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DOPED CH_x CAPSULE FABRICATION FOR CRYOGENIC LMJ TARGETS

20th Target Fabrication Meeting

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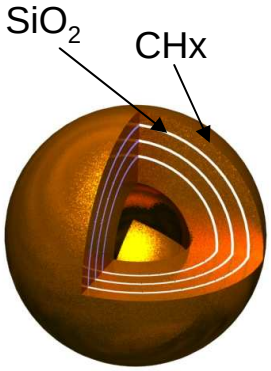
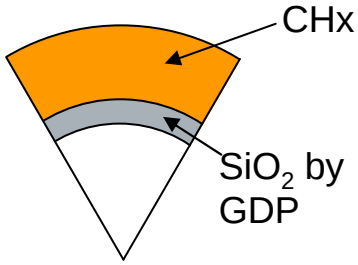
LMJ nominal ablator : doped CH_x

Fusion preparation

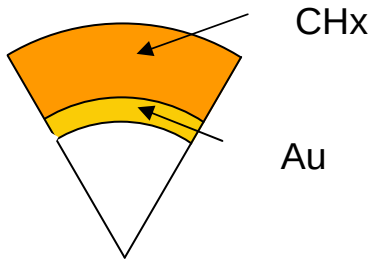
Non cryogenic target :

Gas-retentive shells





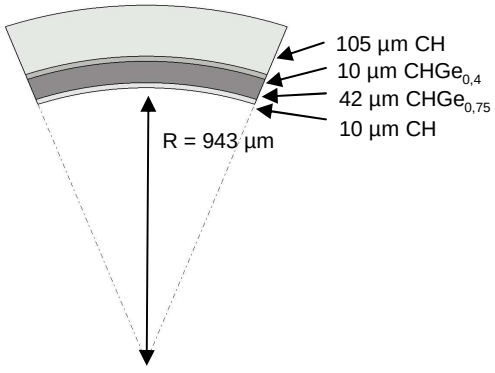
Cf. S. LeTacon's poster



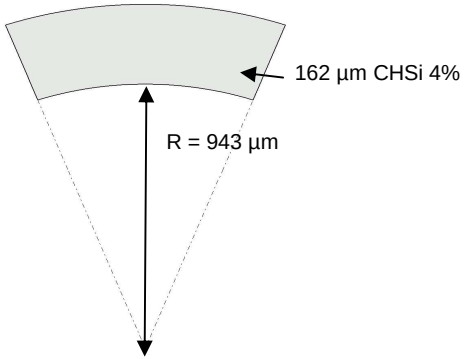
Cf. E. Brun's poster

Fusion

Cryogenic target : development on new nominal A943 design



Graded Ge doped capsule



Si doped capsule

Graded germanium doped GDP capsule

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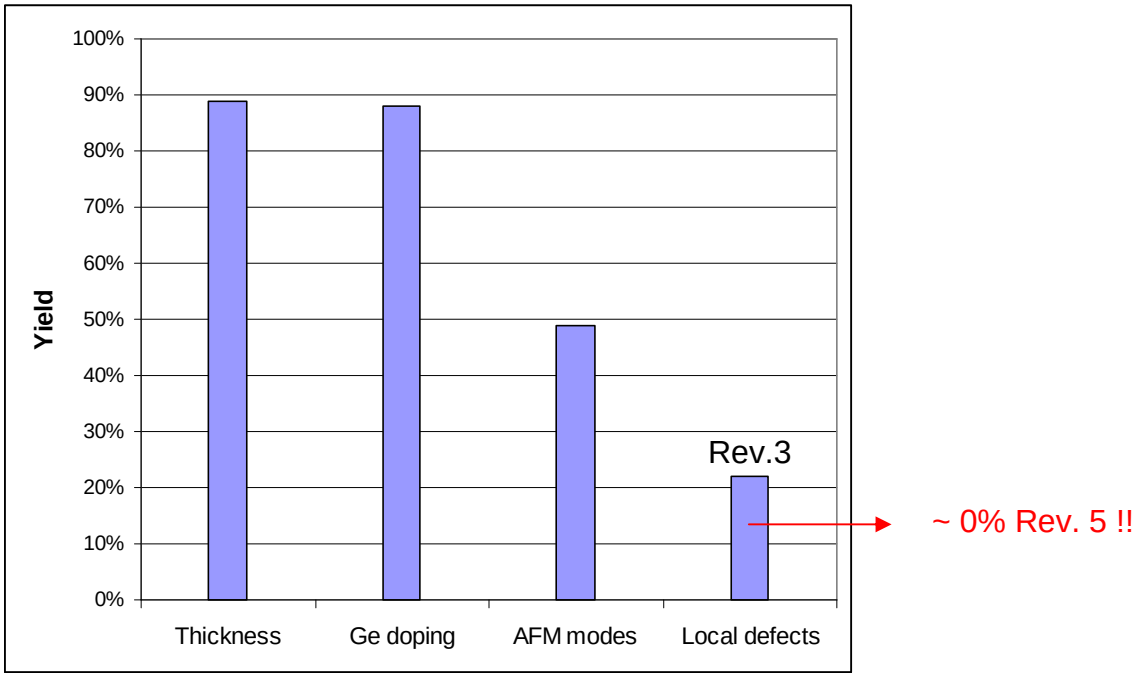
Outline :

Developments on A943 design allow to improve average batch yield



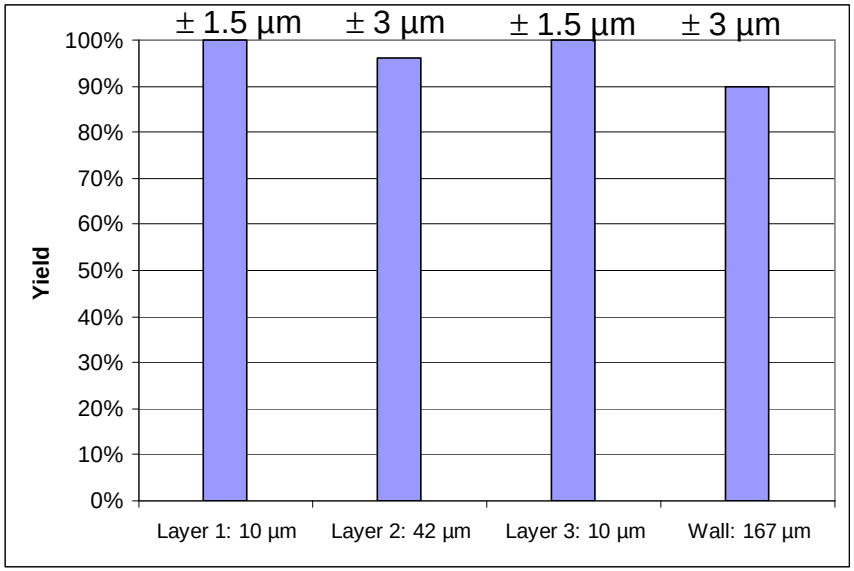
- Main improvement in thickness and Ge doping control
- But in spite of specific effort on GDP process, local defects on surface remain an issue for a consistent average yield production

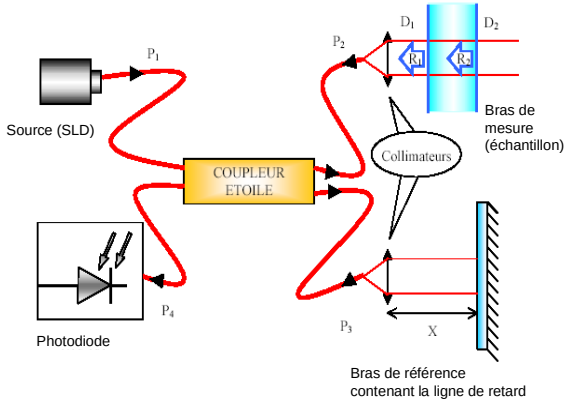
⇒ Development of a polishing process is in progress

Graded germanium doped GDP capsule

Thickness Control

• Each layer thickness is controlled by interrupting coating run (OCT measurement and thickness adjustment to fit spec.)





OCT principle

• No more major improvement is expected, excepted an in-situ measurement device to minimize environment exposure time

Graded germanium doped GDP capsule

Ge Doping Control

Closed-loop process:

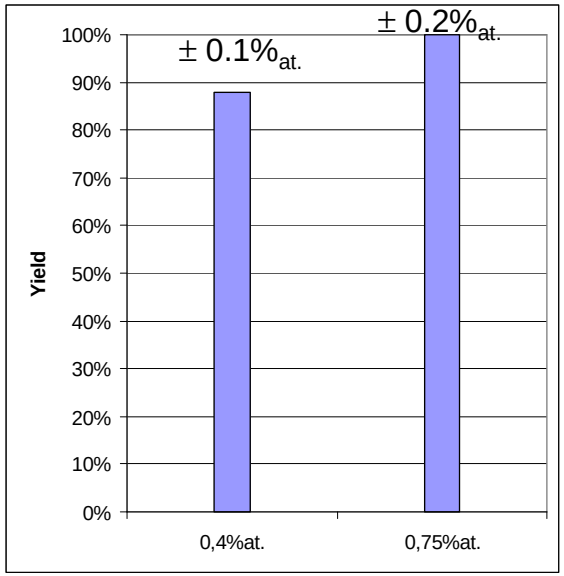
- To compensate for mass flow controller deviation, X-ray fluorescence measurement on witness sample is realized before each doped layer coating run

⇒ improvement of repeatability

- RBS measurement for feedback

CEA / GA measurement comparison in 2010 indicate a systematic error on our RBS experimental data analysis : energy loss by probing ions due to H was not properly simulate

⇒ error solved (new simulation software)



Graded germanium doped GDP capsule

Surface roughness

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AFM modes (local defects extracted) :

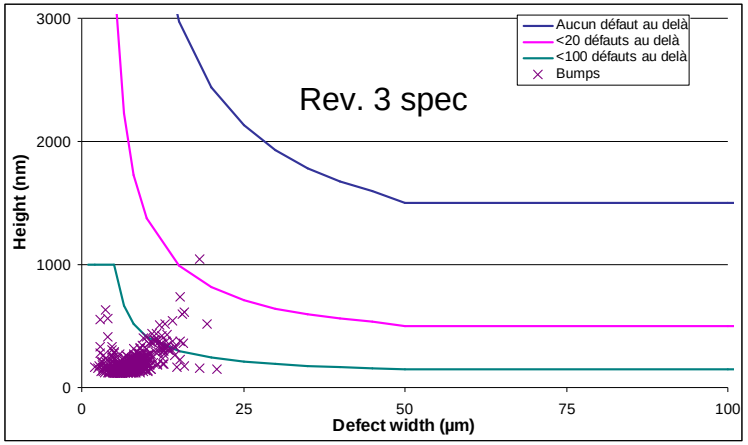
RMS(2) < 70 nm

RMS(2-10) < 80 nm

RMS(>10) < 20 nm

} ~ 50% yield

DHM local defects : ~ 20% yield (Rev.3)



• Most capsules have a mix-mass > 100 ng ⇒ a mix-mass < 10 ng (Rev. 5) specification leads to almost null yield

• No GDP process optimization is expected to consistently meet this specification

⇒ Polishing process has been developed

Graded germanium doped GDP capsule

Polishing process: results

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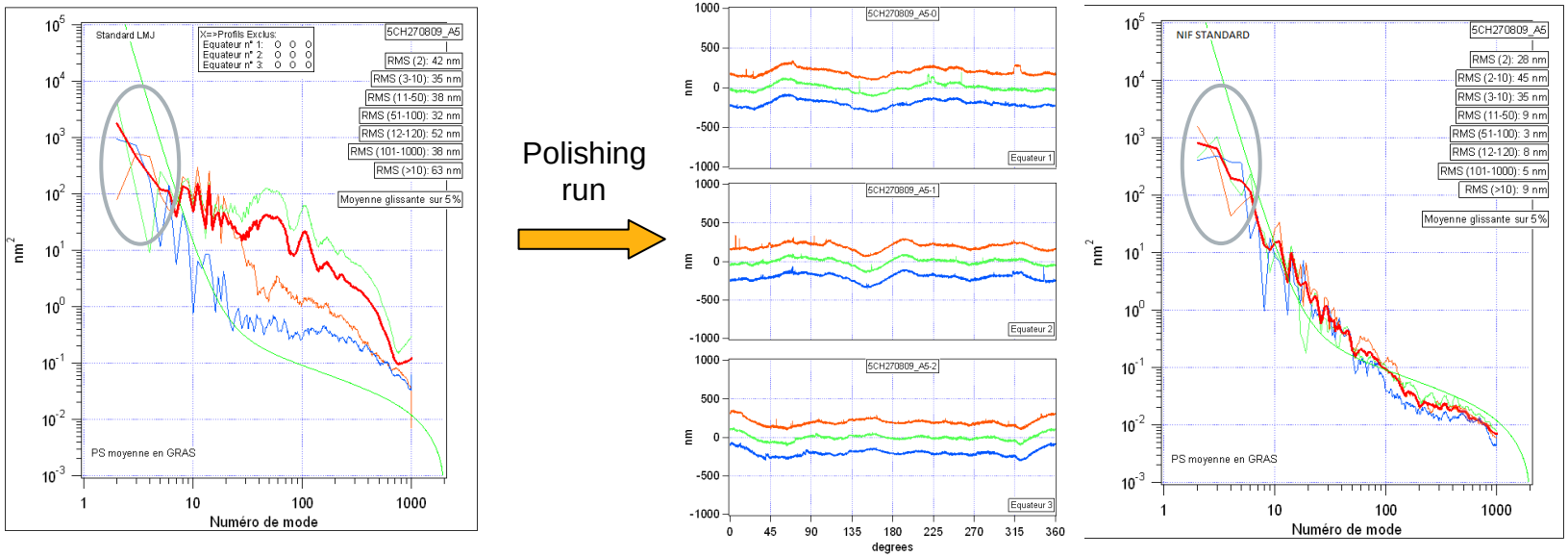
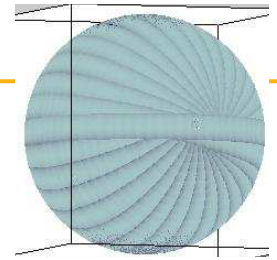
AFM Spheremapper analysis (all defects included):



- Low modes (2-10) are not affected by polishing process due to optimized parameters
- High frequency roughness is drastically improved by removal of local defects

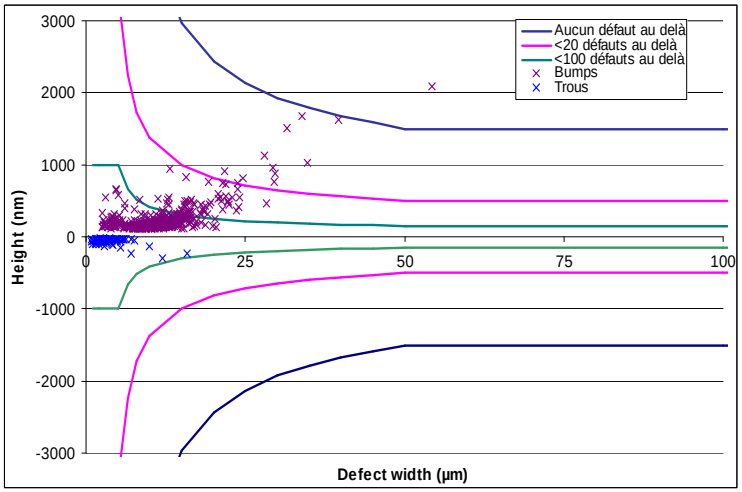
Graded germanium doped GDP capsule



Polishing process: results

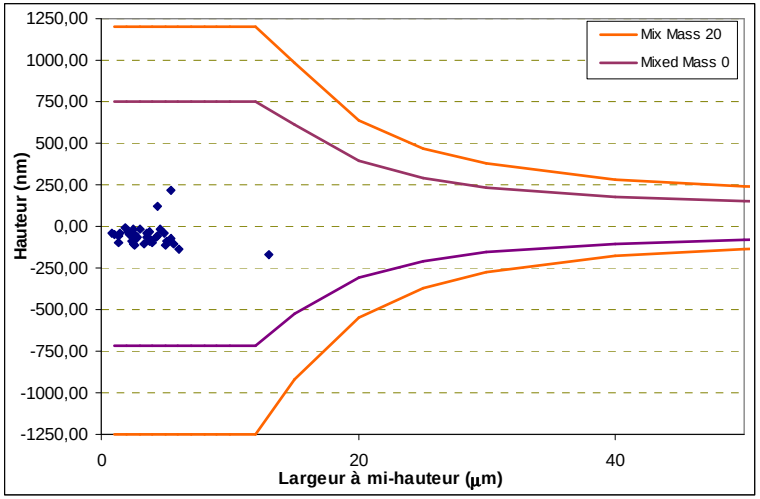
DHM isolated defects:

Rev. 3



Polishing run

Rev. 5

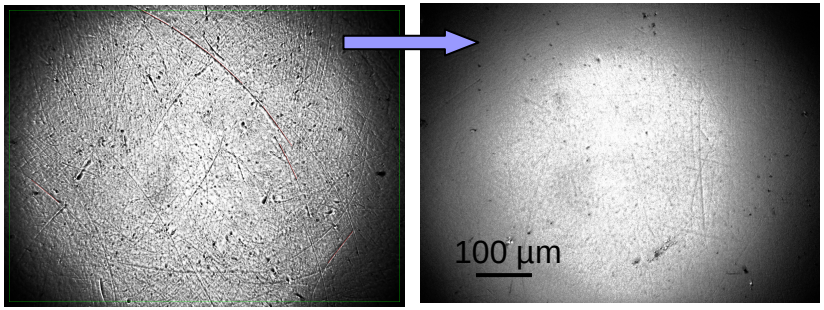


- Removal of isolated bumps is demonstrated to meet the mix mass specification Rev.5
- Still have to be solved:

  - polishing process can create isolated features (i.e. scratches, ripping), mainly dependant of polishing tool material, abrasive particles …

  - scratches size already reduced (<50nm deep) but can be more optimized

Scratches optimization



Silicon doped GDP capsule

Deposition process:

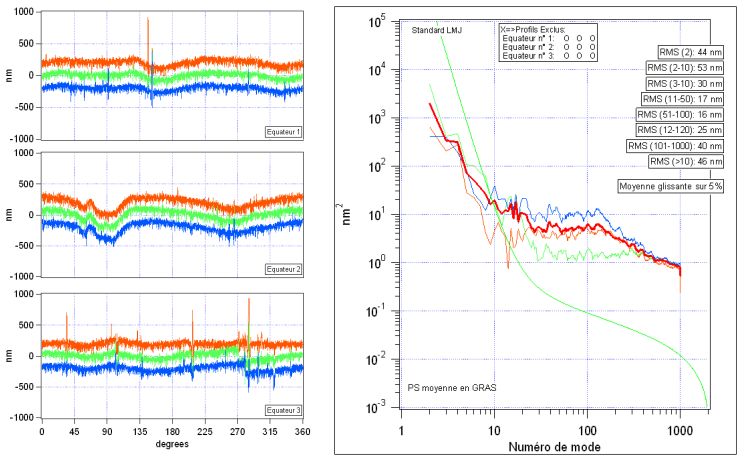
- Tetramethylgermane ($Ge(CH_3)_4$) is replaced with tetramethylsilane ($Si(CH_3)_4$)
- Material structure (CHx) was previously optimized
  - for low doping rate (<1%$_{at}$), no structural modification is observed
  - for doping rate ~ 4%$_{at}$, TMS flow is significant

⇒ increase of deposition rate

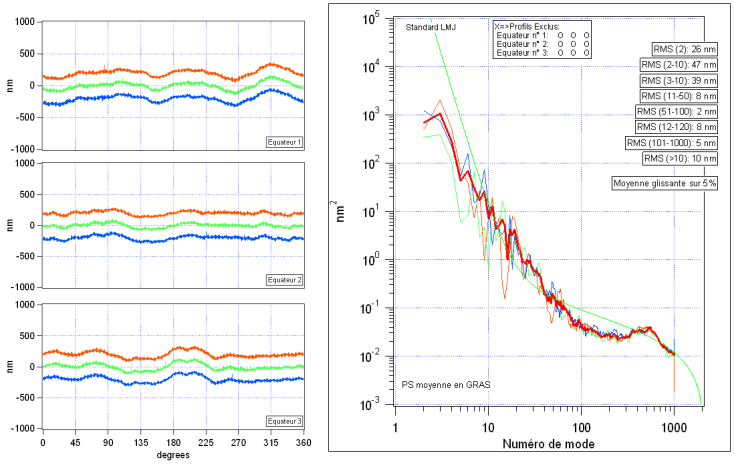
⇒ increase of surface roughness

⇒ increase of stress

Example: CHSi 3.3%



Polishing run



CHSi surface roughness decreased by polishing outer surface

Silicon doped GDP capsule

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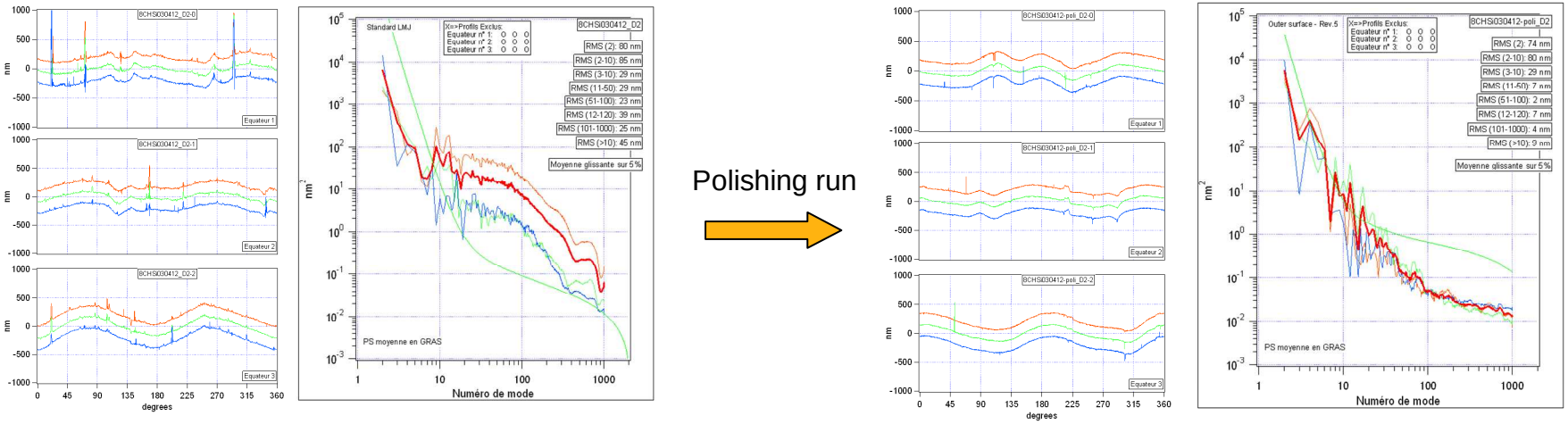
- But for Si doping rate > 3.5%, a systematical capsule cracking is observed due to internal stress (during deposition run or delayed cracking by ambient exposure)
- Producing CHSi capsule with 4% doping rate require specific deposition parameters

  ⇒ total gas flow and precursor flow (T2B, TMS) ratio in the mix have to be decreased

Example: CHSi 3.95%



With these deposition conditions, surface roughness is quite similar to non-doped ablator and isolated surface defects can be eliminated by polishing

SUMMARY

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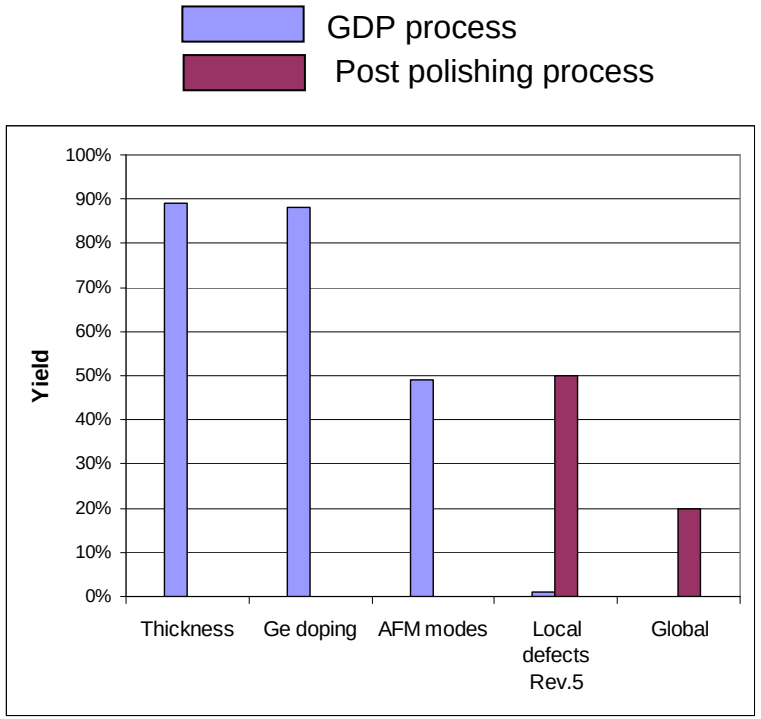
Graded Ge doped CHx capsule:

- Improvement of average yield on new A943 design capsule mainly due to thickness and doping control
- Isolated defects remain the major issue of GDP process and require polishing
- capsules with mix mass < 10 ng produced
- polishing process has to be developed to minimize scratch formation



Si doped CHx capsule:

- Versatility of GDP process allows to modify the doping element
- Depending of Si doping rate, significant internal stress can appear
- First CHSi 4% capsules has been produced