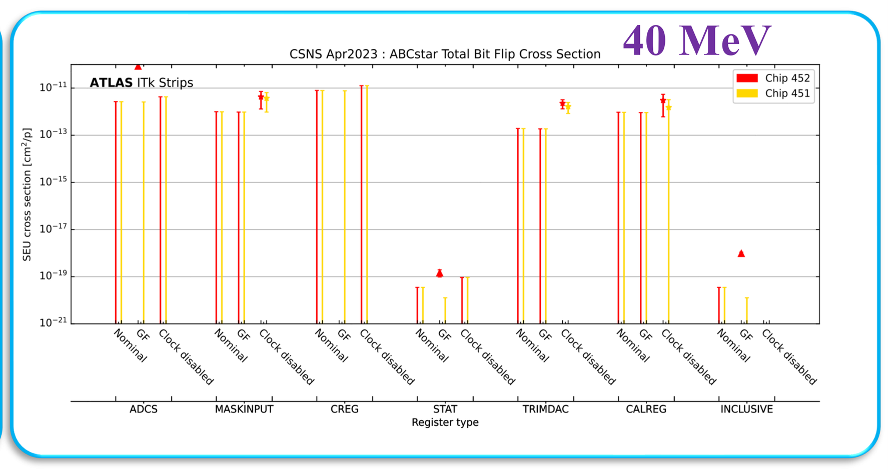
V0: 4.6×10^{-14} cm²/p, V1: 1.0×10^{-18} cm²/p

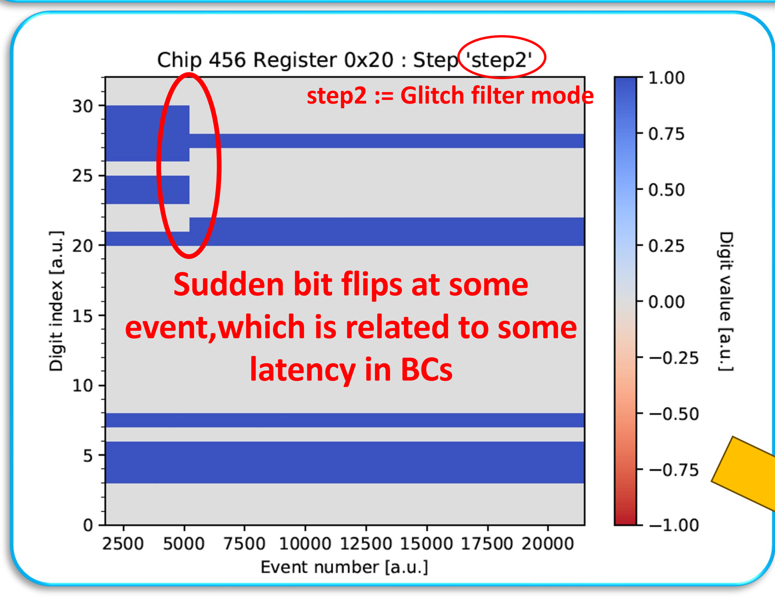


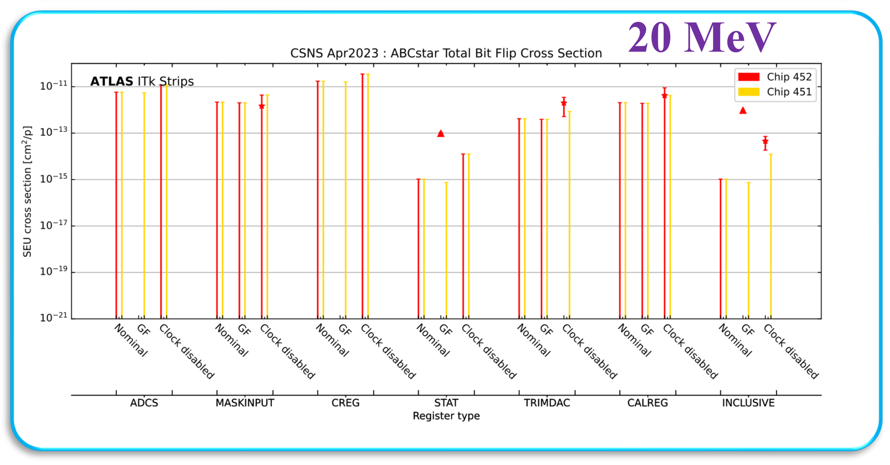


80 MeV





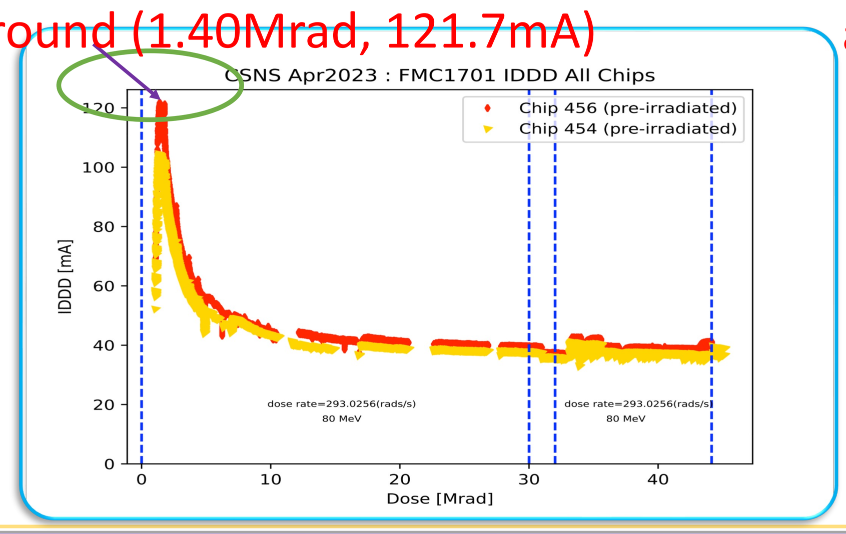


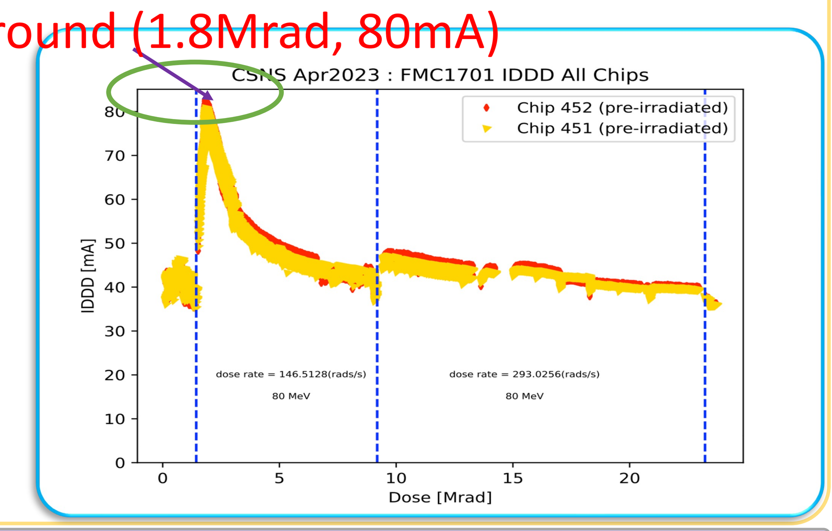


Chip 456 is damaged at some event

3. Total Ionizing Dose (TID)

- ➢Dose(rads) = Fluence × LET × 1.60 × 10^{-8} , LET (Linear Energy Transfer) is in units of MeV/g/cm².
- ➢We use different dose rate (different beam energy and flux)
- ➢TID bump pertains to the irradiation history.
- ➢TID bump about IDDD(digital current) has appeared as expected, and reach a maximum of 80mA ~ 120mA before decreasing to 40mA at higher doses.





Discussion and Conclusion

- SEE irradiation test about ABCStars have been performed at the APEP in CSNS.
- The TMR does have impact on resistance to SEE, which indicate the ability of V1 chips to resist SEE effects has been enhanced as expected.