



Integration of the human factors in the ALARA program for steam generator cleaning operations on EDF fleet units

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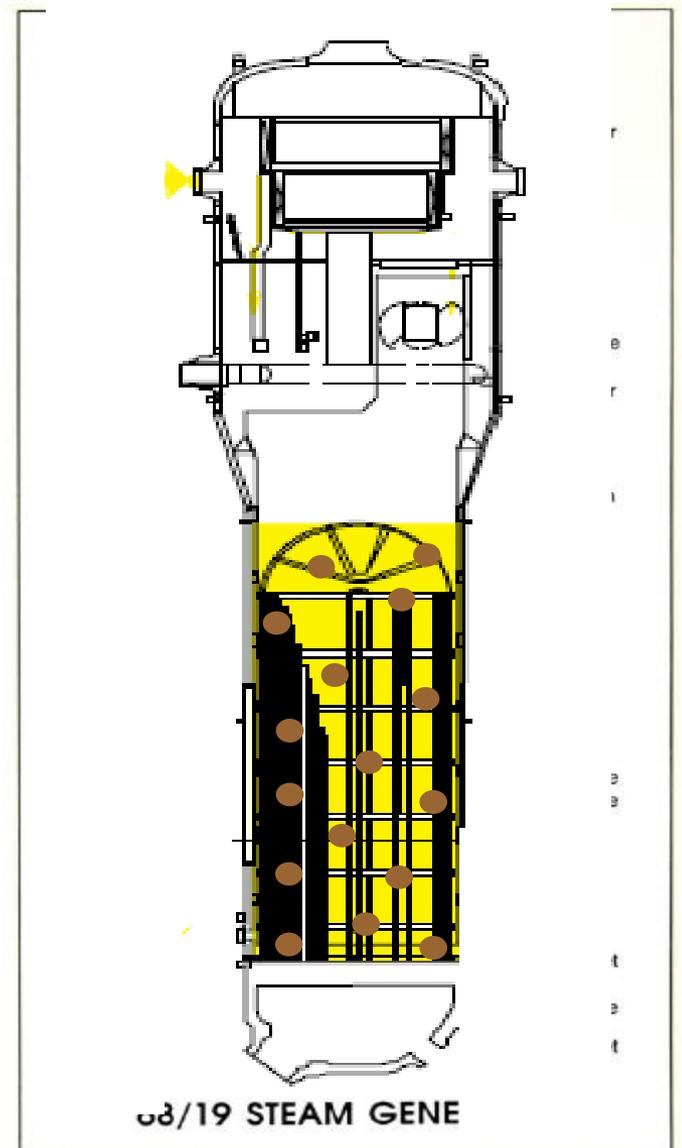


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NPGV context



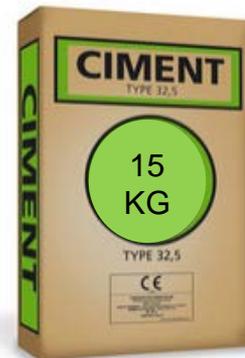
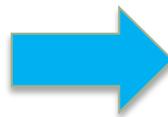
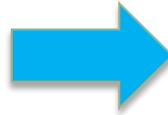
NPGV constraints

- Reactor building
- Cramped areas
- No hoisting means
- Dose rate ~ 0,35 mSv/h (35 mrem/h)
- Total collective effective dose > 100 man.mSv (10 man.rem)



What are Human Factors ?

Human Factors : Adapt the work to the workers



ALARA approach ●○○○



Basic principle :

“The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors”

(Publication 103 – The 2007 recommendations of the ICRP)

ALARA approach ○●○○

Methodology :

1. Radiation source identification

→ 3D PANTHERE modeling

2. Initial collective effective dose

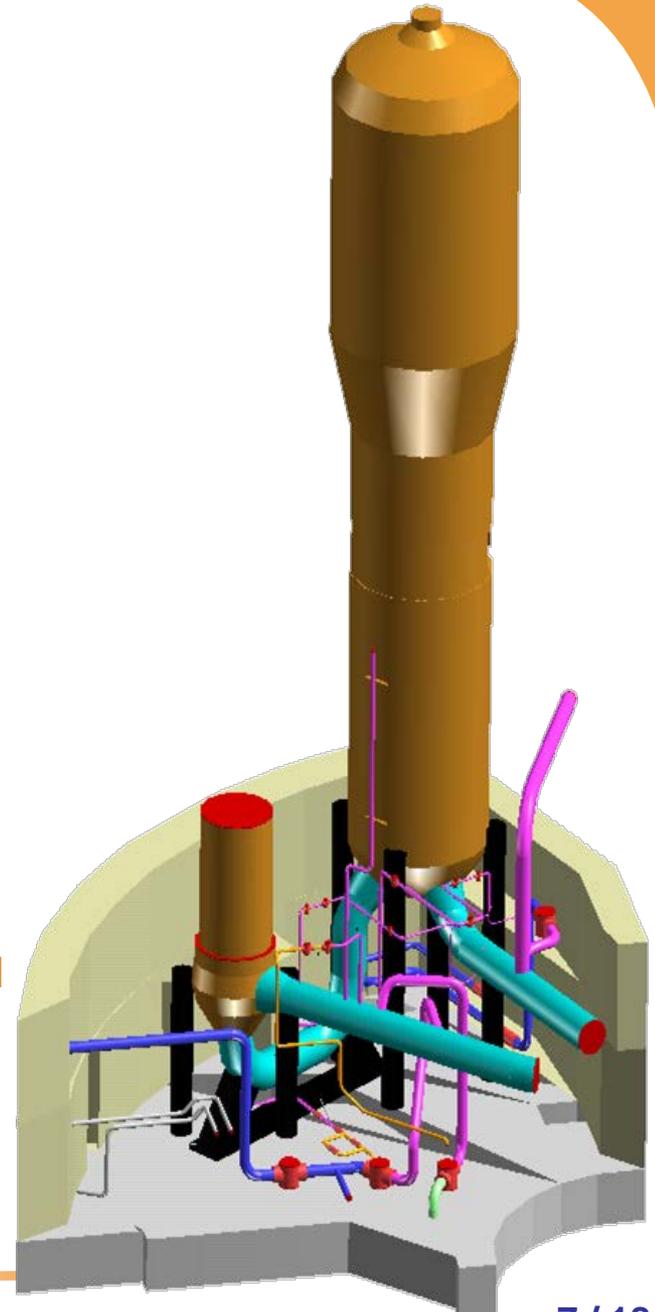
→ Dose-rate by workstation calculation

$$S_{(\text{man.mSv})} = \sum DR_{(\text{mSv/h})} \cdot T_{(\text{h})} \cdot N_{(\text{man})}$$

3. Radiation protection optimization

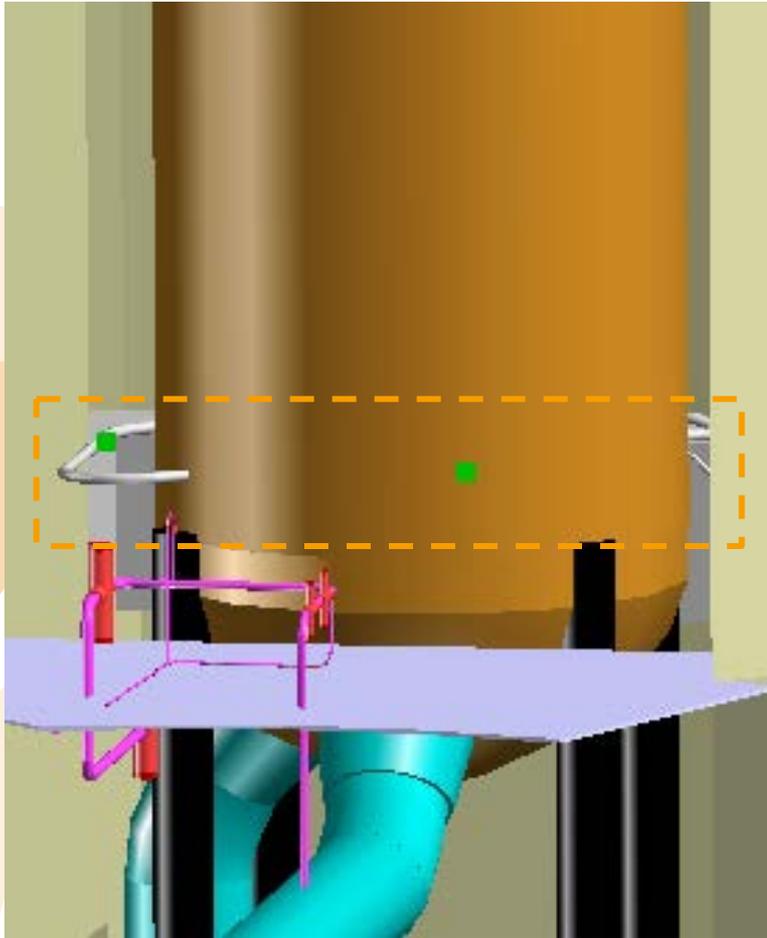
→ Radiation shielding identification and performance evaluation (dosimetric gain, safety and ergonomic approach,...)

→ Final collective effective dose



ALARA approach ○○○○

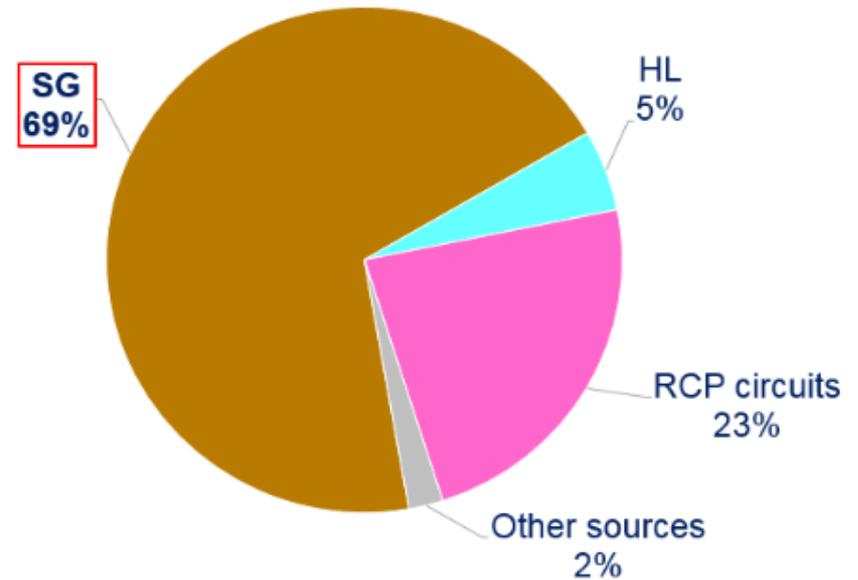
Radiation sources for a NPGV :



Analysis :

70 % of initial collective effective dose is integrated in HH/EH bunker

69 % of dose-rate is generated by SG

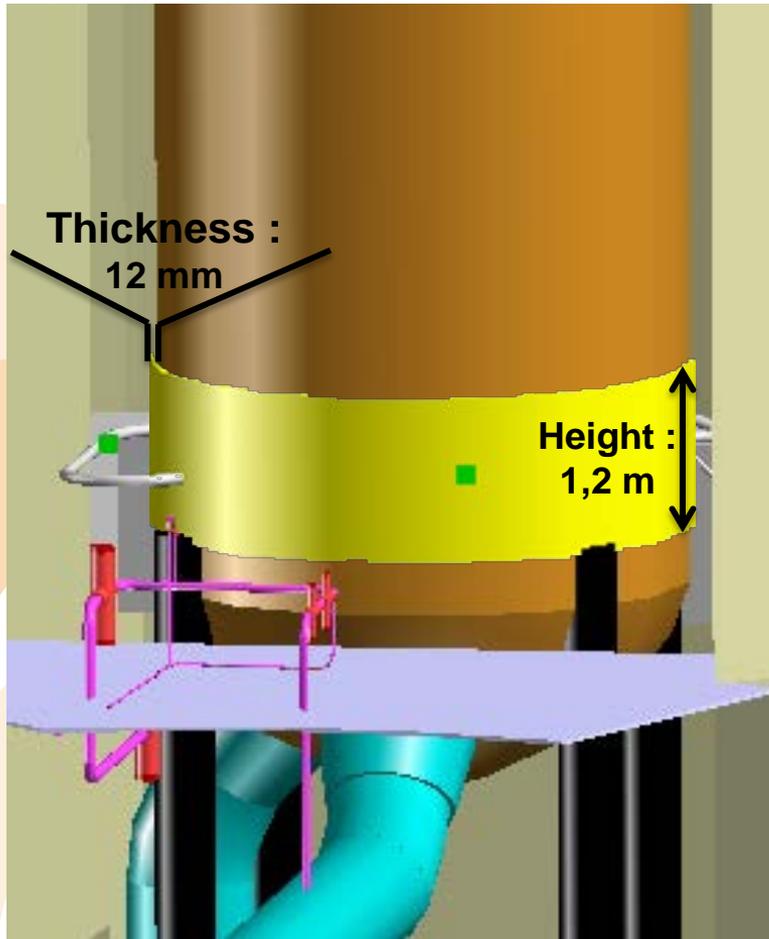


For a 1300 MWe reactor (4 loops)

→ DECREASE THE SG's CONTRIBUTION

ALARA approach ○○○●

Radiation protection optimization for a NPGV :



Solution :

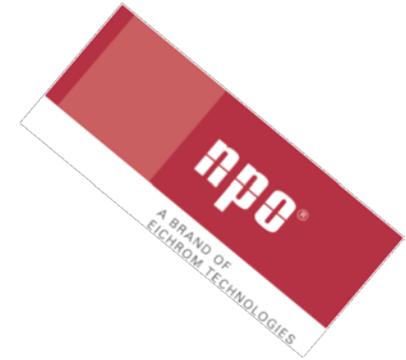
- Install radiation shielding around every SG
(2 tons / SG)

Efficiency :

- DR's reduction : 0,41

→ **COMPLEX AND HARD IMPLEMENTATION**

Shielding package description



NPO principle :

“Better to have a user friendly, light shield than a cumbersome, heavy one ... even if attenuation is reduced”

(NPO – 2012)

Shielding package description ○●○○○



The dimension of the parts are designed for fitting as much as possible :

- Weight legislation (< 25kg) **norme**
- Attenuation calculated by Panthere
- The ergonomics of the installation
 - The number of parts
 - The complexity of the puzzle

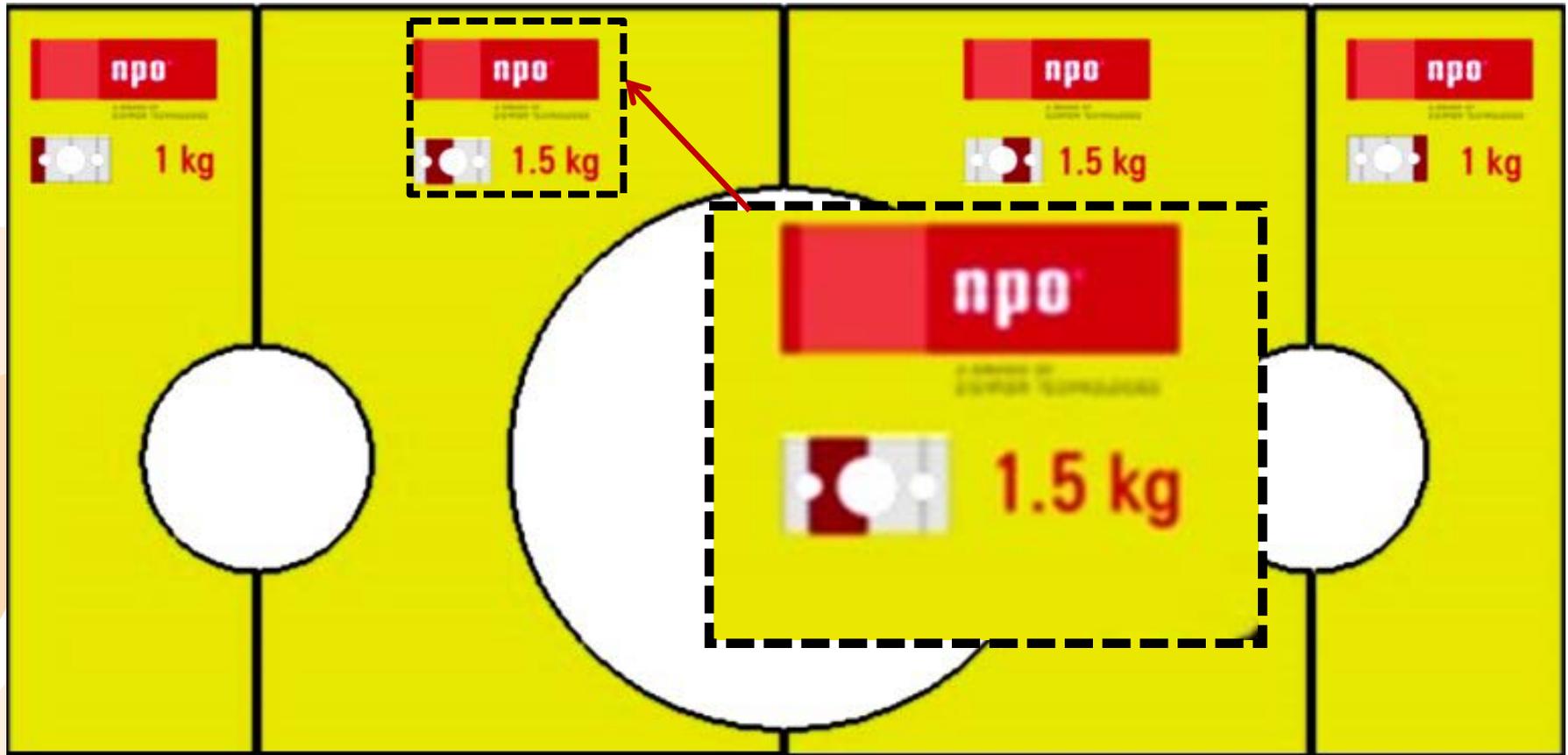
Shielding package description ○○○●○○○

**With the integrated magnets we mix 2 different functions :
Shielding & support**

For having a plug & play shielding package !



Shielding package description ○○○●○



For reducing human mistake during the installation mistake-proofing are now added

Shielding package description ○○○○●



ST ALBAN



PENLY

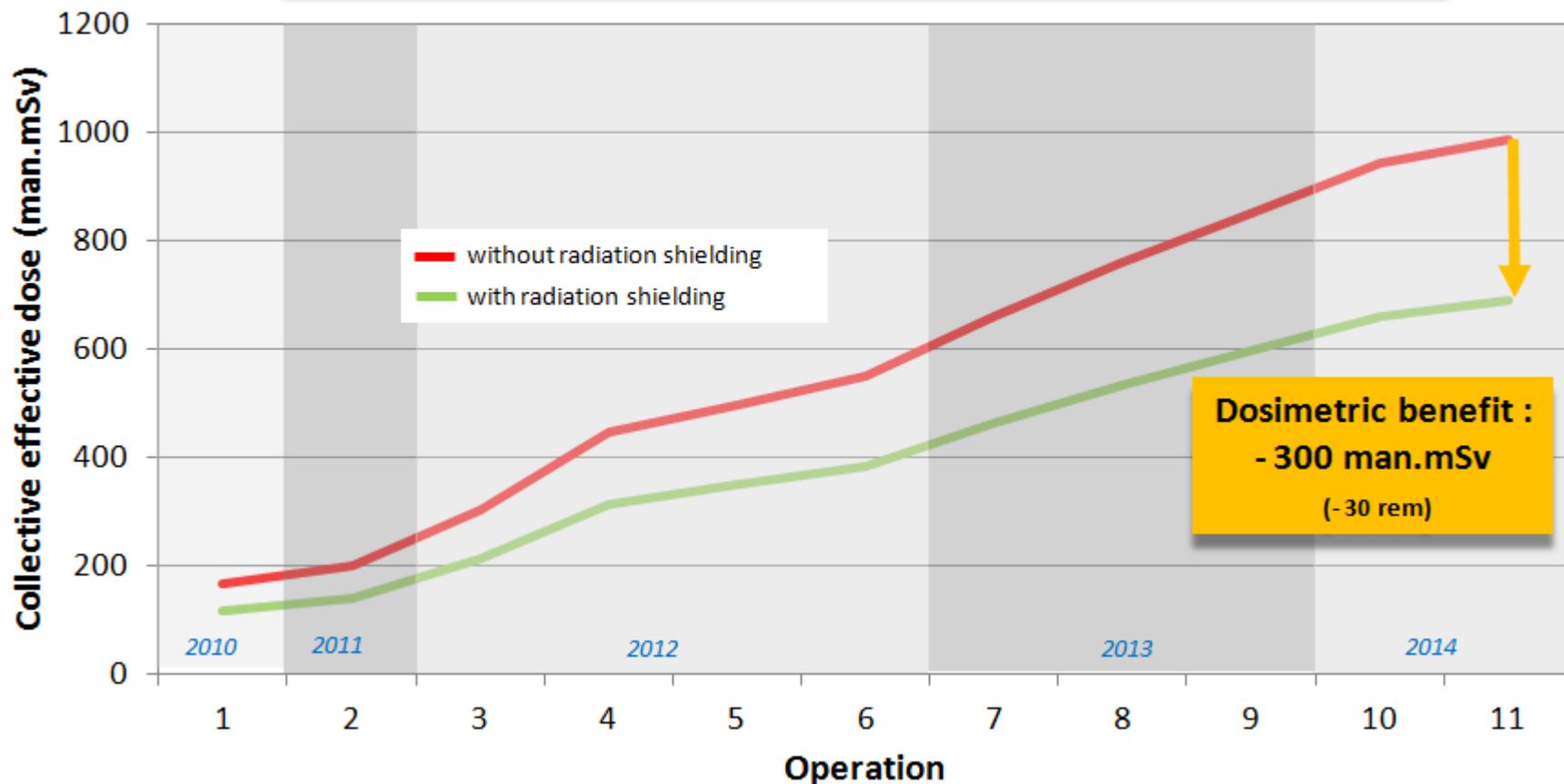
Results ●○

Type of shielding package <i>(For 4 Steam Generators)</i>	Classic	Magnetic
Number	80	80
Type	900 x 500 6 mm 25 kg	400 x 400 12 mm 25 kg
Total weight	2 tons	
Total collective dosimetry		
man.mSv	~ 2,8	~ 1,5
(man.mrem)	(~ 280)	(~ 150)



Results ○●

Collective effective dose accumulation of 11 NPGV (2010-2014)



Dosimetric benefit :
- 300 man.mSv
(-30 rem)

Feedback and conclusion

The 3 points to remember :

- **Easy-to-install shielding**
- **Positive feedback from the workers**
- **NPGV collective effective dose well mastered over time**

Taking into account the ALARA approach and the Human Factors together is a success

Thank you for your attention

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