Comparing GSI and HIT results

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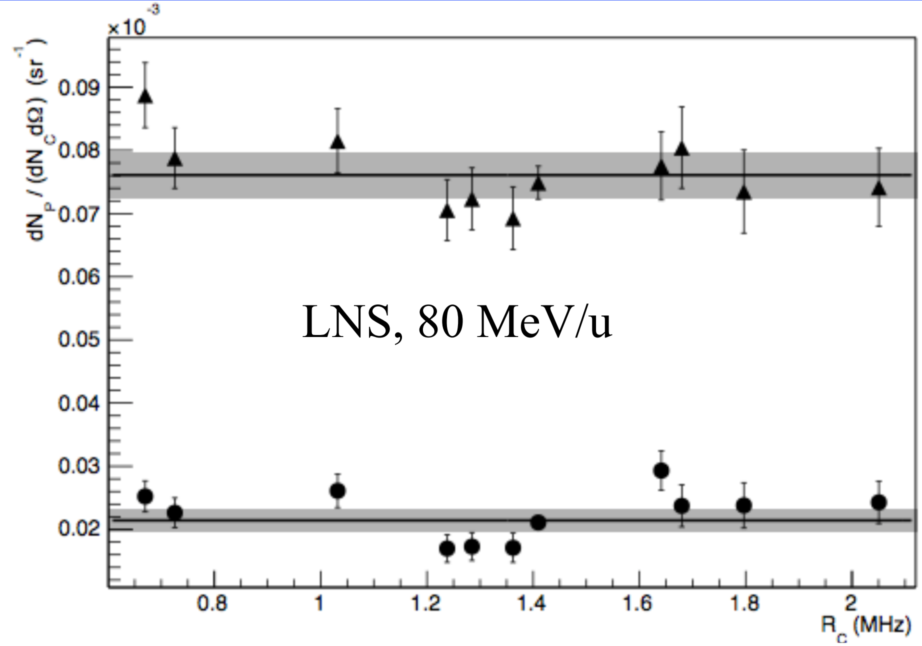
Ensure that we are "consistent"

- Both charged and neutral analyses have been redone with ~ the same setup. A Xchk of the numbers BEFORE publication is crucial.
- For the GSI neutral analysis **we are still in time to catch any mistake:** paper still in preparation.
- The considered inputs are
  - Charged ana:
    - LNS paper (errata)
    - GSI paper
  - Neutrals ana:
    - LNS paper (errata)
    - GSI: preliminary BaF and Lyso papers
    - Ganil latest paper on PG does not provide any flux number…

Flux of charged particles (OLD)

- What we have published so far:
  - LNS: @90°, 80MeV/u, E_{kin}>80 MeV: **ϕ_p = 2.14 10^{-5}**
  - GSI: @90°, 60°, 220 MeV/u:
    - **ϕ_p = 8.8 10^{-3} (60°)**
    - **ϕ_p = 1.8 10^{-3} (90°)**
- The net effect, going from 80 to 220 MeV/u is to enhance the flux for a factor ~ 100.
- The LNS and GSI analyses **did not account for the SC discrimination time correction (Traini's corr.):** fluxes overestimated



$$\frac{dN_P}{dN_C d\Omega}(E_{kin}^{Prod} > 7\ \mathrm{MeV}, \theta = 90°) = (7.61 \pm 0.14_{stat} \pm 0.32_{sys}) \times 10^{-5} sr^{-1}$$

$$\frac{dN_P}{dN_C d\Omega}(E_{kin}^{Prod} > 83\ \mathrm{MeV}, \theta = 90°) = (2.14 \pm 0.06_{stat} \pm 0.10_{sys}) \times 10^{-5} sr^{-1}$$

GSI

$$\frac{dN_p}{N_C d\Omega}(\theta = 60°) = (8.78 \pm 0.07_{stat} \pm 0.64_{sys}) \times 10^{-3}\ \mathrm{sr}^{-1}$$

$$\frac{dN_d}{N_C d\Omega}(\theta = 60°) = (3.71 \pm 0.04_{stat} \pm 0.37_{sys}) \times 10^{-3}\ \mathrm{sr}^{-1}$$

$$\frac{dN_t}{N_C d\Omega}(\theta = 60°) = (0.91 \pm 0.01_{stat} \pm 0.21_{sys}) \times 10^{-3}\ \mathrm{sr}^{-1}$$

$$\frac{dN_p}{N_C d\Omega}(\theta = 90°) = (1.83 \pm 0.02_{stat} \pm 0.14_{sys}) \times 10^{-3}\ \mathrm{sr}^{-1}$$

$$\frac{dN_d}{N_C d\Omega}(\theta = 90°) = (0.78 \pm 0.01_{stat} \pm 0.09_{sys}) \times 10^{-3}\ \mathrm{sr}^{-1}$$

$$\frac{dN_t}{N_C d\Omega}(\theta = 90°) = (0.128 \pm 0.005_{stat} \pm 0.028_{sys}) \times 10^{-3}\ \mathrm{sr}^{-1}.$$

Flux of charged particles (NEW)

➡ Preliminary results from HIT analysis are already available

fluxes at 60deg setup are calculated using efficiency simulations for 90deg setup

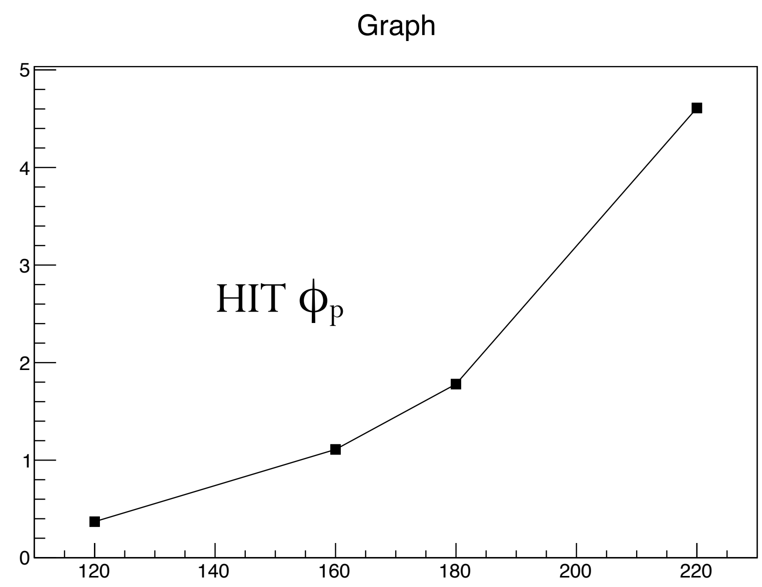
	HIT 90deg	HIT 60 deg	60deg/ 90deg	Sim incl. primaries
Oxy300	*10.66x10^{-3}*	*65.00x10^{-3}*	*6.1*	
Oxy260	*4.90x10^{-3}*	*36.74x10^{-3}*	*7.5*	
Oxy210	*2.84x10^{-3}*	*19.88x10^{-3}*	*9.9*	
*C220 (*GSI)*	*2.73x10^{-3} <all> 1.83x10^{-3} <p> 0.78x10^{-3} <d> 0.12x10^{-3} <t>*	*13.34x10^{-3}<all> 8.78x10^{-3} <p> 3.71x10^{-3} <d> 0.91x10^{-3} <t>*	*4.9*	
C220 <r12-14>	*5.02x10^{-3}*			
C181	*1.95x10^{-3}*			
C160	*1.24x10^{-3}*			
C120	*0.39x10^{-3}*			
*C80 (*Catania)*	*0.27x10^{-3}*			
He145	*1.21x10^{-3}*	*14.02x10^{-3}*	*11.5*	*0.38x10^{-3} (0.02)*
He125	*0.65x10^{-3}*	*9.57x10^{-3}*	*14.7*	*0.40x10^{-3} (0.02)*
He102	*0.61x10^{-3}*	*4.00x10^{-3}*	*6.6*	*0.31x10^{-3} (0.02)*

Sys error is of about one order of magnitude lower than obtained flux value.
Eps_LYSO(Ekin) is not implemented

A more detailed comparison

- To check the order of magnitude:
  - Total Np, N12C, Solid angle, efficiencies, Dead Time.

exp. data	ϕ_p @ 90°	
LNS (80MeV)	2.15 10^{-5}	no traini's corr
GSI (220MeV)	1.8 10^{-3}	no traini's corr
HIT C220	4.61 10^{-3}	with traini's corr
HIT C181	1.78 10^{-3}	
HIT C160	1.11 10^{-3}	
HIT C120	0.37 10^{-3}	



Neutral analysis (I)

- The prompt photons analysis has already a lot of inputs…
  - LNS (80 MeV/u, 90°), LYSO
  - GSI (220 MeV/u, 90°, 60° and 120°), LYSO and BaF
  - HIT
- Only published result is LNS one and did not account for the SC discrimination time correction (Traini's corr.): flux is likely to be overestimated.

$$\frac{dN_\gamma}{dN_C d\Omega}(E > 2\text{MeV}, \theta = 90°) = \left(2.32 \pm 0.01_{\text{stat}} \pm 0.15_{\text{sys}}\right) \times 10^{-3} sr^{-1}.$$

- The GSI LYSO analysis in ~ completed (traini's Corr not yet applied)

Preliminary

$$\Phi_\gamma(E > 2\text{ MeV } @60°) = (6.59 \pm 0.22_{\text{stat}} \pm 1.07_{\text{sys}}) \times 10^{-3}\ sr^{-1}$$

$$\Phi_\gamma(E > 2\text{ MeV } @90°) = (7.39 \pm 0.38_{\text{stat}} \pm 1.27_{\text{sys}}) \times 10^{-3}\ sr^{-1}$$

$$\Phi_\gamma(E > 2\text{ MeV } @120°) = (5.02 \pm 0.24_{\text{stat}} \pm 1.34_{\text{sys}}) \times 10^{-3}\ sr^{-1}$$

Neutral analysis (II)

- From LNS to GSI..
  - The flux increases ~ a factor 3
  - The huge increase in the uncertainties is due to the unfolding procedure! [might change now that we are recomputing the unfolding matrix and *maybe* the unfolding procedure ;) …]
- Also GSI BaF results have to be considered…. (traini's Corr not yet applied)

Preliminary

BaF, GSI, 220 MeV/u

	60°	90°
Data	$(1.15 \pm 0.11)\times10^{-2}$	$(1.29 \pm 0.22)\times10^{-2}$
BIC	$(2.15 \pm 0.02)\times10^{-2}$	$(1.83 \pm 0.02)\times10^{-2}$
QMD	$(2.33 \pm 0.03)\times10^{-2}$	$(1.88 \pm 0.03)\times10^{-2}$
INCL	$(1.31 \pm 0.02)\times10^{-2}$	$(1.09 \pm 0.02)\times10^{-2}$

From HIT, raw yields

From I. Mattei

CARBON RUNS	eff_DT	N primaries	correction	Nprimaries_corr	Ngamma(2-9MeV)	Ngamma(2-9MeV)/(Nprim_corr*eff_DT)
ProductionRun_230214_Test_Carbon120_19.dat	0,9083	131726755	1,16	152803035,8	5130,260	3,69639E-05
ProductionRun_230214_Test_Carbon160_17.dat	0,8681	577842727	1,10	635626999,7	3591,820	6,50942E-06
ProductionRun_230214_Test_Carbon160_18.dat	0,8655	311660686	1,11	345943361,5	1870,050	6,2457E-06
ProductionRun_230214_Test_Carbon181_15.dat	0,8328	414377928	1,11	459959500,1	3025,240	7,89768E-06
ProductionRun_230214_Test_Carbon181_16.dat	0,8271	162961117	1,11	180886839,9	1226,590	8,1985E-06
ProductionRun_230214_Test_Carbon220_12.dat	0,9022	145602650	1,08	157250862	1407,110	9,91818E-06
ProductionRun_230214_Test_Carbon220_13.dat	0,5439	231759061	1,24	287381235,6	1046,710	6,69652E-06
ProductionRun_230214_Test_Carbon220_14.dat	0,7394	341284877	1,08	368587667,2	2768,890	1,01598E-05

12C (*10^{-6})

120_19 = 36.96

160_17, 160_18 = 6.51, 6.25

181_15,181_16 = 7.90, 8.20

220_12, 220_13, 220_14 = 9.92, 6.70, 10.16

HIT raw yields

From I. Mattei

FLUKA parametrization: $Z_{BP} = -0.8272 + 0.01629 * E_{beam} + 0.0001202 * E^2_{beam}$

	BP position in PMMA Z_{BP} (cm)
^{12}C 120 MeV/u	2.86
^{12}C 160 MeV/u	4.86
^{12}C 181 MeV/u	6.06
^{12}C 220 MeV/u	8.57

In carbon runs (just 90°) the PMMA was always 10 cm long.

	HIT (10^{-6} Gamma(2-9MeV)/ ($^{12}C_{corr}$*epsDT)	FLUKA (10^{-6} Gamma/primary)
^{12}C 120 MeV/u	36.96	*Sim processed with AnaFluka new*
^{12}C 160 MeV/u	6.25 - 6.51	
^{12}C 181 MeV/u	7.90 - 8.20	
^{12}C 220 MeV/u	6.70 - 10.16	**11.9(@90°; 13.0@60°)**

The prompt γ overview

	(a)	(b)
Nγ		
N12C		
Ω		
ε		
DT		

exp. data	ϕ @ 90°	
LNS LYSO (80MeV)	$0.23\ 10^{-2}$	no traini's corr
GSI LYSO (220MeV)	$0.74\ 10^{-2}$	no traini's corr
GSI BAF (220MeV)	$1.15\ 10^{-2}$	no traini's corr

Comparison with Ganil

- Phys. Med. Biol. 60 (2015) 565–594
  - At the entrance of a PMMA target, where the contribution of secondary nuclear reactions is negligible, prompt-gamma counts per incident ion, per millimetre and per steradian equal to **(124 ± 0.7stat ± 30sys) × 10^{-6} for 95 MeV/u carbon ions**, **(79 ± 2stat ± 23sys) × 10^{-6} for 310 MeV/u carbon ions**, and (16 ± 0.07stat ± 1sys) × 10^{-6} for 160 MeV protons were found for prompt gammas with energies higher than 1 MeV
  - As such, if an average value between the entrance and the maximum yield immediately upstream of the prompt-gamma falloff is used, conditioned by a 2 MeV energy threshold, an absolute yield of **(174 ± 0.9stat ± 50sys) × 10^{-6} counts/ion*mm*sr** is obtained. The corresponding value published by Agodi and colleagues after considering the projected ion range of **80 MeV/u carbon ions in PMMA** (15.42 mm, estimated with SRIM 2013) is **(150 ± 0.6stat ± 10sys) × 10^{-6} counts/ion*mm*sr**. The agreement with previously published results from independent collaborations is remarkably good.
- Problem for GSI?
  - Our friends, going from 95 to 310 are reducing the yield per mm of a factor 0.64. **For us, going from 80 to 220** means a ~ *3 flux and a ~ *5.36 range [assuming 8.25 cm] for a 0.56 net scaling factor…. If we use the BaF result, the reduction is smaller (0.83).. compatible with the lower energy range?