Momentum spectra of hydrogen and helium isotopes from C-12 fragmentation.

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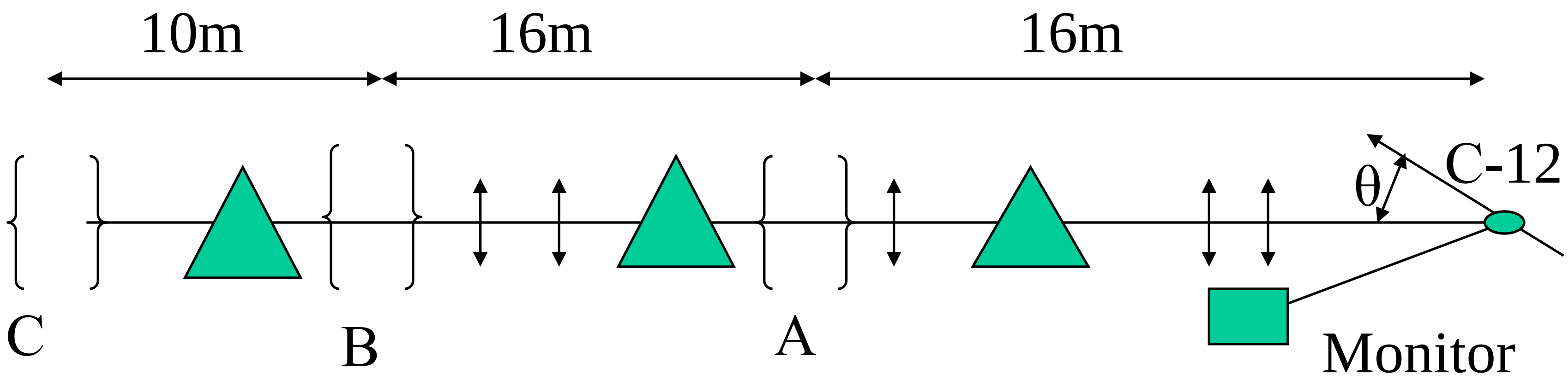
C-12 beam from 200 to 600 MeV/nucleon

Motivation for nuclear fragmentation study

1. Measurement of nuclear composition of secondary beams at ITEP heavy ion accelerator.
2. Precise measurement of high energy fragment spectra for
   a) search for cumulative effect in fragment production in heavy ion collisions,
   b) test of the coalescence model in the unstudied region of high momentum.
3. Now systematic data are needed as input to transport codes for radiotherapy with heavy ions, for shielding calculation for long-duration space missions and for RIB design

Experimental set up



-- thin foil Be-target

-- bending magnet

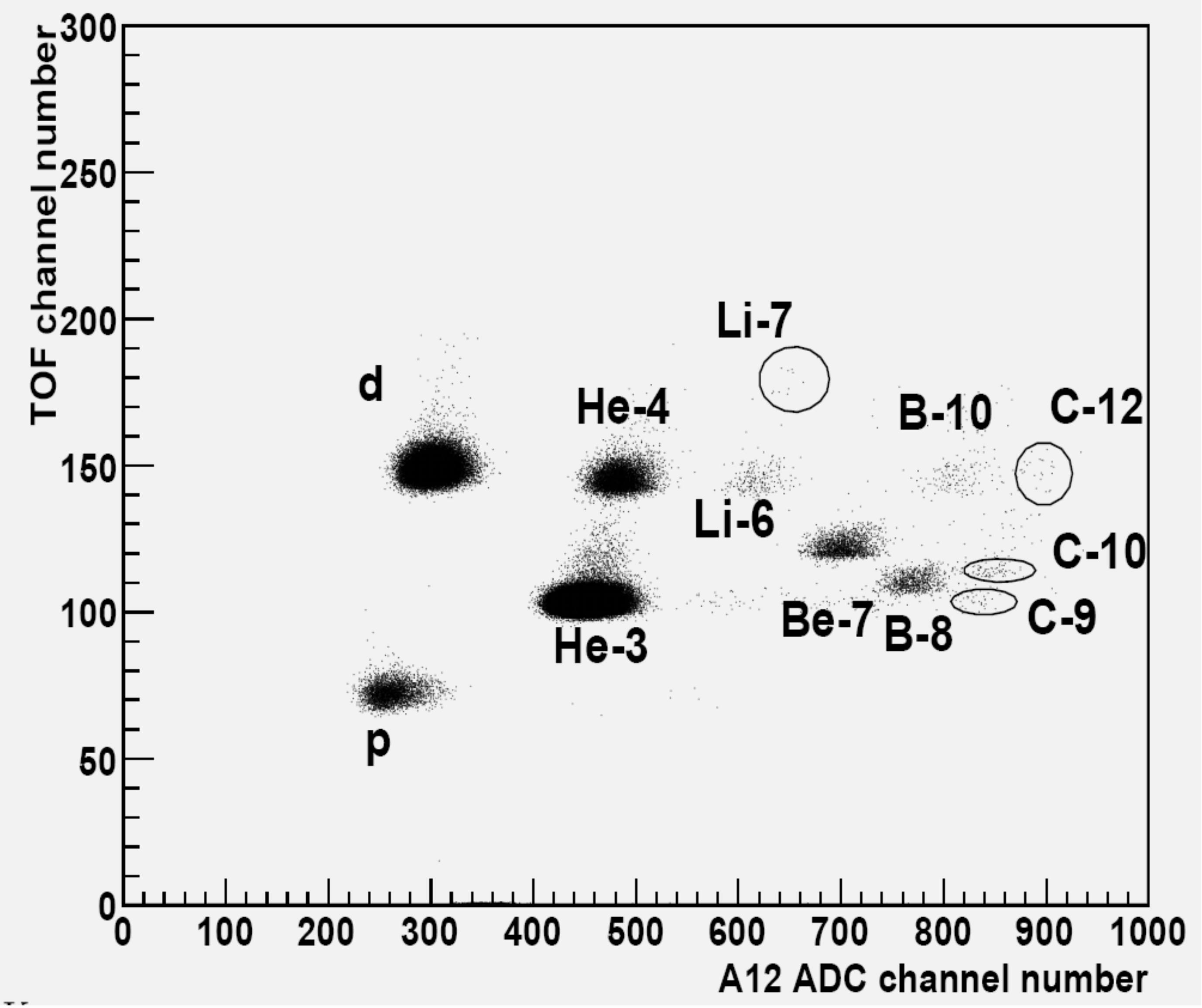
-- quadrupole

$\theta = 3.5^{O}$

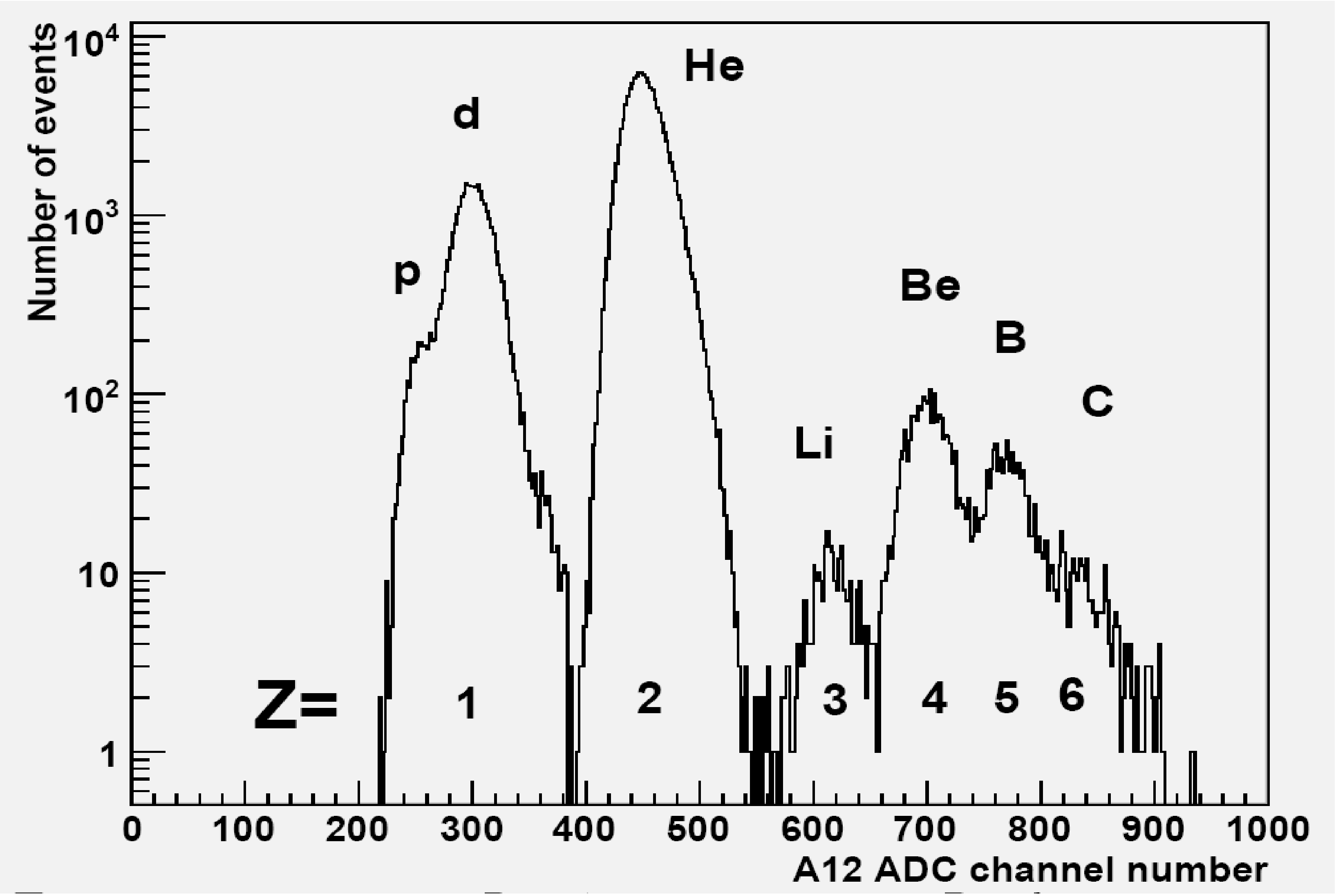
Scintillation counters

A	3(TOF+dE/dx) + H(20x10)
B	2(TOF+dE/dx)
C	14(TOF) 0.6x2.0 mxm

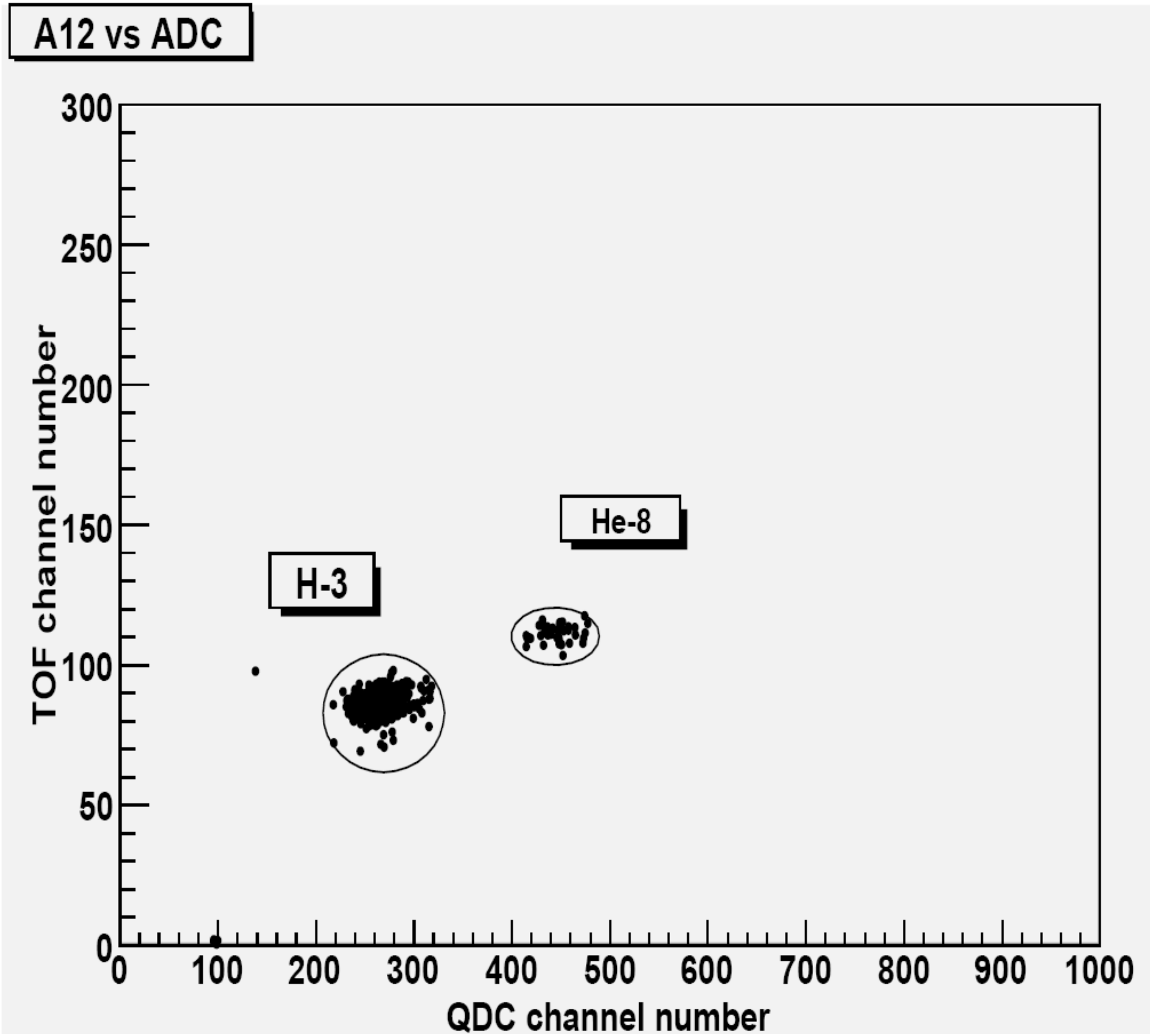
C-12 ions 300 MeV/nucleon, rigidity 1.2 GeV/c/Z



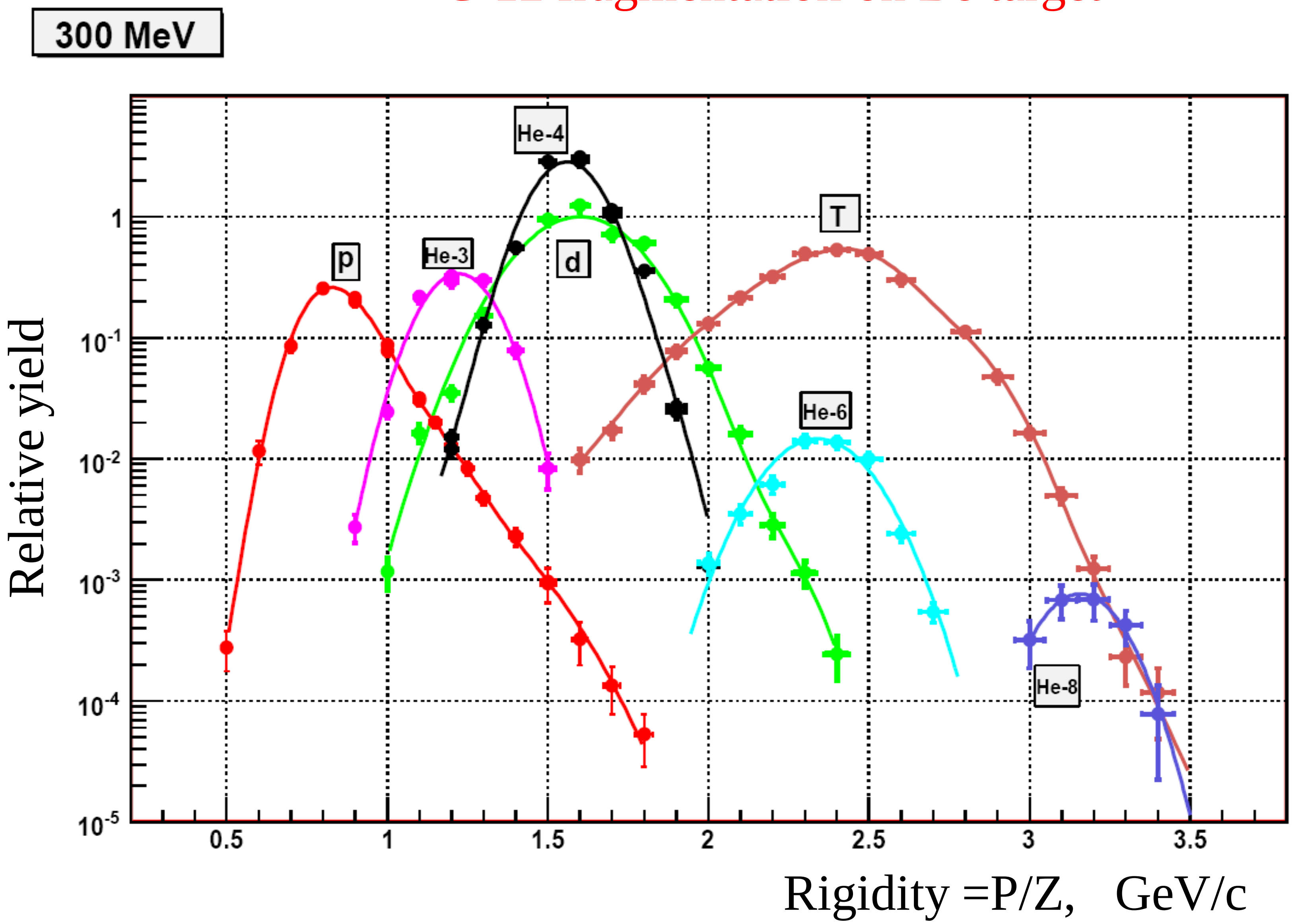
C-12 ions 300 MeV/nucleon, rigidity 1.2 GeV/c/Z



C-12 ions 600 MeV/nucleon, rigidity 4.75 GeV/c/Z



Relative yield of H and He isotopes at 3.5^0 from C-12 fragmentation on Be target



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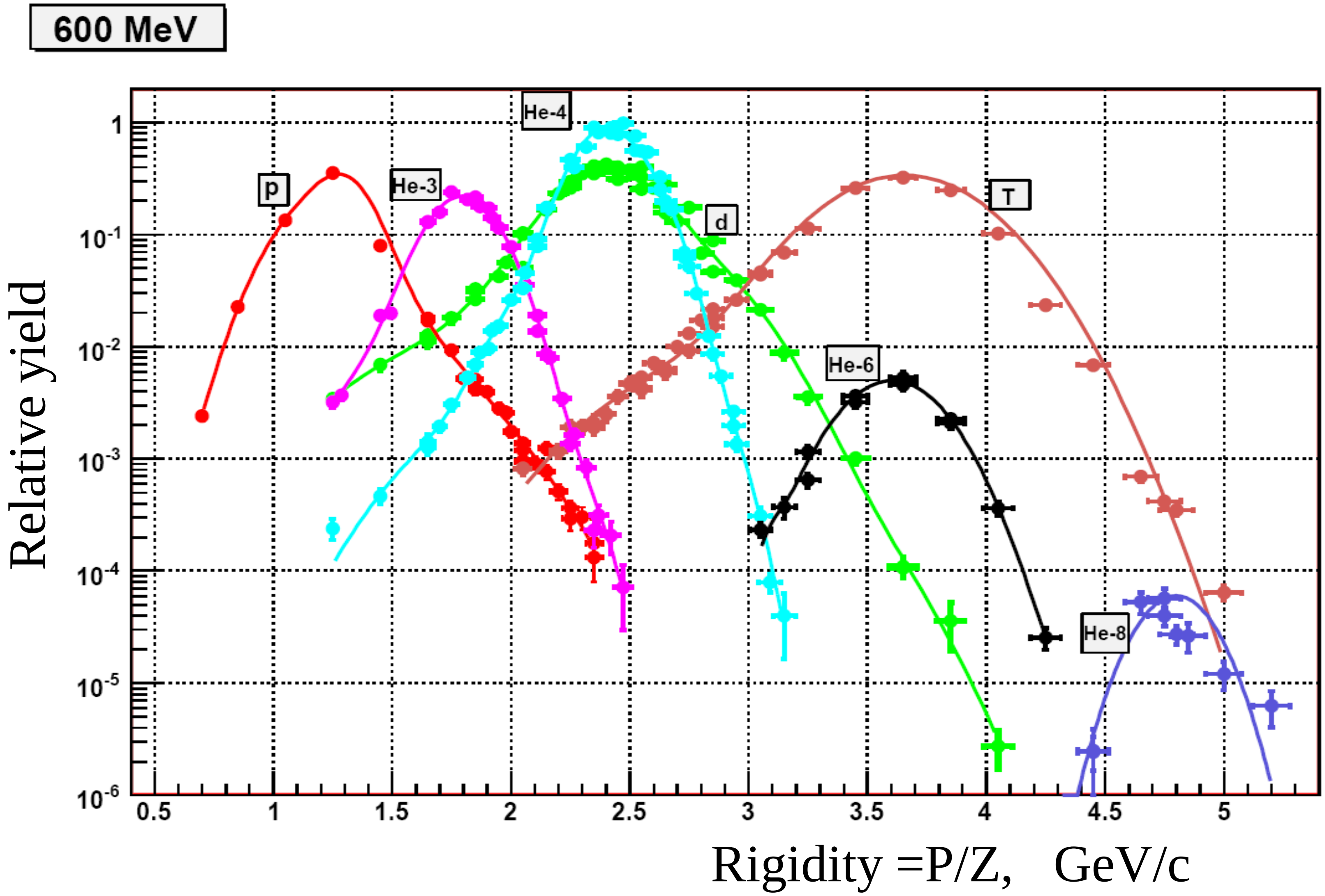


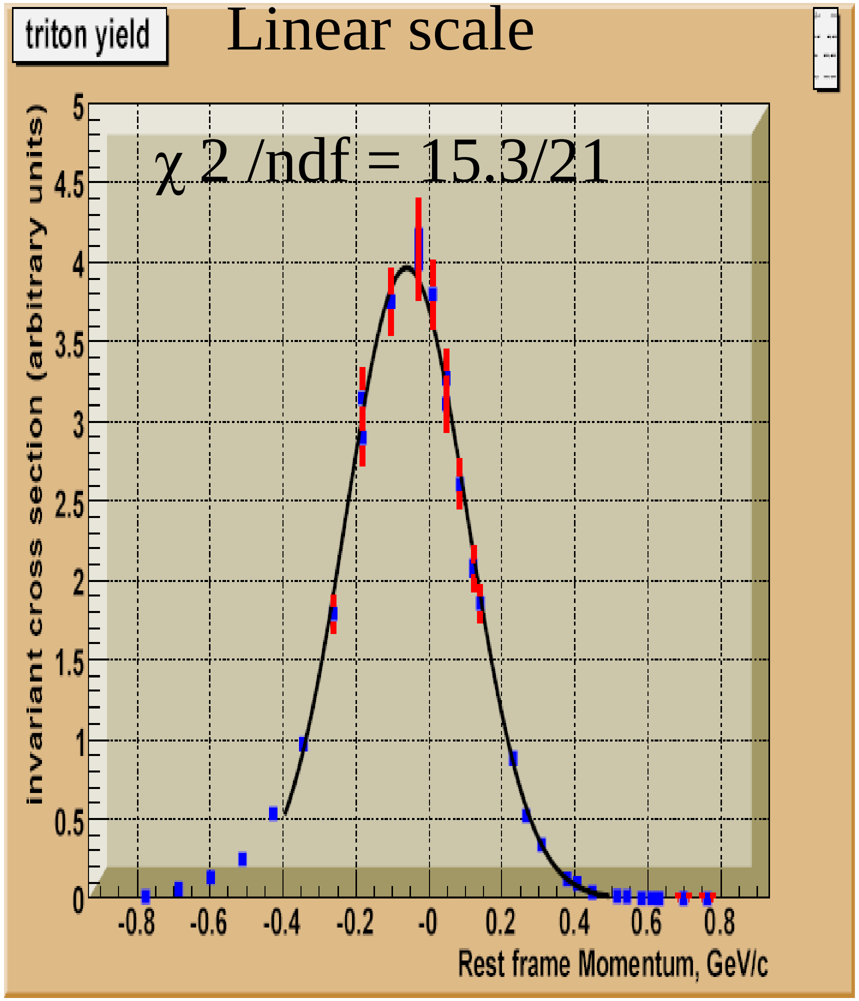
Main statements of statistical models.

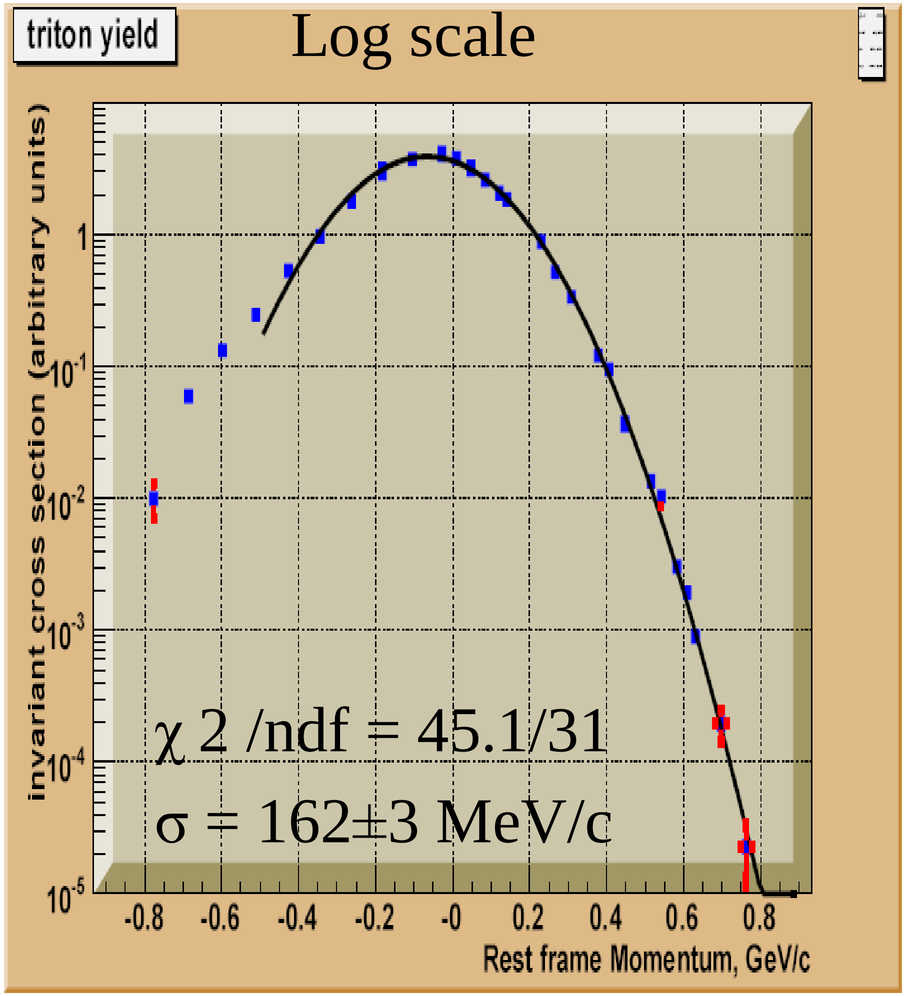
1. In the rest frame of the nucleus a fragment momentum distribution is of gaussian shape, identical for logitudinal and transvers directions.

2. Parabolic law for rms of momentum distributions
   $\sigma^2{}_F = \sigma^2{}_0 A_F(A - A_F)/(A\text{-}1)$,

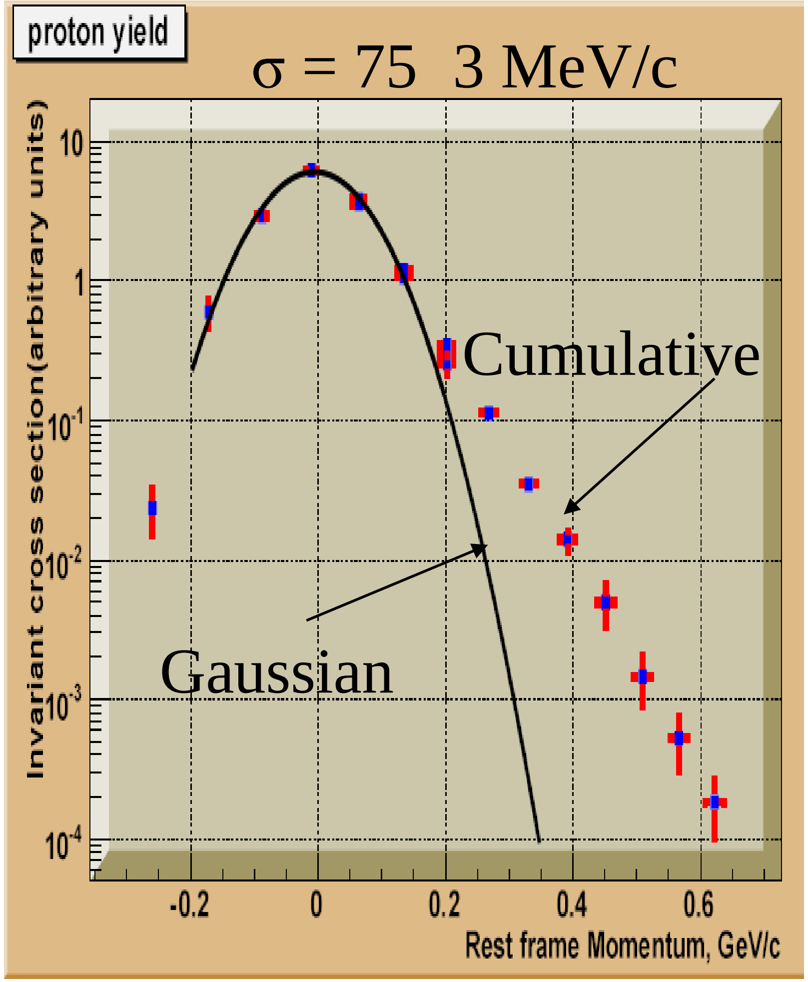
3. Limiting fragmentation hypothesis. Fragmentation properties are independent of projectile energy and target mass.

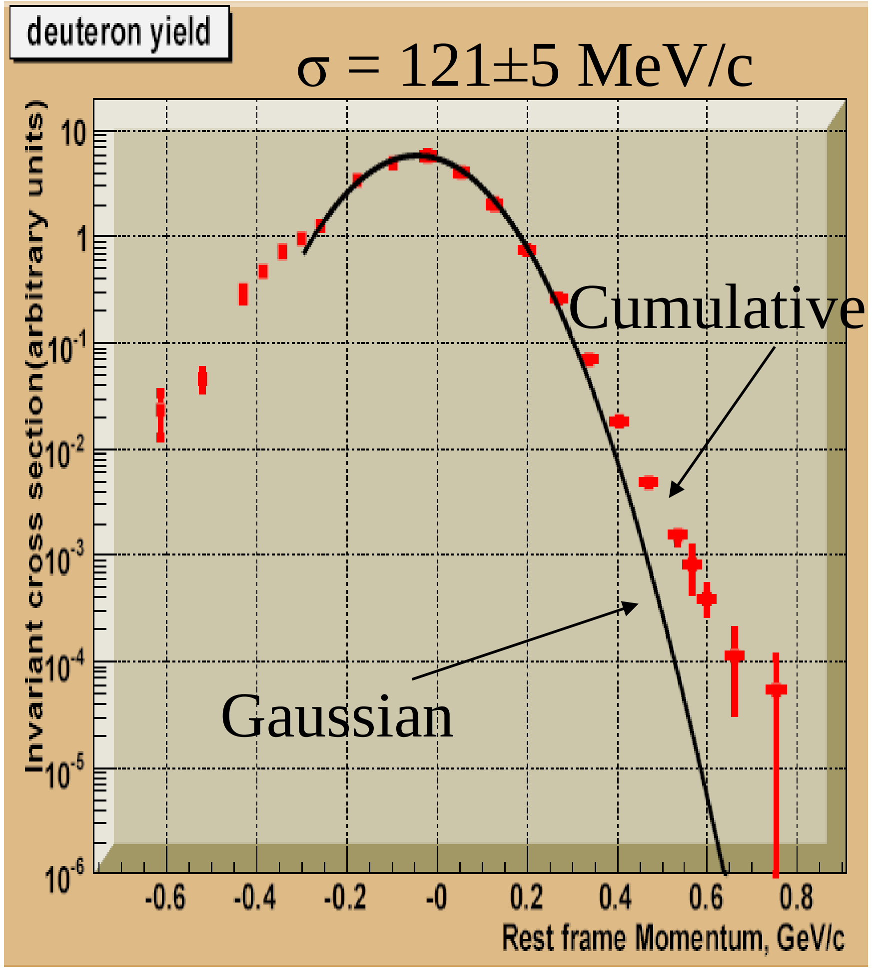
Triton momentum distribution in projectile rest frame. Fit with Gaussian.



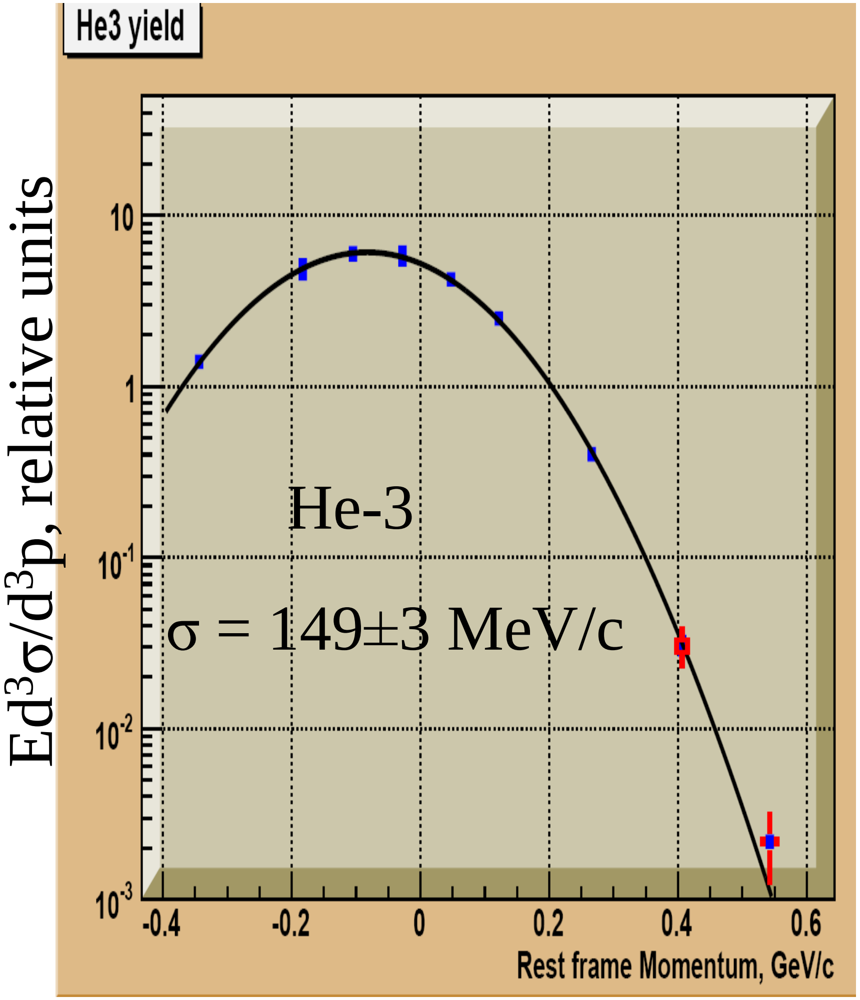


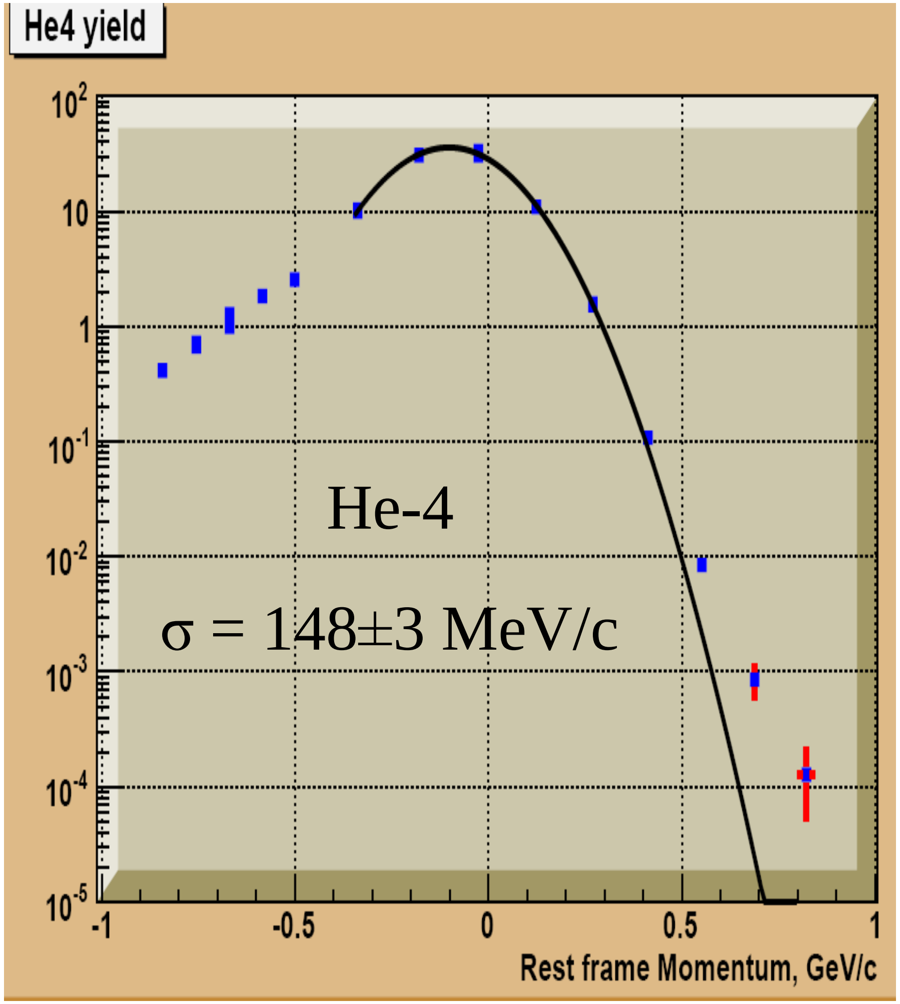
Proton and deuteron momentum distributions in projectile rest frame. Fit with Gaussian from -0.2 to 0.2 GeV/c.





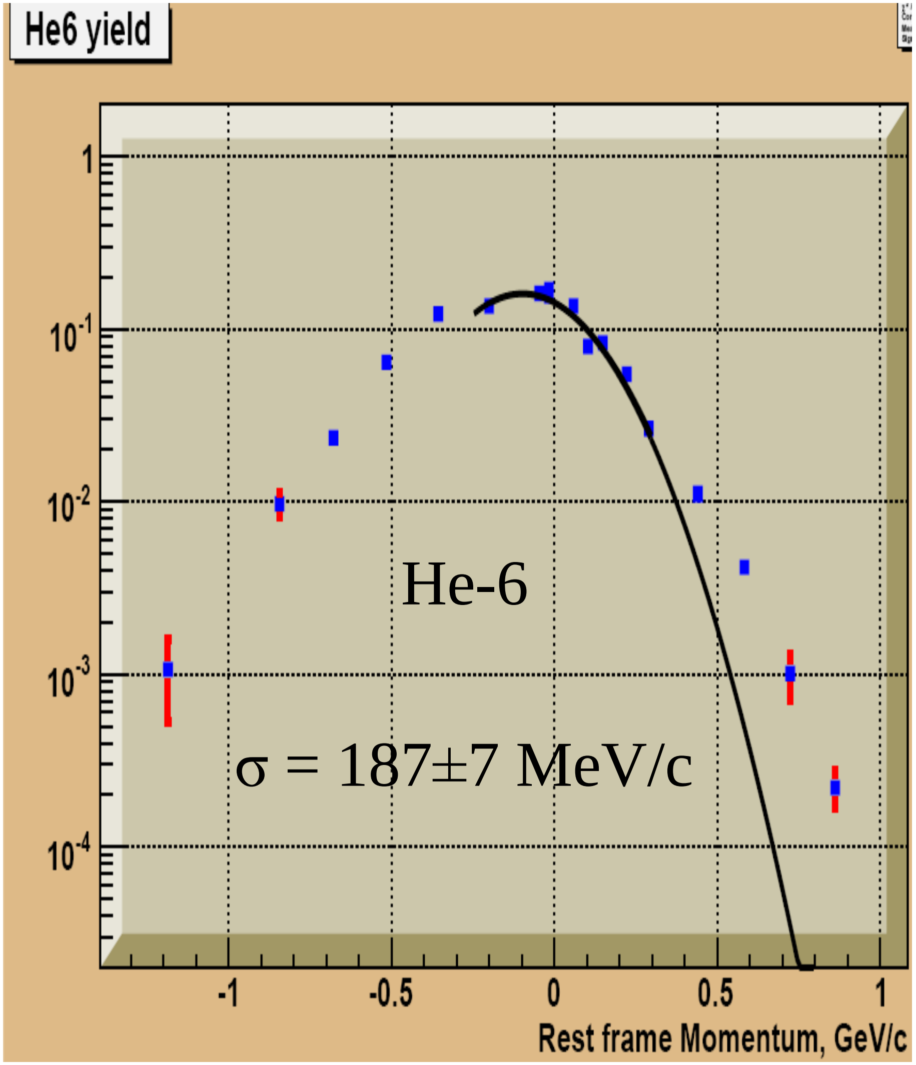
He-3 and He-4 momentum distributions

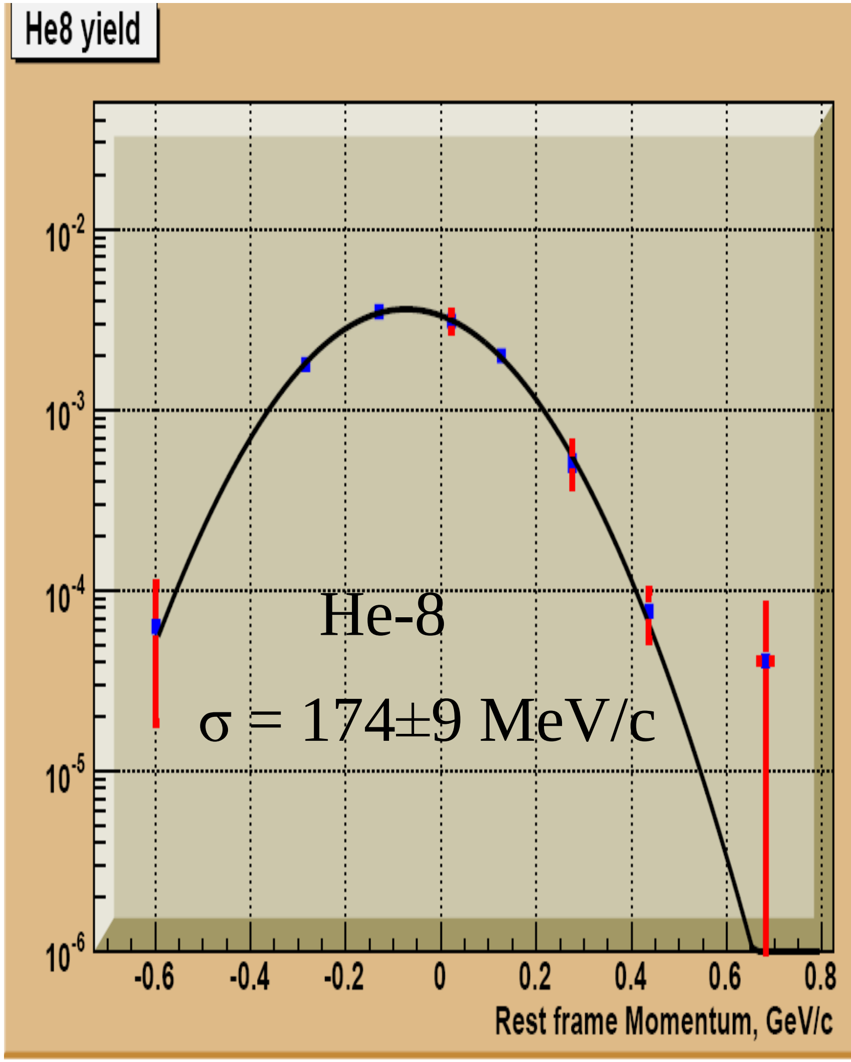




He-3 and He-4 momentum distributions

$Ed^3\sigma/d^3p$, relative units





Comparison of σ_F with data of D.E.Greiner et al. PRL35,152(1975) and theoretical prediction of A.S.Goldhaber,PL53B,306(1974)

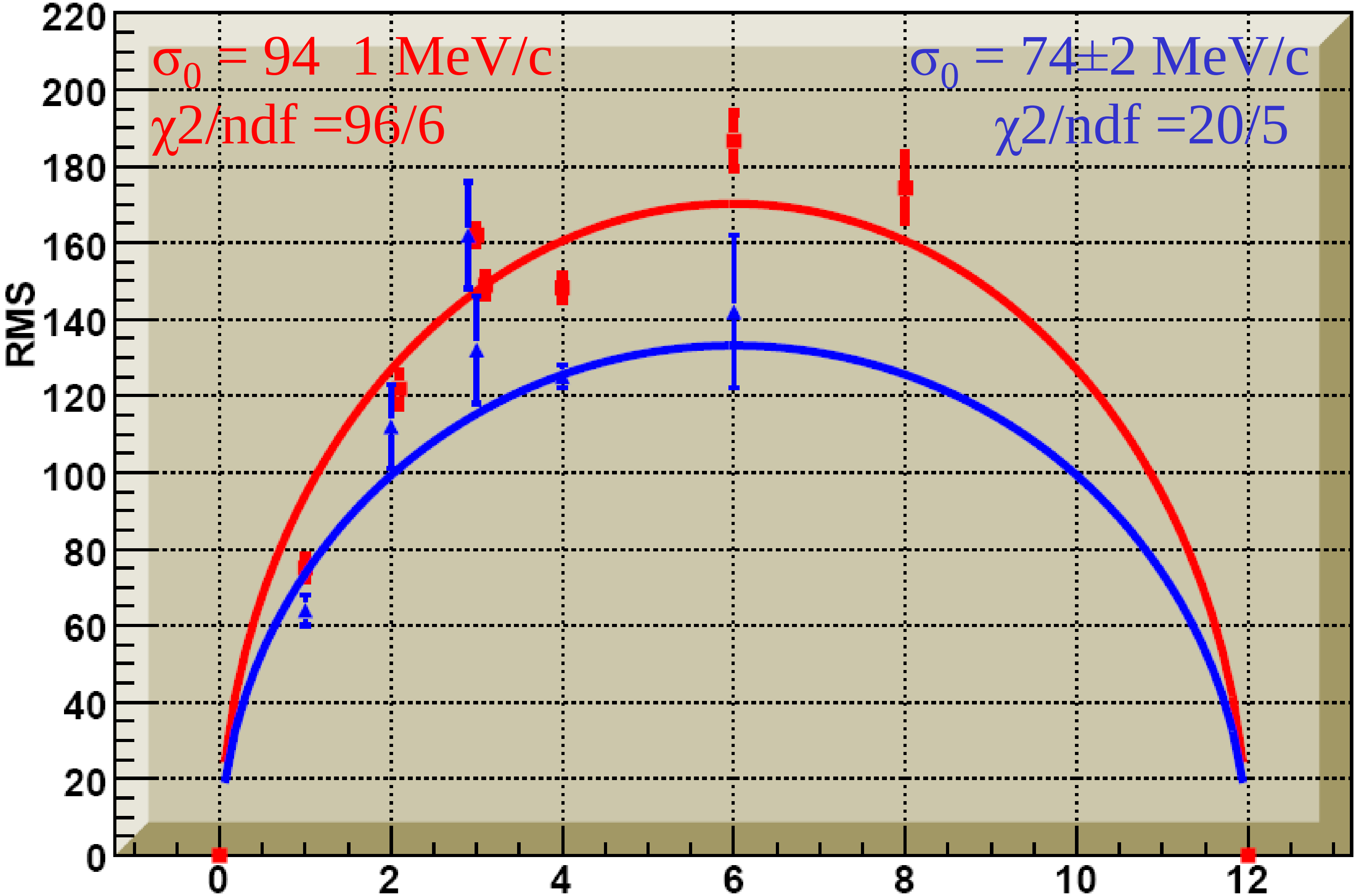
$$(\sigma_F)^2 = (\sigma_0)^2 F(A_{proj.} - F)/(A_{proj.}-1),$$ where σ_0 = 90 MeV/c

	0.3 GeV/n this exp.	1.0 GeV/n Greiner et al.	σ_0
p	75.1 3.1	63±4	75.1±3.1
d	121.8±4.5	112±11	90.3±3.3
t	162.0±2.5	162±14	103.4±1.5
He-3	148.9±2.9	132±14	95.0±1.7
He-4	148.2±3.2	125±3	86.8±1.9
He-6	186.6±7.3	142±20	103.1±4.2
He-8	174.3±8.8	-------	102.1±5.3

Test of Goldhaber parabolic law

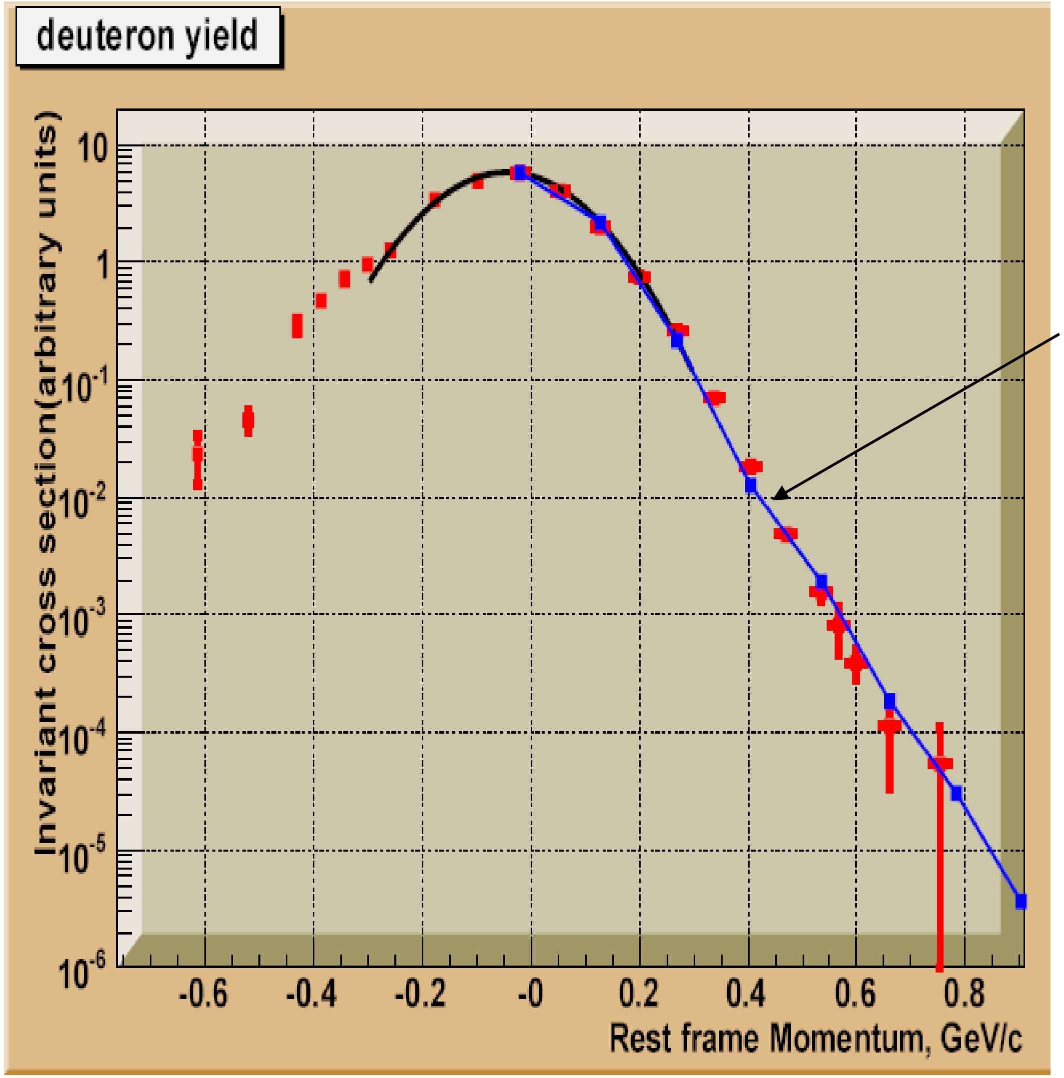
This experiment – 0.3 GeV/n

Griener et al.- 1GeV/n



σ_0 = 90 MeV/c used by SM

Test of coalescence model for high energy deuterons in C-12 fragmentation.

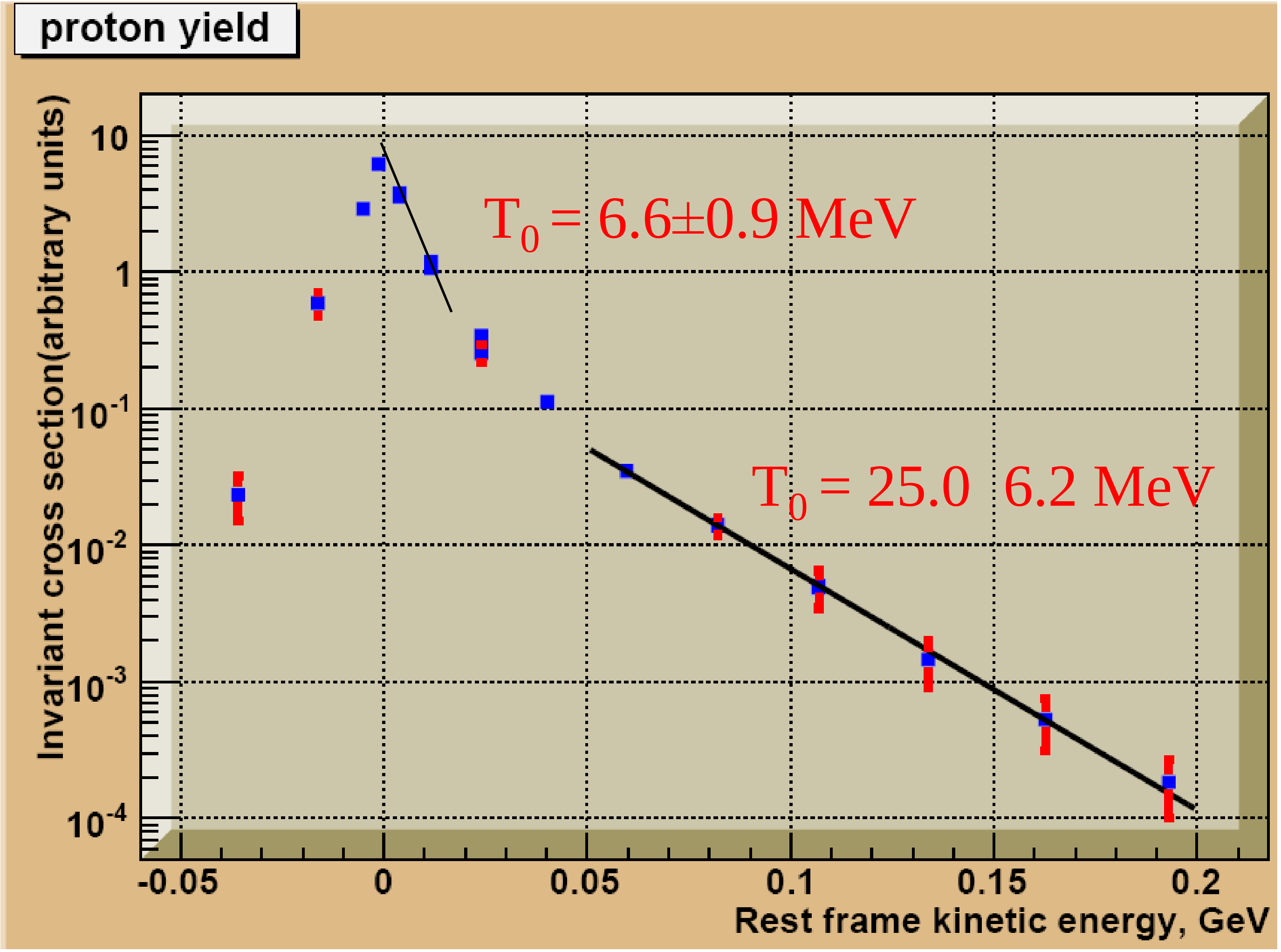


$$E_d(d^3\sigma_d/dp_d^{\,3}) =$$

$$C_2[E_p(d^3\sigma_p/dp_p^{\,3})]^2,$$

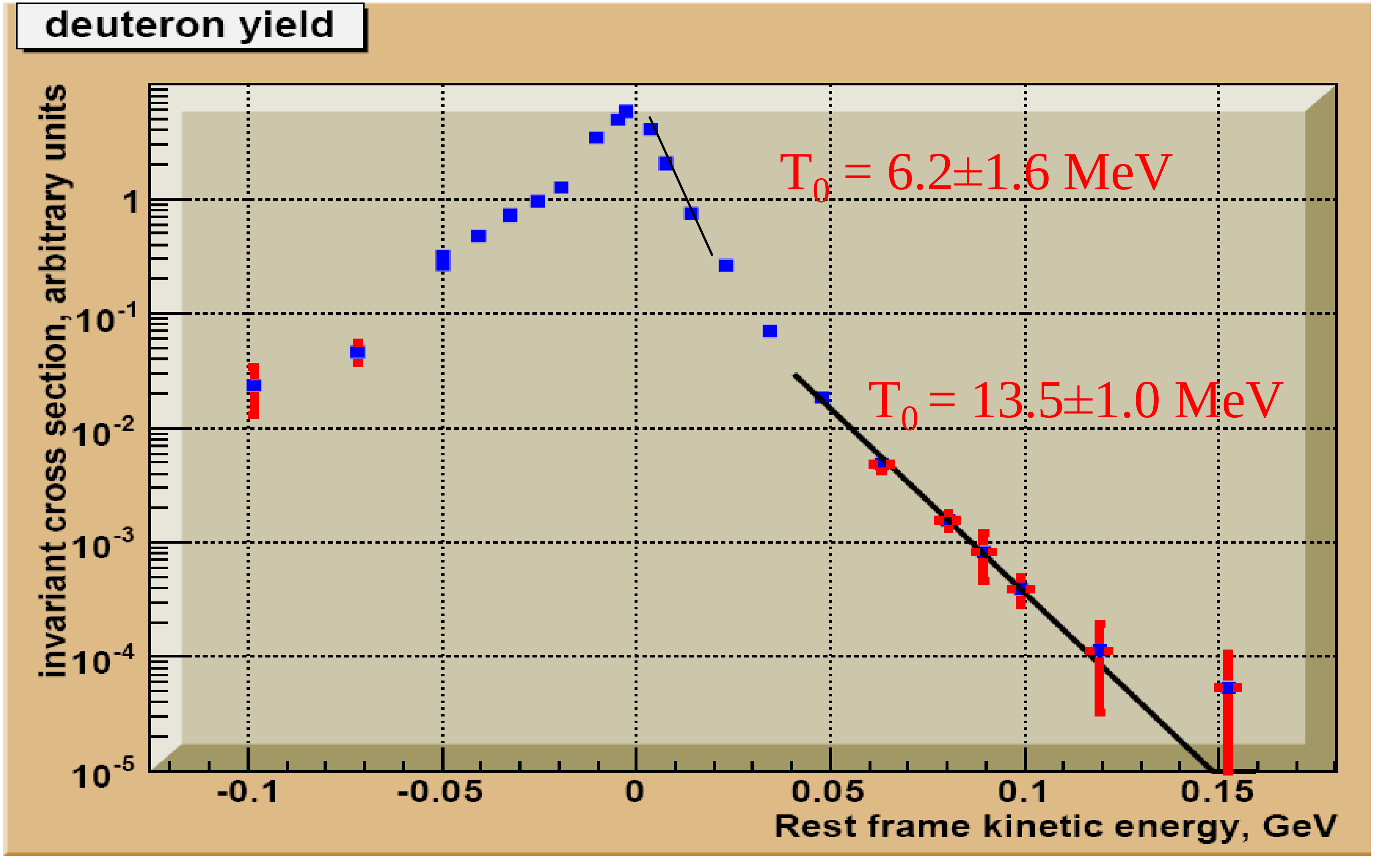
$$p_d = 2p_p$$

Temperature from slope parameter.
$Ed^3\sigma/d^3p \sim \exp(-T/T_0)$ for protons



Temperature from slope parameter.

$Ed^3\sigma/d^3p \sim \exp(-T/T_0)$ for deuterons



Temperature from slope parameter at 300 MeV/nucleon.

1. At $T<20$ MeV $T_0 = 6$ MeV and is equal to σ^2_F/M_F, where σ_F is rms of momentum distribution.

2. At $T > 50$ MeV T0 = 25 MeV for protons and 13.5 MeV for deuteron. It is far from 50 (40) MeV measured in cumulative region at high energy.

CONCLUSION

1. **Yield of Hydrogen and Helium isotopes was measured in C+Be collisions at 200, 300 and 600 MeV/nucleon. New data are available for the tests of fragmentation models.**

2. **High momentum part of fragment spectra was measured with high precision covering up to 6 orders of magnitude in cross section.**

3. **For proton and deuteron the transition from gaussian shape typical for fragmentation from thermodynamic equilibrium to exponential shape typical for cumulative processes was observed.**

4. **Coalescence model describes well the shape of deuteron spectrum up to the highest momentum measured.**