



**ANIMMA**

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# Benchmark study of TRIPOLI-4 through experiment and MCNP codes

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# Outlines

- **TRIPOLI-4**
- **MCNP5 and MCNPX**
- **Studies' overview**
  - Comparison of MCNPX and TRIPOLI-4 to MCNP5
  - Comparison of TRIPOLI-4 to MCNPX
  - Intercomparison of the codes with the experiment
- **Conclusion**

# Codes' overview

# MCNP5 and MCNPX

Monte Carlo N-Particle (eXtended)

- Fortran 90
- Forked in 2003 (future merge?)
- Simulates
  - all kinds of particles (MCNPX),
  - neutrons, photons, e<sup>-</sup> (MCNP5)
- World widely used (important users' community)
- I/O data not-so-user-friendly (directly)
- Current international release\*:
  - MCNPX 2.6.0 (April 2008)
  - MCNP5-RSICC-1.40 (2005)

# Monte Carlo codes 1/2

## TRIPOLI-4

(TRIdimensional POLYkinetic)

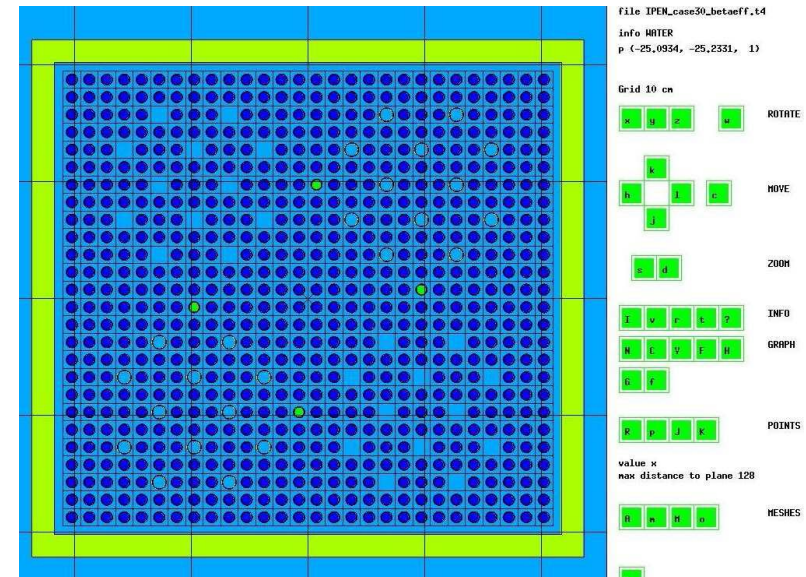
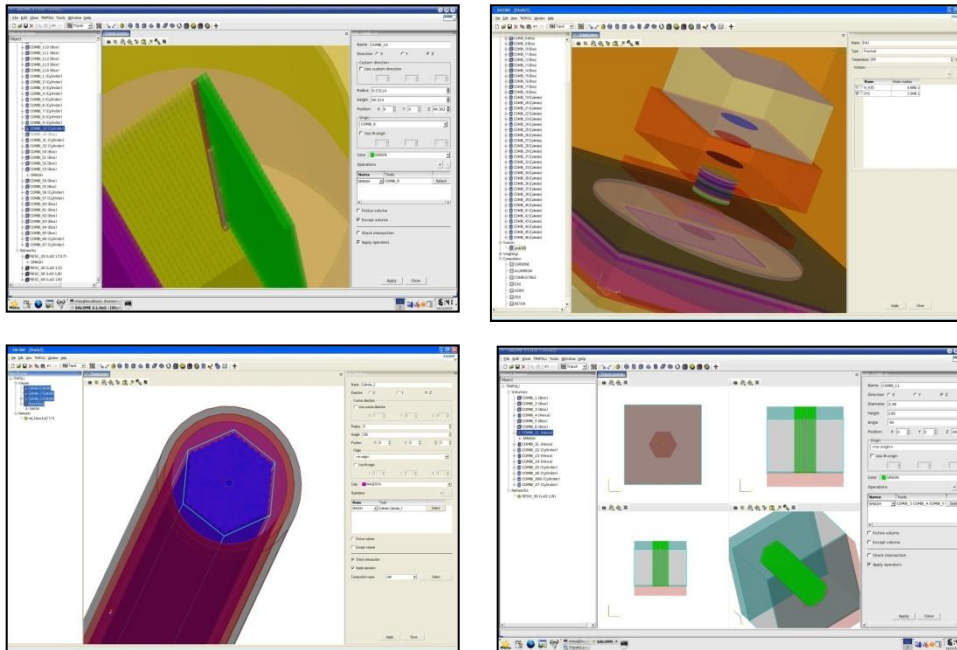
- C (++)
- Continuously developed since the 1970's
- Simulates
  - neutrons, photons, e<sup>-</sup> and e<sup>+</sup>
- French reference code for reactor criticality and radiation protection
- User-friendly
- N-1 versions released to OECD (v4.7 in November)

\* From MCNPs' homepages (<http://mcnpx.lanl.gov/> and <http://mcnp-green.lanl.gov/manual.html>)

# Monte Carlo codes 2/2

## TRIPOLI-4 : Man-machine interface in the SALOME framework (Open CASCADE Technology) <sup>(1)</sup>

## T4G view of the cross section of the IPEN reactor (Brazil) <sup>(2)</sup>



(1) J.-C. Trama, *TRIPOLI-4 overview*, 2011 International Congress on Advances in Nuclear Power Plants

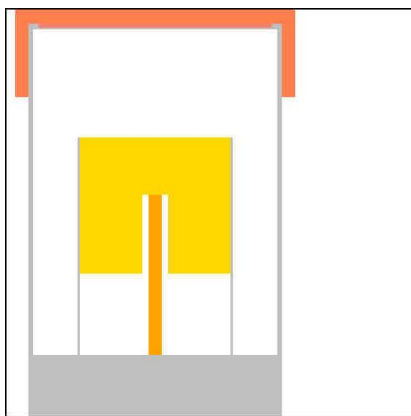
(2) F.X. Hugot and Y.K. Lee , *Calculation of the effective delayed neutron fraction by TRIPOLI-4 code for IPEN/MB-01 research reactor*, International Conf. on Mathematics and Computational Methods applied to Nucl. Sc. and Engineering.

# Studies' overview and results

# HPGe detectors geometries overview

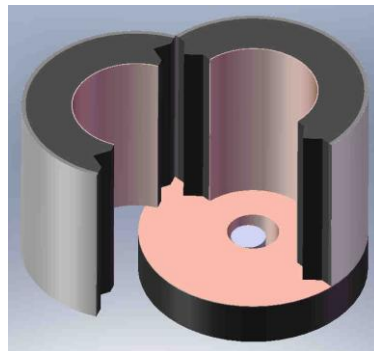
## 1<sup>st</sup> study:

TRIPOLI-4 and MCNPX vs MCNP5



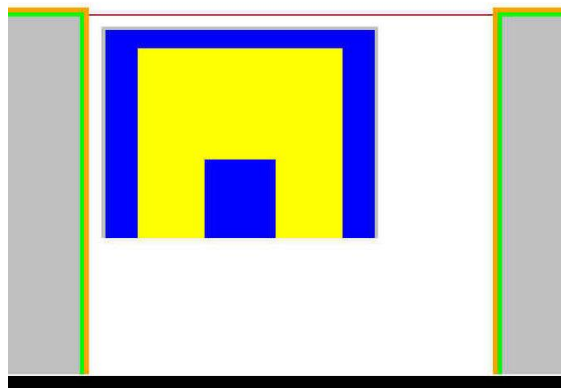
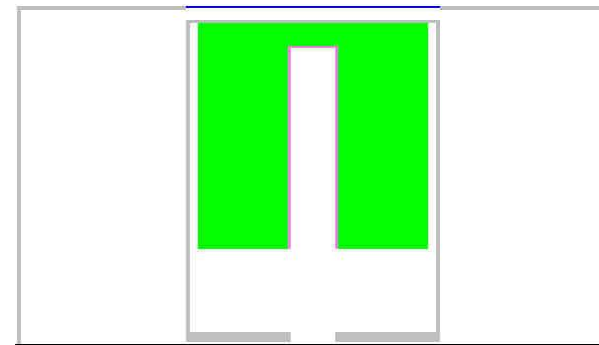
## 2<sup>nd</sup> study:

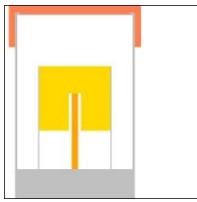
TRIPOLI-4 vs MCNPX



## 3<sup>rd</sup> study:

TRIPOLI-4 and MCNPX vs experiment





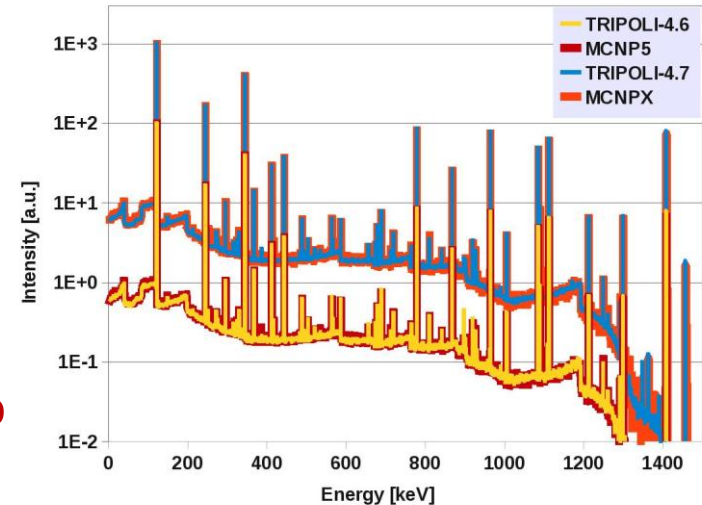
## First study: MC codes vs MCNP5

- **Qualitatively:**
  - Identical Compton spectra
- **Quantitatively:**
  - Relative error ( $\mathcal{E}$ ) on main photopeaks of TRIPOLI-4 **<12%**

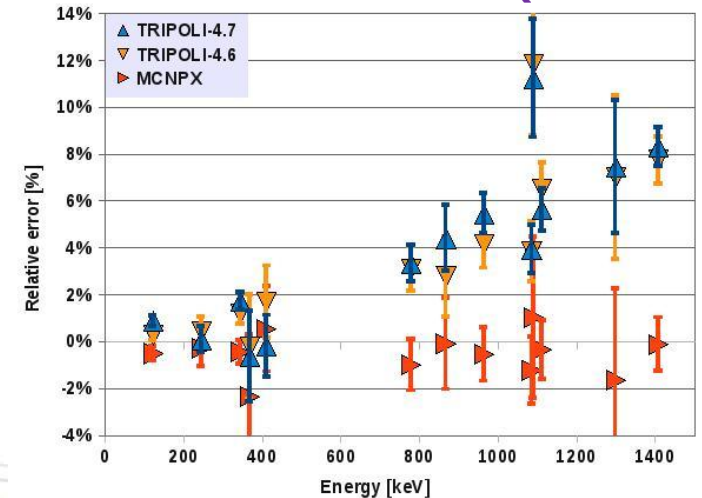
$$\mathcal{E}_i = \frac{N_i - N_{\text{Ref}_i}}{N_{\text{Ref}_i}}$$

- **Problem:**  
 geometry rather simple  
 → need for a test using a more complex geometry

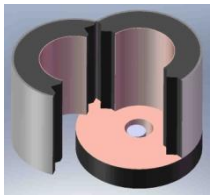
MC codes spectra



MC codes relative error (to MCNP5)







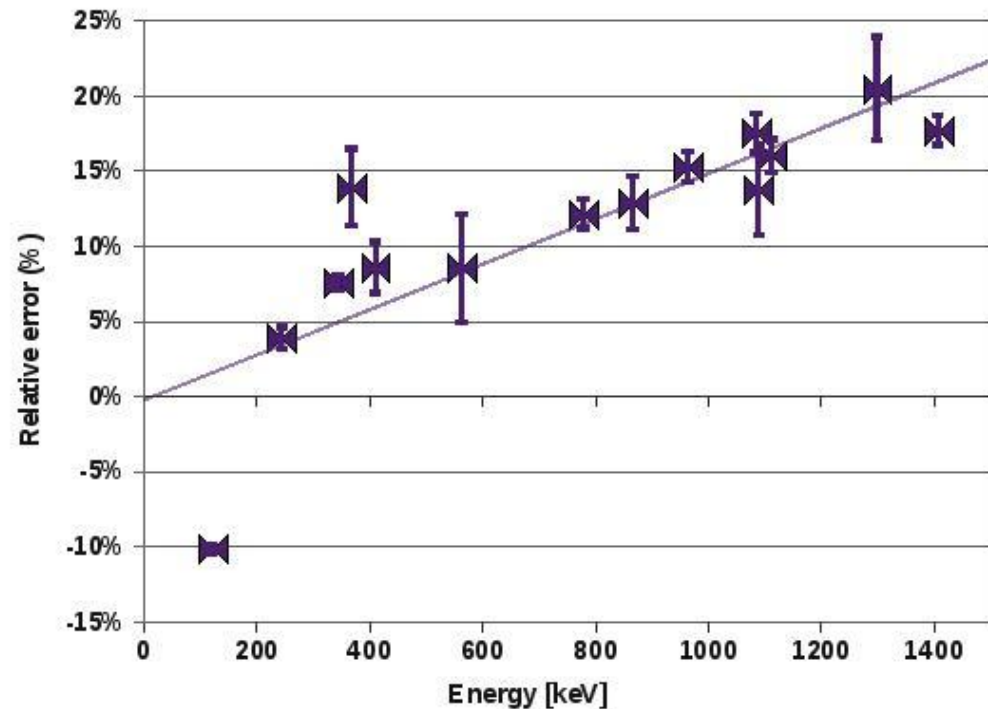
## Second study: TRIPOLI-4 vs MCNPX

### Increase of the relative error:

- 3.8 % @ 244 keV
- 20.5 % @ 1299 keV

This increase, inconsistent with previous and next studies, is currently investigated.

TRIPOLI-4 main photopeaks relative error



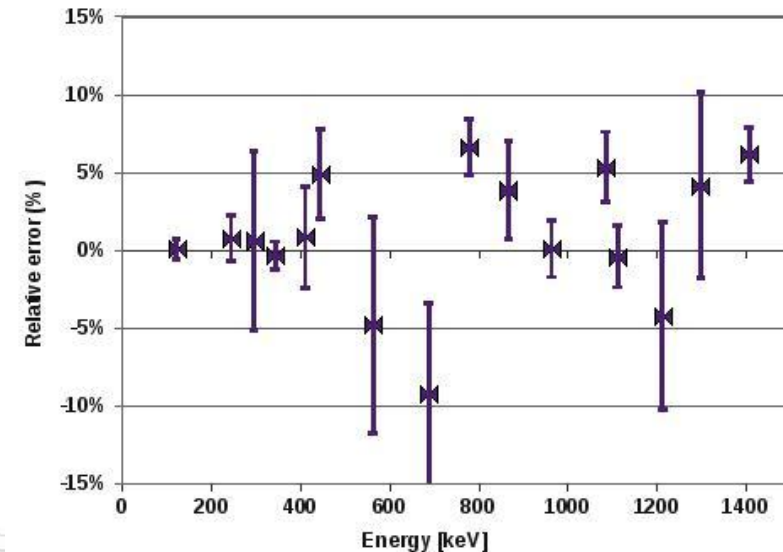
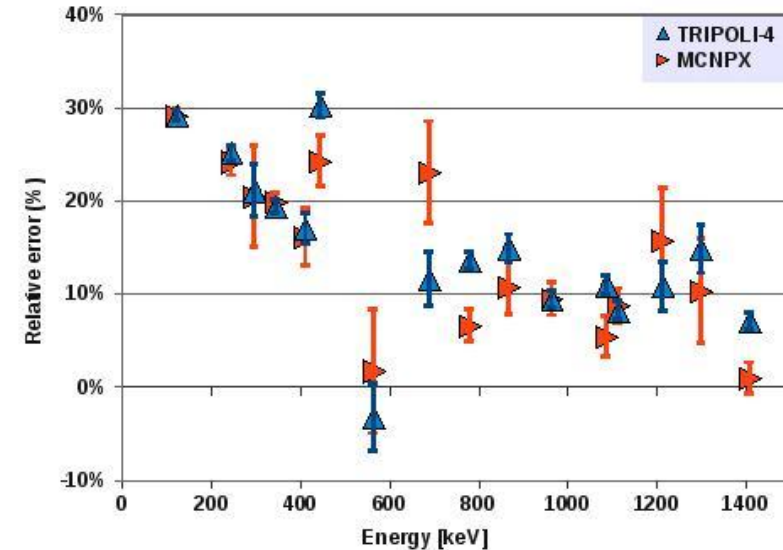
## Third study: intercomparison with experiment

### • Codes vs experiment:

- 29% @ 121 keV
- 1% @ 1408 keV
- Mean  $\approx 12\%$
- Large discrepancies compared to calibration results, at:
  - 444 keV (both codes)
  - 564 keV (both codes)
  - 689 keV (MCNPX)

### • TRIPOLI-4 vs MCNPX

- $|\epsilon_{\max}| < 10\%$   
(mean uncertainty = 3.43%)



## To conclude 1/2

- **1<sup>st</sup> study**
  - Similar results of TRIPOLI-4 relatively to both MCNP5 and MCNPX 2.6d:
    - $|\epsilon_{\max}| < 12\%$  (mean uncertainty=1.43%)
  - Problem: simple geometry
- **2<sup>nd</sup> study**
  - Geometry to test photon scattering
  - Problem: increasing relative error of TRIPOLI-4 (ongoing investigation)
- **3<sup>rd</sup> study**
  - Comparison with the experiment:
    - relative error of TRIPOLI-4 ranging from 29% (121 keV) to 0.90% (1408 keV)
  - TRIPOLI-4 vs MCNPX:
    - $|\epsilon_{\max}| < 10\%$  (mean uncertainty=3.43%)

**→ TRIPOLI-4 can be considered a good alternative to MCNPs' F8 tally**

## Conclusion 2/2

- **Cost of measurements is higher and higher**  
⇒ experimental → simulation
- **Computational power rises and is cheaper**  
  
→ **Monte-Carlo simulation codes are appropriate, from the design stage**  
  
→ **for nuclear industry, it is essential to be able to rely on independent MC codes to cross-validate design calculations and optimize them**
- **For accurate results when simulating gamma spectrometry, precise knowledge of the geometry and materials is mandatory**

# Thank you for your attention.

## TRIPOLI-4

## MCNP5 and MCNPX

```

/* UNITS
      LENGTH 1.0 MM
      ENERGY 1.0 MEV

END_UNITS */
TYPE 1 BOX 40. 30. 15
VOLU 1 COMBI 20. 15. 7.5 FINV
SURF 21 CYLZ 1.0 2.0 5.0
SURF 22 PLANZ 0.0
SURF 23 PLANZ 5.0
VOLU 2 EQUA PLUS 1 22 MINUS 2 22 23 ECRASE 1 1 FINV
COMPOSITION 1
      DENSITY 300 AIR 1.2E-3 3 // AIR
      C-NAT 0.0131
      N-NAT 0.7551
      O-NAT 0.2318

END_COMPOSITION
GEOMCOMP
      AIR 1 1
      PLASTIQUE 1 2

END_GEOMCOMP
LIST_SOURCES 1 SOURCE PHOTON PUNCTUAL 0. 0. 10.
      ANGULAR_DISTRIBUTION ISOTROPIC
      ENERGETIC_DISTRIBUTION SPECTRE RAY_SPECTRUM 4
      0.12178      4.7583E+03
                  0.12569      3.1822E+00
                  0.14801      5.8620E+00
                  0.19260      1.1388E+00
      TIME_DISTRIBUTION DIRAC 0 // TIME INDEPENDENT

END_SOURCES
END_LIST_SOURCES
LIST_DECOUPAGE 1 ENER_BIN 2000 0.001 0.002...2.0 END_LIST_DECOUPAGE
REPNSES 1 DEPOSITED_SPECTRUM PHOTON FIN_REPNSES
SCORE 1 1 DEPOSITED_SPECTRUM DECOUPAGE ENER_BIN VOLU LIST 1 7 FIN_SCORE
SIMULATION BATCH 10 SIZE 100000
      PARTICLE 1 PHOTON

END_SIMULATION
    
```

```

c CELLS CARDS
1 0      1      IMP:P=0 IMP:E=0 $
Vacuum
2 1      -0.0012  -1 #3      IMP:P=1 IMP:E=1 $ AIR
3 2      -0.93    +3 -2 -4
c SURFACE CARDS
1 BOX -20. -15. 0. 40 0 0 0 30 0 0 0 15
2 C/Z 1.0 2.0 5.0
3 PZ 0.0
4 PZ 5.0
c MATERIAL
M1      006012  -0.000124  $ AIR
      007014  -0.755268
      008016  -0.231781
      018040  -0.012827
c PHYSIC AND SOURCE
MODE P E
PHYS:P 2
NPS 1000000
SDEF POS=0. 26.45 6.805 PAR=2 ERG=D3
SI3 L 0.12178 0.12569 0.14801 0.19260
SP3 4.7462E-03 3.1742E-06 5.8472E-06 1.1359E-06
F8:P,E 6
E8:P,E 0 1999i 2.000
    
```

## Third study: intercomparison with experiment

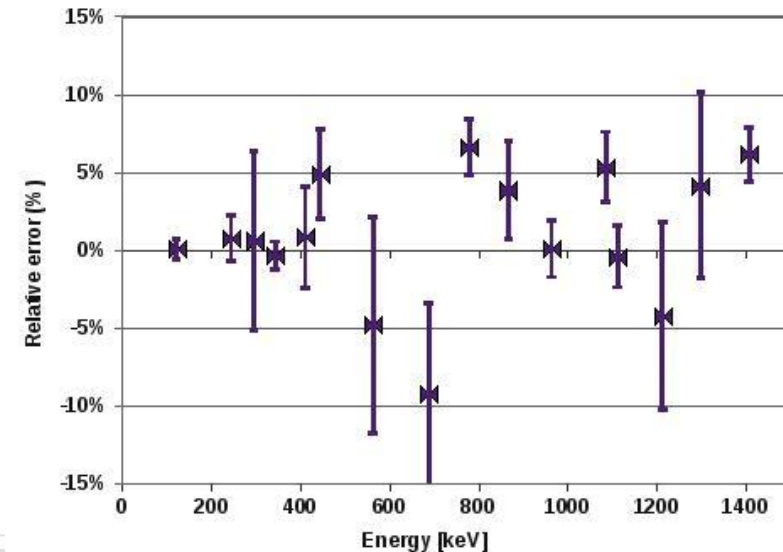
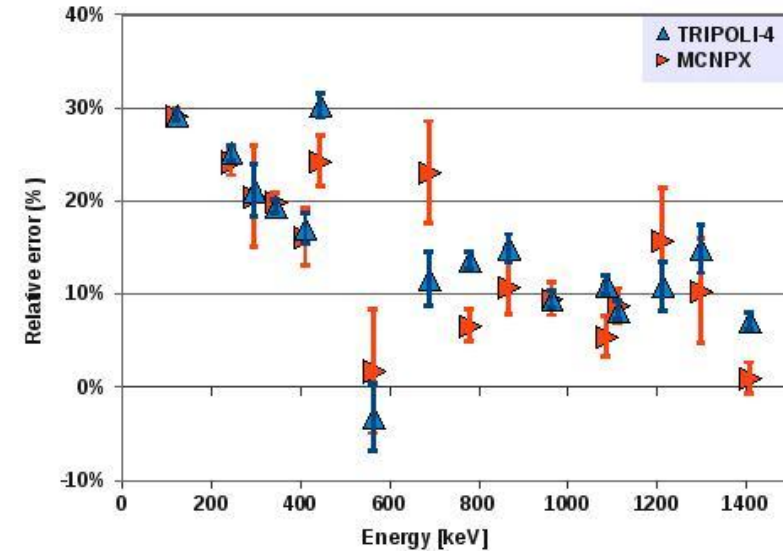
$$I_i = \frac{N_i}{\eta_{\text{JANIS}}}$$

### • Codes vs experiment:

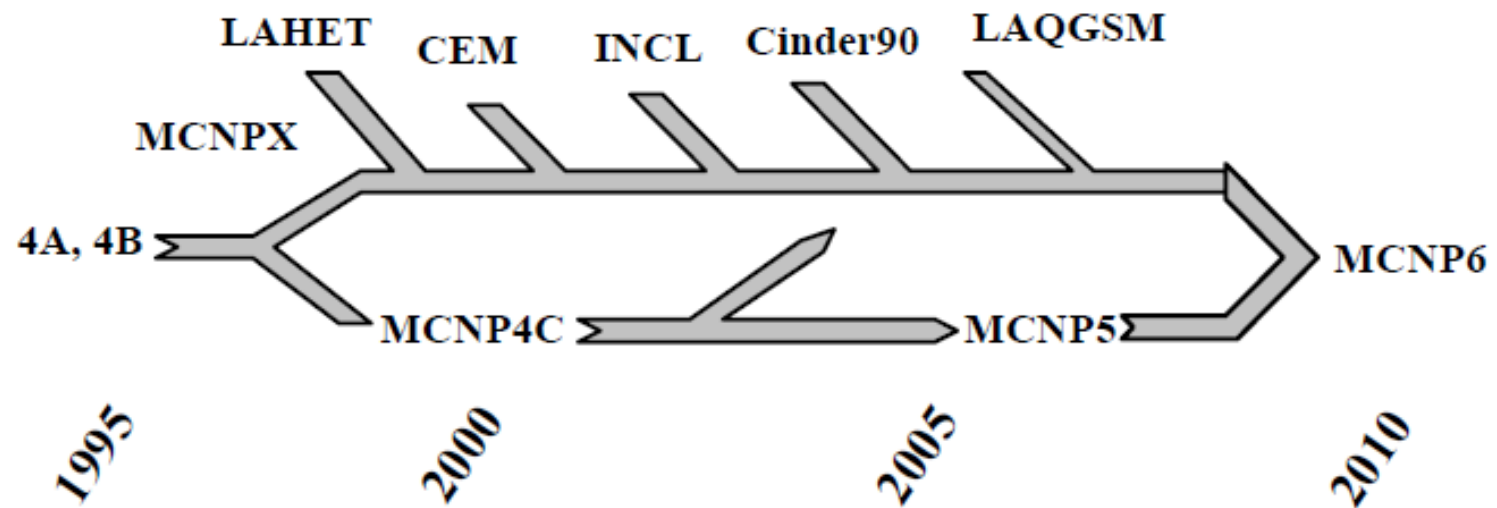
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- Large discrepancies compared to calibration results, at:
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### • TRIPOLI-4 vs MCNPX

- $|\epsilon_{\text{max}}| < 10\%$   
(mean uncertainty = 3.43%)



# MCNPX/5 timeline



L. Waters and R. Schwarz, *MCNP/MCNPX Intermediate Workshop*, NEA, Paris, France February 28 – March 4, 2011