Old FCAL tungsten inventory (status after TB 2025)

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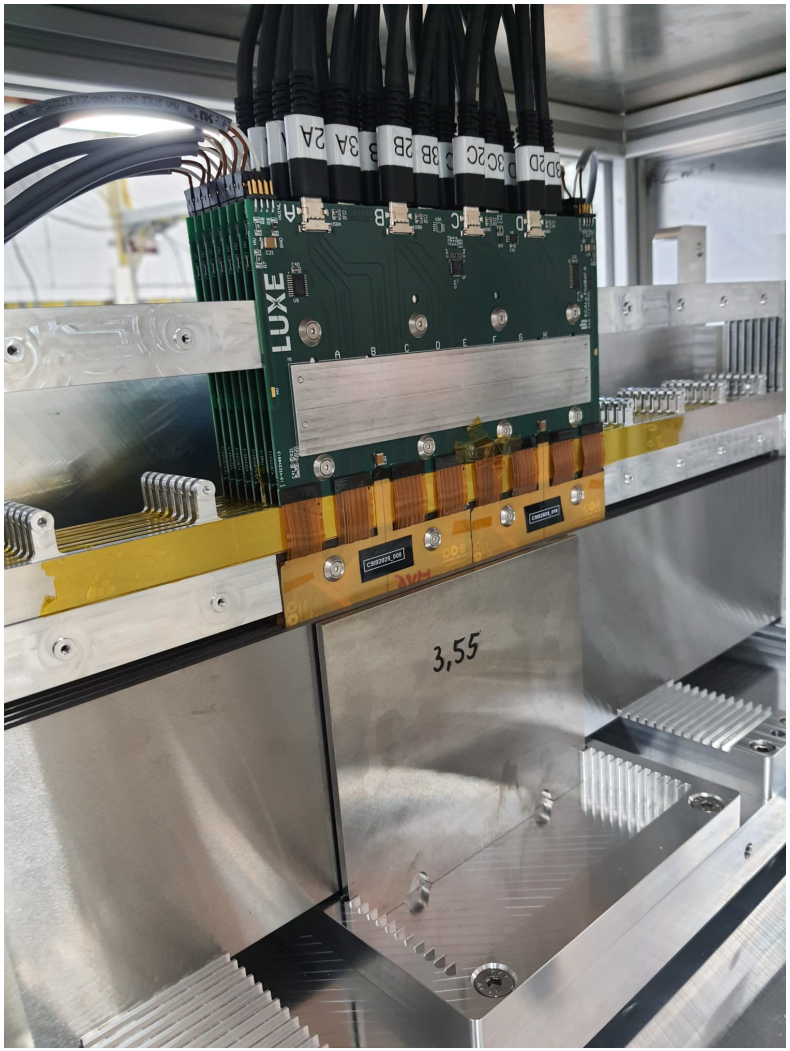
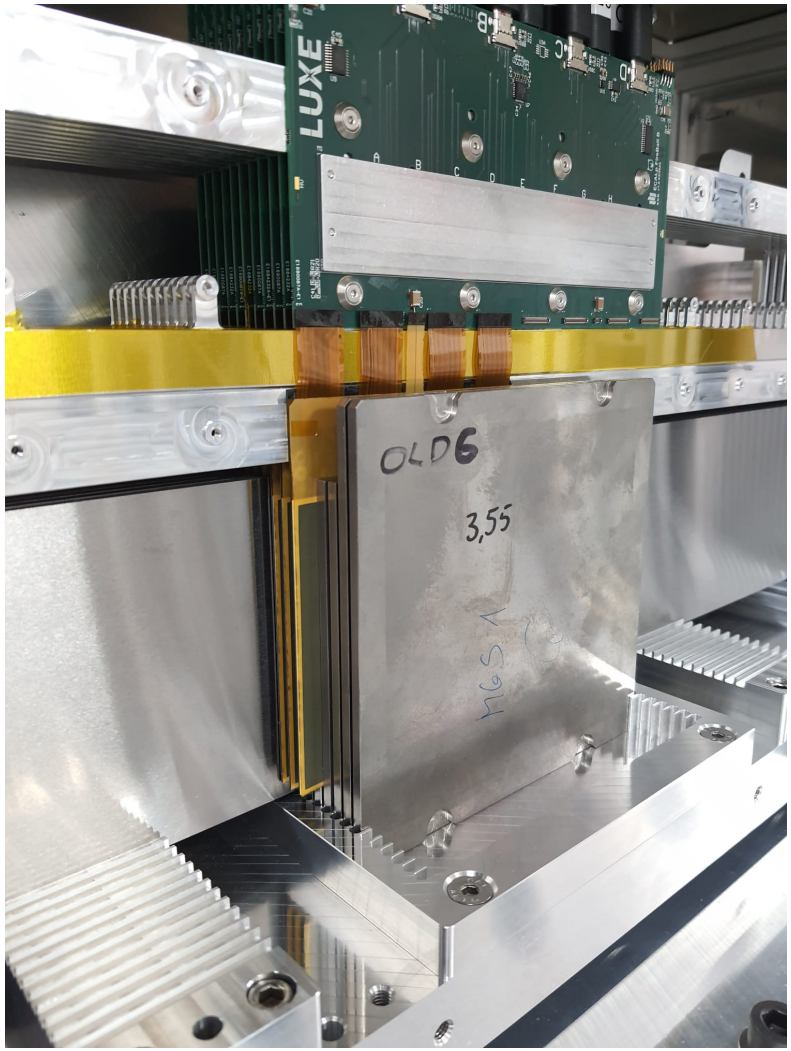
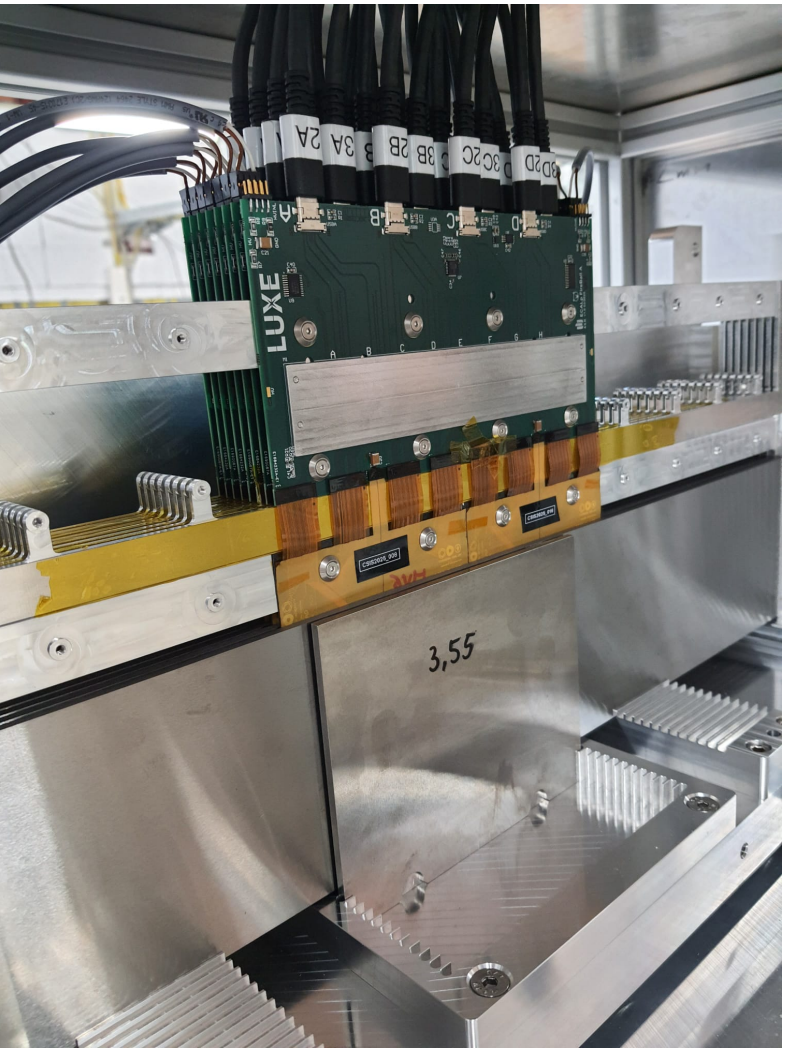
Old FCAL tungsten

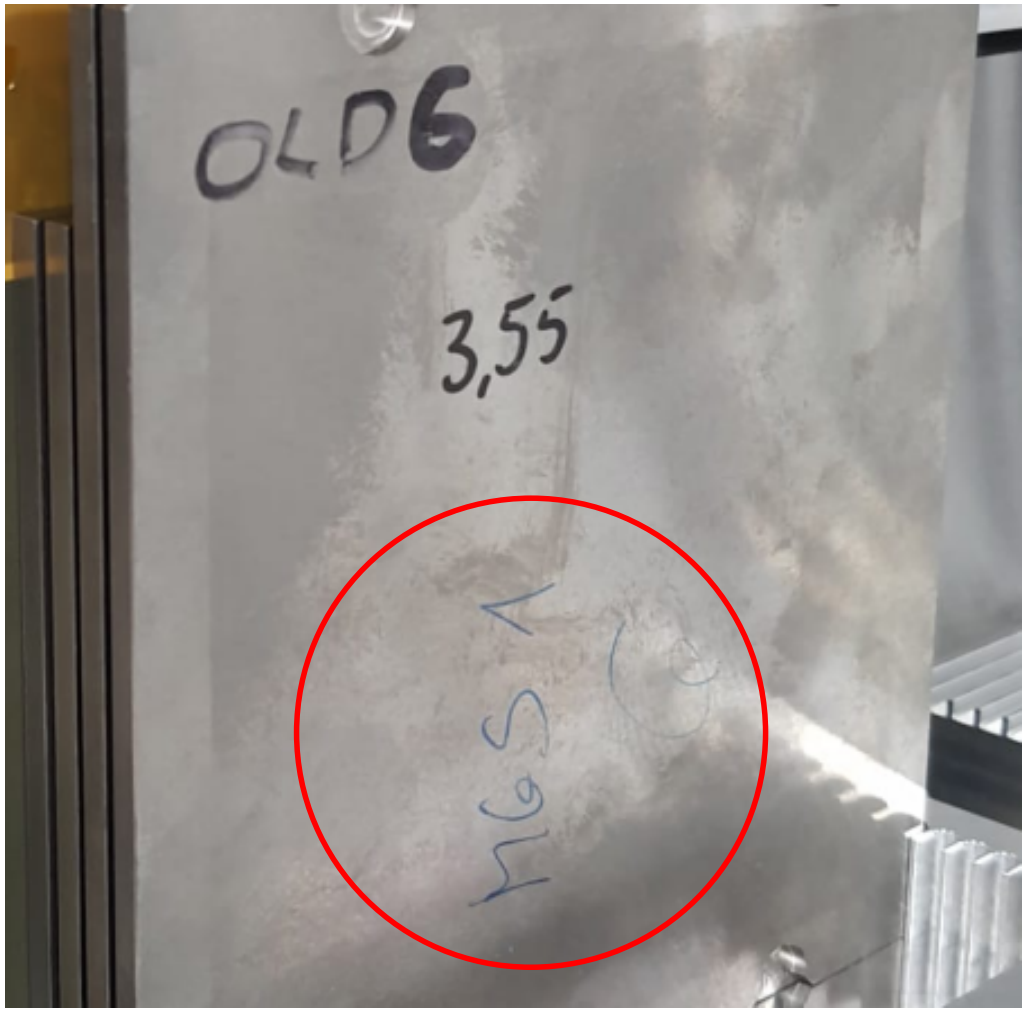




- 15 old plates prepared for TB'25, 12 were used (4 of them were cut)
- **chemical composition** (and density) for Geant4 MC simulation is needed !

Old FCAL tungsten (zoom)





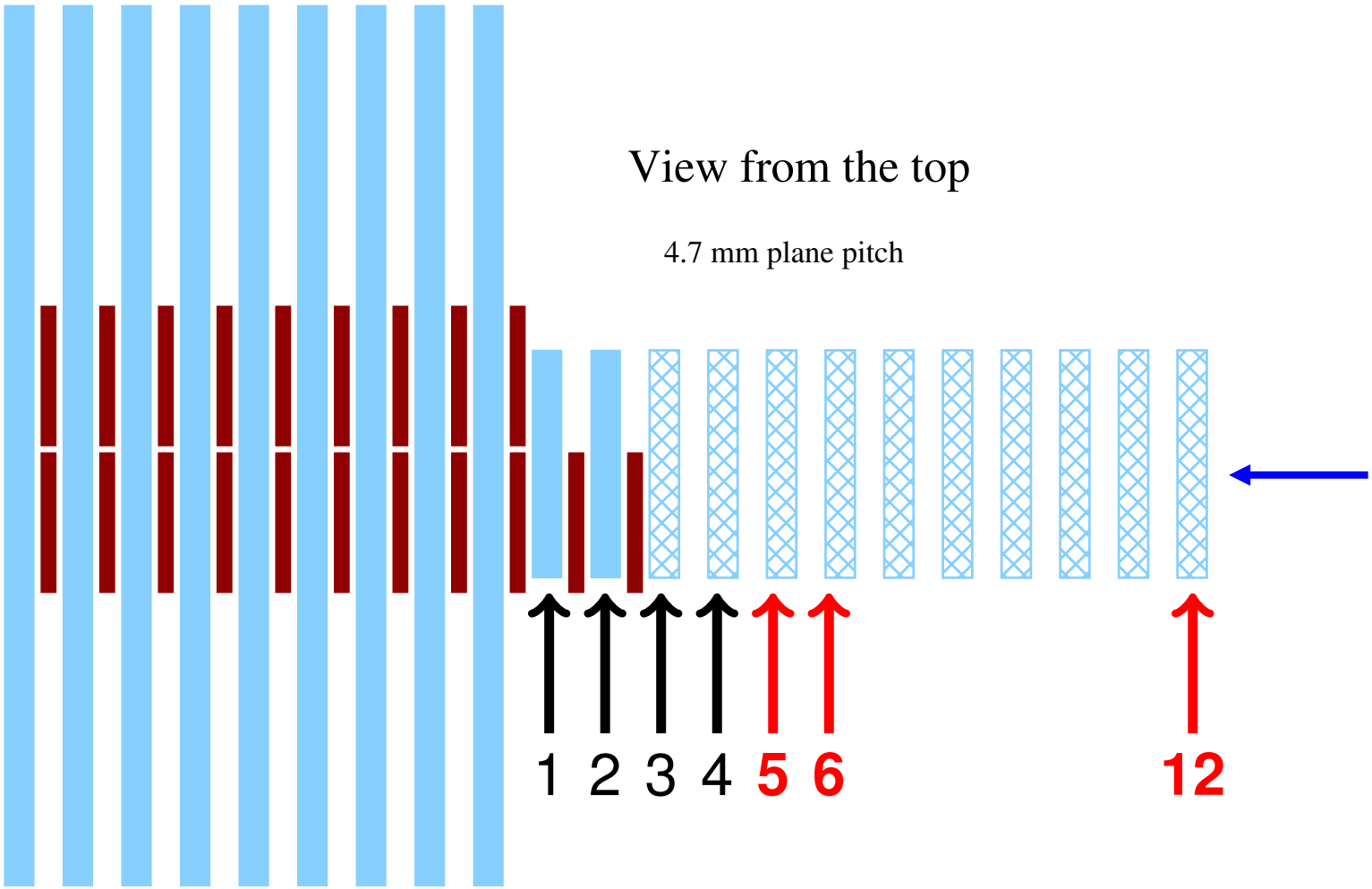
- labels (vendor code) on permaglass frames were lost...
- only few plates have some hand written info... (plate no. 6 $\rightarrow$ MGS)

Old tungsten vendors: summary by Wolfgang & Itamar

company	mass density	composition	number of plates
Plansee	18 gcm-3	W 95% , rest unknown	8
MGS	17.7 gcm-3	W 93%, Ni 5.25%, Cu 1.75%	6
JINR	17.47 gcm-3	W 92.5%, Ni 5.25%, Cu 2.25%	25
JINR	17.47 gcm-3	W 92.4%, Ni 5.18%, Cu 2.42% (by Alexey)	
	(19.25 gcm-3 for pure tungsten)		

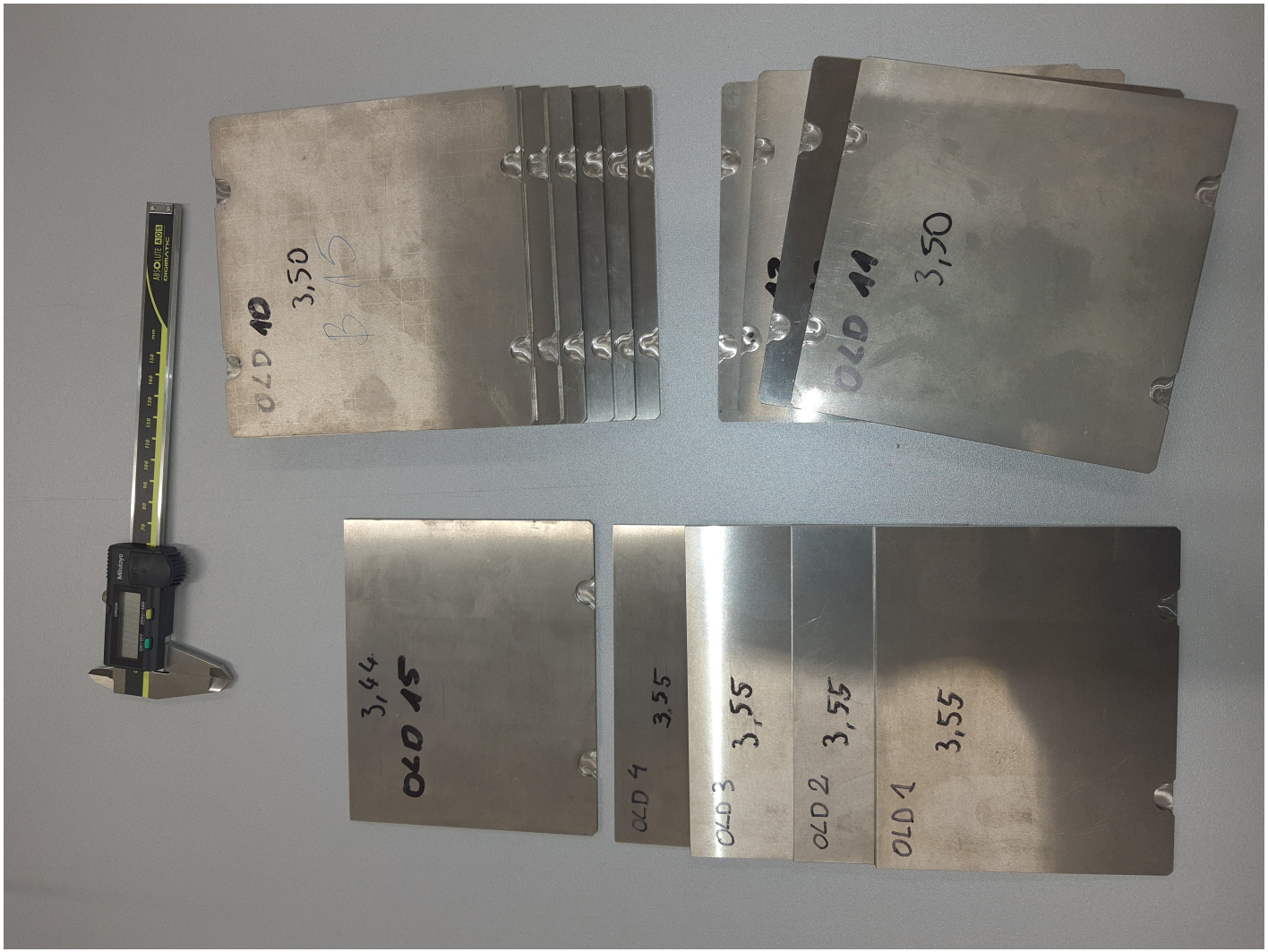
- "*Since the density is almost the same it is very likely impossible to identify different vendors. Chemical methods may work, Itamar recommended X-ray florescence analysis, to be discussed with experts.*"
- **challenge accepted ! :)**

New + Old tungsten configuration and numbering



- new plates from left: B1, B2, B3, X1, X2, X3, N1, N2, N3
- old plates from left: old1, old2, old3, old4, **OLD5, OLD6, ... OLD12**
- (lowercase for cut plates, **red bold for full plates**)

Old FCAL tungsten: 15 plates for TB'25



- 1-15 numbering was arbitrary (first plates with thickness close to 3.55 mm)
- cut plates: 1-4 and 15 (not used)

Some numbers

- density W = 19.254 g/cm3, Z = 74
- density Ni = 8.907 g/cm3, Z = 28
- density Cu = 8.935 g/cm3, Z = 29

- Alloy density W/Ni/Cu (92% / 5% / 3%) = 18.43 g/cm3
- Alloy density W/Ni/Cu (95% / 3% / 2%) = 18.73 g/cm3

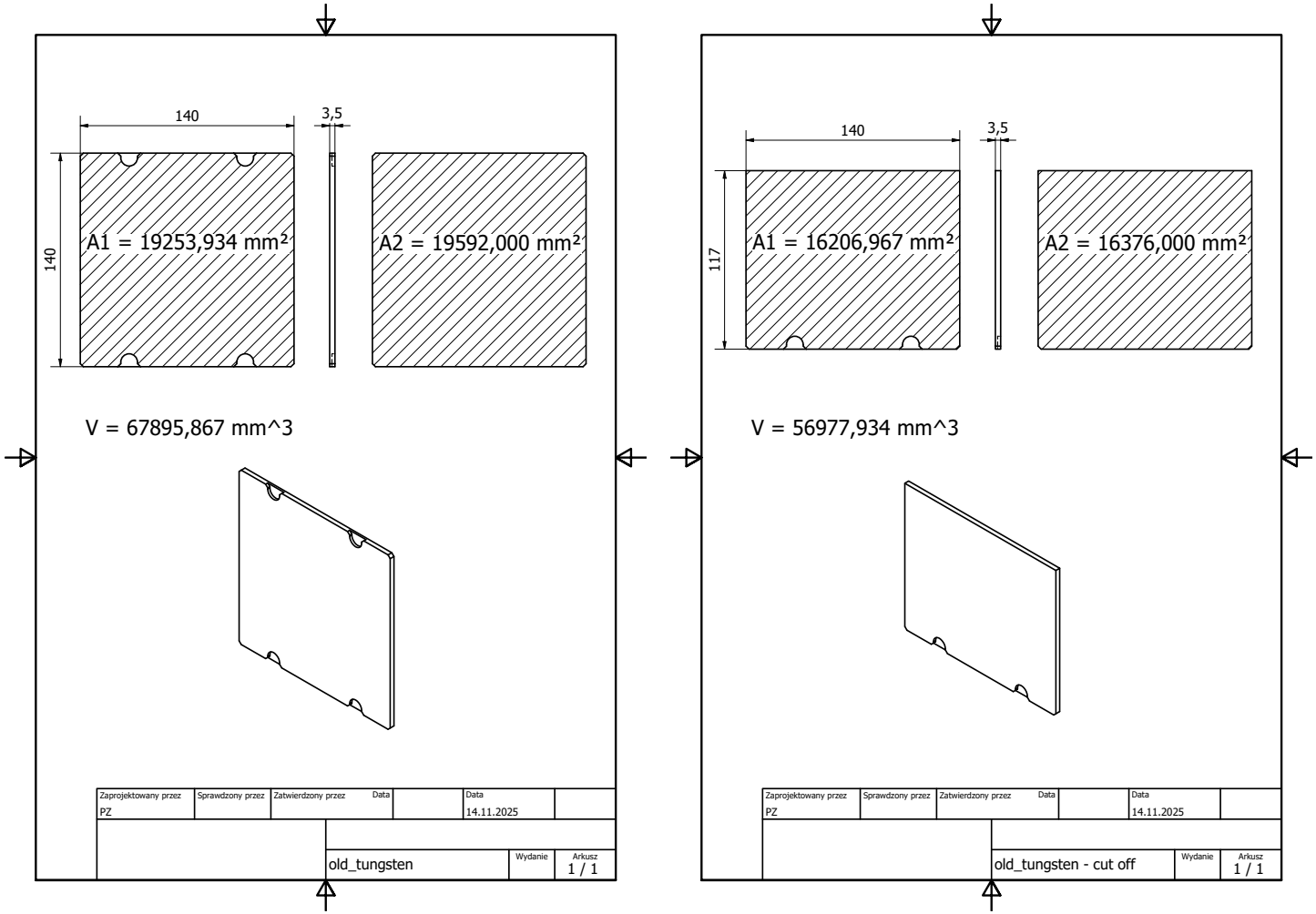
only 0.3 g/cm3 difference on density !

For powder technology (sintering process):

VNM 5-3 (W 92%, Ni 5%, Cu 3%) rho = 17.0 g/cm3
VNM 3-2 (W 95%, Ni 3%, Cu 2%) rho = 17.9-18.1 g/cm3

about 1.0 g/cm3 difference ! but more technology dependent and bigger spread...

Old FCAL tungsten: 3D CAD models: nominal volume (z=3.5 mm)



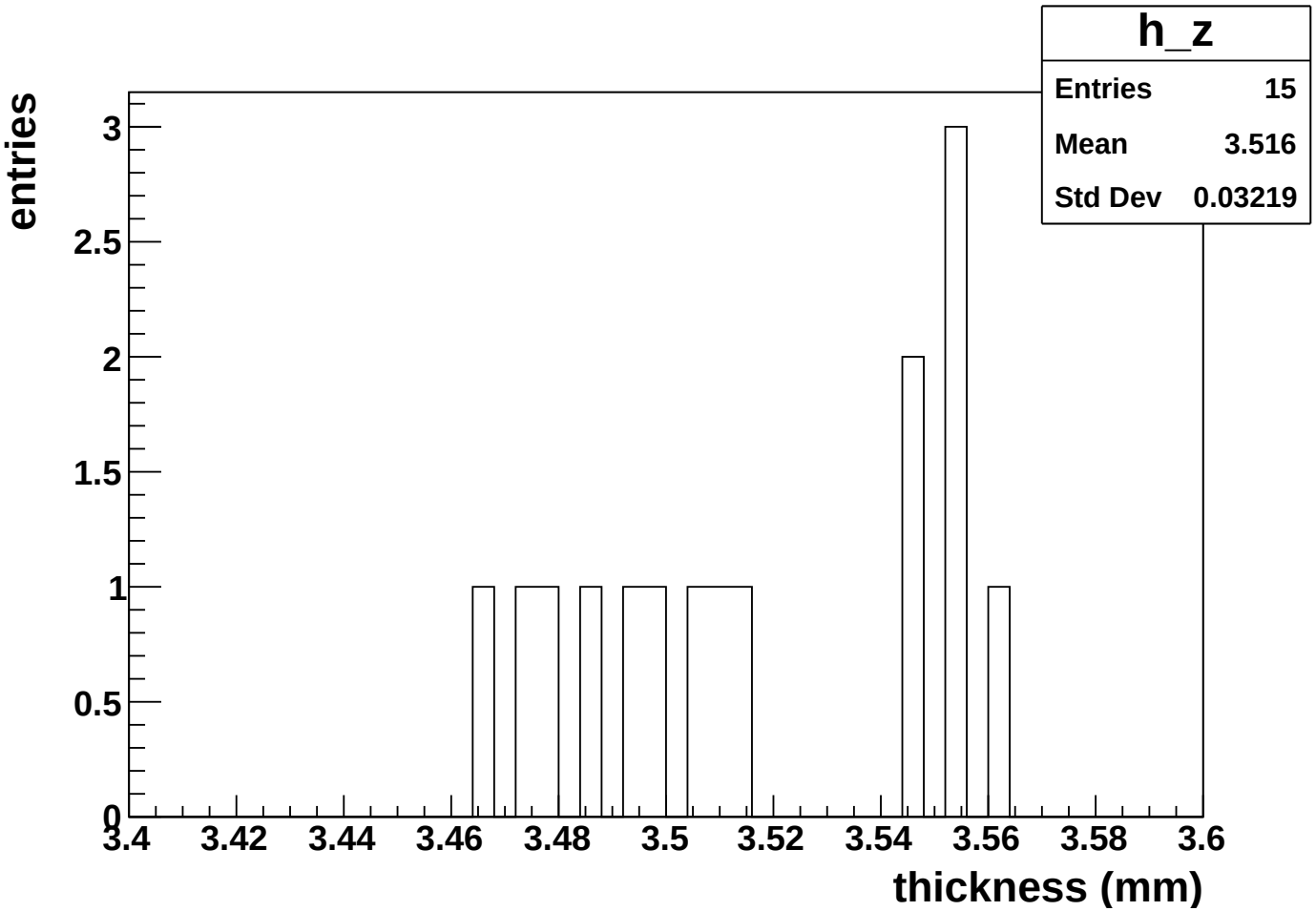
- corners cutoffs and undercuts area (84.5 mm^2) included in volume calculations
- **for 92% and 95% tungsten $\sim$ 20 g difference on plate mass expected**
- but this is similar to mass difference due to 0.1 mm thickness variation !!!

Old tungsten metrology

no.		LABEL	z(mm)	z2(mm)	x(mm)	y(mm)	mass (g)
OLD-01	cut	_____	3.5450	1.4350	139.930	116.855	1010.775
OLD-02	cut	_____	3.5525	1.4150	139.950	116.915	1017.165
OLD-03	cut	_____	3.5450	1.3950	139.920	116.865	1016.355
OLD-04	cut	_____	3.5525	1.4300	139.910	116.900	1015.755
OLD-05	nom	_____	3.5550	1.4375	139.900	139.920	1203.825
OLD-06	nom	MGS1-6	3.5625	1.4450	139.960	139.950	1214.290
OLD-07	nom	_____	3.5150	1.4250	139.970	139.940	1199.415
OLD-08	nom	B21___	3.5100	1.4600	139.930	139.950	1195.495
OLD-09	nom	_____	3.5050	1.4350	140.000	139.990	1238.120
OLD-10	nom	B15___	3.4975	1.4300	139.940	140.040	1193.445
OLD-11	nom	_____	3.4950	1.4650	139.980	140.000	1182.340
OLD-12	nom	1_____	3.4875	1.4950	140.020	140.010	1224.215
OLD-13	nom	_____	3.4650	1.4800	140.020	139.990	1223.435
OLD-14	nom	_____	3.4750	1.4725	139.970	139.980	1181.725
OLD-15	cut	_____	3.4775	1.4750	139.980	116.870	981.945

- z : mean thickness over 4 corners (digital caliper measurement)
- z2: mean thickness of undercuts area
- mass: mean over 3 measurements (nominal weight accuracy 0.1 g)

Thickness (z) distribution



- thickness spread / range $\sim$ 0.1 mm ($\sim$ 3.46 – 3.56 mm)

Old tungsten density

no.		LABEL	mass (g)	Volume (mm^3)	rho (g/cm3)
OLD-01	cut	_____	m = 1010.77	V = 57605.48 V_err = 327.29	rho = 17.55 _err = 0.10
OLD-02	cut	_____	m = 1017.16	V = 57761.60 V_err = 327.50	rho = 17.61 _err = 0.10
OLD-03	cut	_____	m = 1016.36	V = 57599.54 V_err = 327.29	rho = 17.65 _err = 0.10
OLD-04	cut	_____	m = 1015.75	V = 57740.07 V_err = 327.37	rho = 17.59 _err = 0.10
OLD-05	nom	_____	m = 1203.83	V = 68864.59 V_err = 391.75	rho = 17.48 _err = 0.10
OLD-06	nom	MGS1-6	m = 1214.29	V = 69056.26 V_err = 392.00	rho = 17.58 _err = 0.10
OLD-07	nom	_____	m = 1199.41	V = 68135.16 V_err = 392.00	rho = 17.60 _err = 0.10
OLD-08	nom	B21___	m = 1195.49	V = 68036.01 V_err = 391.91	rho = 17.57 _err = 0.10
OLD-09	nom	_____	m = 1238.12	V = 67985.30 V_err = 392.22	rho = 18.21 _err = 0.11
OLD-10	nom	B15___	m = 1193.44	V = 67834.25 V_err = 392.19	rho = 17.59 _err = 0.10
OLD-11	nom	_____	m = 1182.34	V = 67797.94 V_err = 392.19	rho = 17.44 _err = 0.10
OLD-12	nom	1_____	m = 1224.21	V = 67688.05 V_err = 392.33	rho = 18.09 _err = 0.10
OLD-13	nom	_____	m = 1223.43	V = 67239.79 V_err = 392.27	rho = 18.20 _err = 0.11
OLD-14	nom	_____	m = 1181.72	V = 67400.70 V_err = 392.10	rho = 17.53 _err = 0.10
OLD-15	cut	_____	m = 981.95	V = 56547.54 V_err = 327.43	rho = 17.36 _err = 0.10

- assuming x,y,z errors 0.02 mm (digital caliper)
- mass error 0.3 g (conservative) (weight precision 0.1 g)
- using measured volume (not nominal value)
- **rho error = 0.1 g/cm3** driven by V_err (z_err : 10^{-3} relative precision)
- (relative mass precision $\sim 10^{-4}$)

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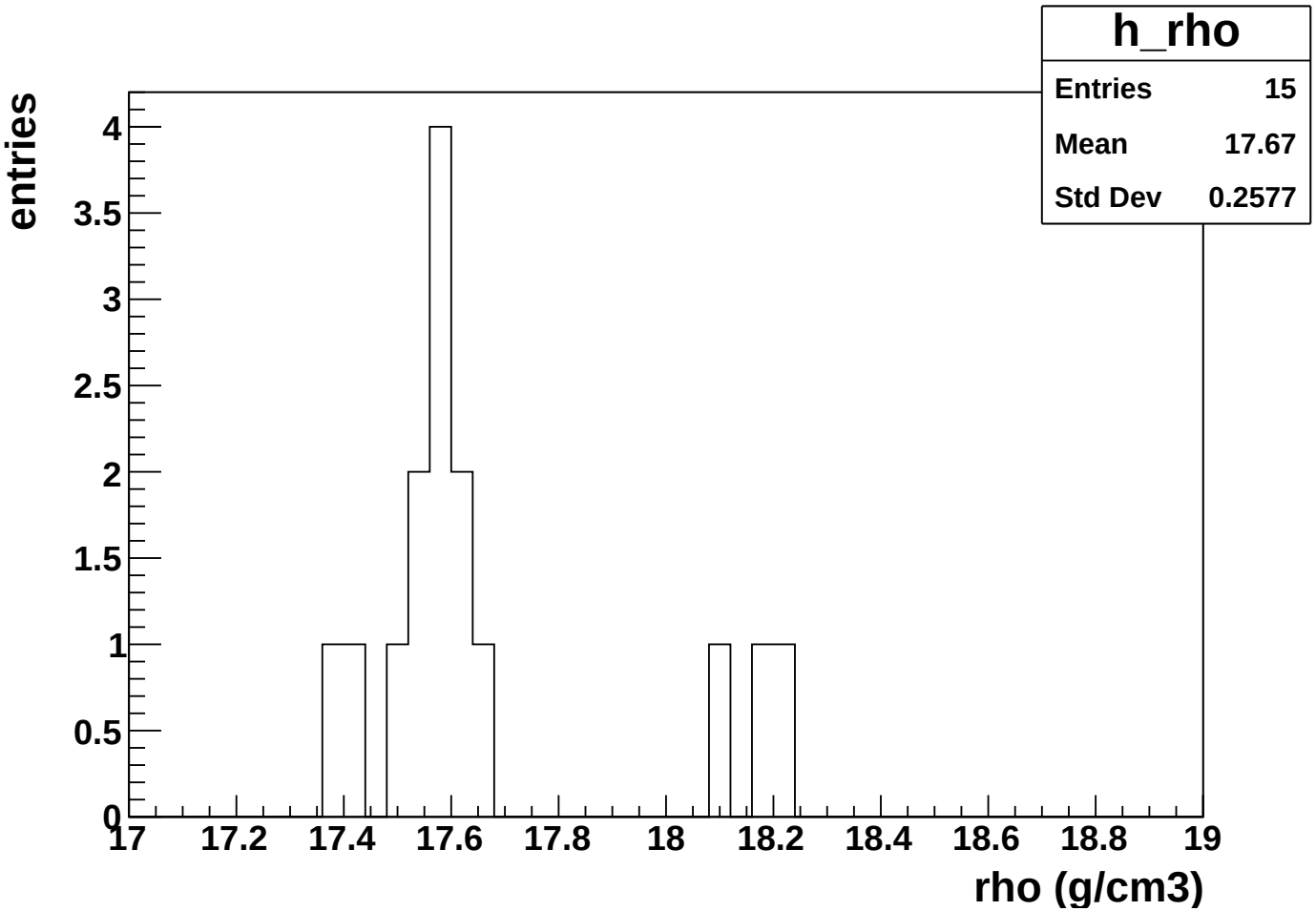
- two class of plates clearly visible :
  ∼ 17.5 g/cm3 (JINR or MGS ?) and
  ∼ 18.2 g/cm3 (Plansee)

Old tungsten density distribution



- rho precision $\sim$ 0.1 g/cm3
- two class of plates clearly visible :
  $\sim$ 17.5 g/cm3 (JINR [17.47 g/cm3] or MGS [17.7 g/cm3] ?) and
  $\sim$ 18.2 g/cm3 (Plansee)

Conclusions / recommendations for MC

- **for all old plates → use measured density (rho) and thickness (z)**
- for Plansee plates → use W 95.0% and assume Ni 2.5% and Cu 2.5%
- plate OLD6 is MGS → use W 93.0%, Ni 5.25%, Cu 1.75%
- rest of JINR and MGS plates are indistinguishable...
  statistic favors JINR, rho distribution favors MGS...
  difference is very small and probably negligible...
  for practical solution see next page...
- for all new plates use pure tungsten W 100% and
  rho = 19.25 g/cm3 and z=3.55 mm

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Plansee	18 gcm-3	W 95% , rest unknown	8
MGS	17.7 gcm-3	W 93%, Ni 5.25%, Cu 1.75%	6
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Conclusions / recommendations for MC / practical solution

```
no.         LABEL    rho (g/cm3)  z (mm)
=========================================
OLD-01 cut JINR__   rho = 17.55 z = 3.5450
OLD-02 cut MGS___   rho = 17.61 z = 3.5525
OLD-03 cut MGS___   rho = 17.65 z = 3.5450
OLD-04 cut MGS___   rho = 17.59 z = 3.5525
OLD-05 nom JINR__   rho = 17.48 z = 3.5550
OLD-06 nom MGS___   rho = 17.58 z = 3.5625
OLD-07 nom MGS___   rho = 17.60 z = 3.5150
OLD-08 nom JINR__   rho = 17.57 z = 3.5100
OLD-09 nom Plansee rho = 18.21 z = 3.5050
OLD-10 nom MGS___   rho = 17.59 z = 3.4975
OLD-11 nom JINR__   rho = 17.44 z = 3.4950
OLD-12 nom Plansee rho = 18.09 z = 3.4875
OLD-13 nom Plansee rho = 18.20 z = 3.4650
OLD-14 nom JINR__   rho = 17.53 z = 3.4750
OLD-15 cut JINR__   rho = 17.36 z = 3.4775
```

- keep 3 Plansee plates
- (17.7+17.47)/2 = 17.58 defines JINR/MGS boundary $\rightarrow$ gives 6 JINR + 6 MGS
- 6 out of 6 MGS plates selected (!?) $\rightarrow$ but from the same box at DESY...
- JINR ambiguity still to be resolved...
- Gent4: having rho and composition rest is air ? (porous structure ?)

Conclusions / recommendations for MC / alternative

```
no.         LABEL    rho (g/cm3)  z (mm)
=========================================
OLD-01 cut AVERAGE rho = 17.55 z = 3.5450
OLD-02 cut AVERAGE rho = 17.61 z = 3.5525
OLD-03 cut AVERAGE rho = 17.65 z = 3.5450
OLD-04 cut AVERAGE rho = 17.59 z = 3.5525
OLD-05 nom AVERAGE rho = 17.48 z = 3.5550
OLD-06 nom AVERAGE rho = 17.58 z = 3.5625
OLD-07 nom AVERAGE rho = 17.60 z = 3.5150
OLD-08 nom AVERAGE rho = 17.57 z = 3.5100
OLD-09 nom Plansee rho = 18.21 z = 3.5050
OLD-10 nom AVERAGE rho = 17.59 z = 3.4975
OLD-11 nom AVERAGE rho = 17.44 z = 3.4950
OLD-12 nom Plansee rho = 18.09 z = 3.4875
OLD-13 nom Plansee rho = 18.20 z = 3.4650
OLD-14 nom AVERAGE rho = 17.53 z = 3.4750
OLD-15 cut AVERAGE rho = 17.36 z = 3.4775
```

- keep 3 Plansee plates
- for rest JINR/MGS plates use some average composition, keeping measured rho and z: `AVERAGE : W 92.75%, Ni 5.25%, Cu 2.0%`
- $\rightarrow$ gives simple and more homogenous structure
- unless we discover DATA/MC disagreement...